THE LAKE CHARLES CCS PROJECT
PHASE 1 TOPICAL REPORT

Period Start Date: November 16, 2009
Period End Date: June 16, 2010

Principal Author: Doug Cathro, Leucadia Energy, LLC

Report Date: July 14, 2010

DOE Award Number: DE-FE0002314

Leucadia Energy, LLC
315 Park Avenue South
New York, NY
10010-3607

Significant Subcontractors:

Denbury Onshore, LLC
5100 Tennyson Parkway #1200
Plano, TX 75024

Black & Veatch Special Projects Corp.
6601 College Blvd.
Overland Park, KS 66211

Gulf Coast Carbon Center
Bureau of Economic Geology
Jackson School of Geosciences
University of Texas
10100 Burnet Rd.
Austin, TX 78758

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

Abstract

The Lake Charles CCS Project is a large-scale industrial carbon capture and sequestration (CCS) project which will demonstrate advanced technologies that capture and sequester carbon dioxide (CO_2) emissions from industrial sources into underground formations. Specifically the Lake Charles CCS Project will accelerate commercialization of large-scale CO_2 storage from industrial sources by leveraging synergy between a proposed petroleum coke to chemicals plant (the LCC Gasification Project) and the largest integrated anthropogenic CO_2 capture, transport, and monitored sequestration program in the U.S. Gulf Coast Region. The Lake Charles CCS Project will promote the expansion of EOR in Texas and Louisiana and supply greater energy security by expanding domestic energy supplies. The capture, compression, pipeline, injection, and monitoring infrastructure will continue to sequester CO_2 for many years after the completion of the term of the DOE agreement.

The objectives of this project are expected to be fulfilled by working through two distinct phases.

The overall objective of Phase 1 was to develop a fully definitive project basis for a competitive Renewal Application process to proceed into *Phase 2 - Design, Construction and Operations*. Phase 1 includes the studies attached hereto that will establish:

- the engineering design basis for the capture, compression and transportation of CO_2 from the LCC Gasification Project, and
- the criteria and specifications for a monitoring, verification and accounting (MVA) plan at the Hastings oil field in Texas.

The overall objective of Phase 2, provided a successful competitive down-selection, is to execute design, construction and operations of three capital projects:

- the CO_2 capture and compression equipment,
- a Connector Pipeline from the LLC Gasification Project to the Green Pipeline owned by Denbury and an affiliate of Denbury, and
- a comprehensive MVA system at the Hastings oil field.

Table of Contents

Executive Summary 1
Report Details 3
List of Acronyms and Abbreviations 11

Appendices

1. Phase 1 SOPO Task 1.5.1.1, Optimization Study of Rectisol and CO_2 Compression.

2. Phase 1 SOPO Task 1.5.2.1, Preliminary Engineering of CO_2 Compression Equipment.

3. Phase 1 SOPO Task 1.5.2.2, Preliminary Interconnection Study.

4. Phase 1 SOPO Task 1.5.2.3, Optimization of the CO_2 Compression Equipment Selection.

5. Phase 1 SOPO Task 1.5.3, CO_2 Injection Site Confirmation.

6. Phase 1 SOPO Task 1.5.4.1, Draft Risk Assessment and MVA Plan.

7. Phase 1 SOPO Task 1.5.4.2, Site-Specific MVA Options Evaluation.

8. Phase 1 SOPO Task 1.5.4.3., Final MVA Plan and Detailed Budget.

9. Phase 1 SOPO Task 1.8.1, Project Management Plan

10. Environmental Information Volume

11. Non-Proprietary Programmatic and Technical Prospectus (Fact Sheet)

Executive Summary

Leucadia Energy, LLC signed a Cooperative Agreement with the U.S. Department of Energy (DOE) in November 2009 to complete the first phase of a large scale industrial carbon capture and sequestration (CCS) project. The Lake Charles CCS Project includes integration of CO_2 capture, transportation/delivery and sequestration with comprehensive monitoring, verification and accounting (MVA). Leucadia Energy teamed with Denbury Onshore, Black & Veatch and the University Of Texas Bureau Of Economic Geology to execute this project.

The Lake Charles CCS Project will receive several CO_2 streams at 20, 40, and/or 60 psia from the Rectisol® units and compress the combined stream to 2,165 psia for injection into the proposed Connector Pipeline. The Connector Pipeline will transport the CO_2 to the Green Pipeline and then on to oil fields on the Gulf Coast where it will be used for enhanced oil recovery. A comprehensive MVA plan for over 2 million tpy of CO_2 will be implemented at the Hastings oil field to demonstrate the safe and effective storage of CO_2 in the oil bearing geological formations with the additional benefit of enhancing oil recovery in existing oil fields.

Phase 1 of the project included preliminary engineering studies to optimize the combined cost and energy consumption for Rectisol® and CO_2 compression including the startup and shutdown energy requirements from the local grid. It also included a preliminary engineering investigation into the MVA specifications for two oil fields. Denbury also completed a feasibility study of the most effective route for the Connector Pipeline. The cost of this study was not included in the scope of the Phase 1 award. Leucadia Energy has also performed preliminary engineering of the Rectisol® units. The cost of the Rectisol® preliminary engineering was not included in the Phase 1 award.

This Topical Report summarizes work completed on the project from November 16, 2009 through April 15, 2010. During this period, all of the tasks identified in the Phase 1 SOPO were completed. Weekly, monthly and quarterly reports were submitted and will continue to be prepared until the end of the Phase 1 period. An EIV for the Lake Charles CCS project was prepared and is attached as Appendix 10. Firm and binding commitments for the project sites were confirmed. Teaming agreements with key offtakers, licensers, and contractors were developed. Preliminary design of capture, compression, transportation and MVA systems was completed and comprehensive plans for such facilities, including detailed budgets and schedules, have been developed. This work has all been documented in the Phase 2 Renewal Application. Attached to this Topical Report, are the following studies upon which much of this work was based:

- Phase 1 SOPO Task 1.5.1.1, Optimization Study of Rectisol and CO_2 Compression.

- Phase 1 SOPO Task 1.5.2.1, Preliminary Engineering of CO_2 Compression Equipment.
- Phase 1 SOPO Task 1.5.2.2, Preliminary Interconnection Study.
- Phase 1 SOPO Task 1.5.2.3, Optimization of the CO_2 Compression Equipment Selection.
- Phase 1 SOPO Task 1.5.3, CO_2 Injection Site Confirmation.
- Phase 1 SOPO Task 1.5.4.1, Draft Risk Assessment and MVA Plan.
- Phase 1 SOPO Task 1.5.4.2, Site-Specific MVA Options Evaluation.
- Phase 1 SOPO Task 1.5.4.3., Final MVA Plan and Detailed Budget.
- Phase 1 SOPO Task 1.8.1, Project Management Plan.
- Environmental Information Volume
- Non-Proprietary Programmatic and Technical Prospectus (Fact Sheet)

Report Details

The following is a discussion of the SOPO tasks that were completed during Phase 1:

C1.1 Project Management and Planning

C1.1.1 Project Management Plan

- A project management plan in the form of a resource loaded, CPM schedule (RLS) was created using Microsoft Project 2007 and submitted to DOE/NETL. Planned costs were loaded as resources to those activities/tasks that were part of the cost share.

C1.1.2 Reporting

- The project team began reporting progress with updates to the RLS on a monthly and quarterly basis. Quarterly reports were also submitted under ARRA guidelines.

- Weekly status reports were issues and reviewed during weekly update calls with DOE/NETL.

C1.2 Environmental Impacts and Permits

C1.2.1 National Environmental Policy Act (NEPA)

- January 18, 2010 Denbury Onshore sent out Requests for Proposals for the connector pipeline EIV and awarded the project on February 1, 2010 to CH2M Hill with a required completion due to Denbury Onshore on March 1, 2010.

- January 28, 2010 Denbury Onshore sent out the Request for Proposals for the EIV on the West Hastings Field and awarded the project to Walden and Associates on February 8, 2010 with a required completion due to Denbury Onshore on March 1, 2010.

- URS, who was previously contracted to support permitting of the Lake Charles Gasification Project, was awarded the EIV by Leucadia Energy for the capture and compression facilities.

- An EIV has been prepared and is attached to assist DOE in the evaluation of the potential environmental impacts of the proposed Lake Charles CCS Project. The Lake Charles CCS Project will involve the capture and compression of over 85% of the CO_2 produced at the LCC Gasification Facility (LCGF). The compressed CO_2 will be transported via an 11.6-mile pipeline (the “Connector Pipeline”) from the fenceline of the LCGF to the Green Pipeline owned by Denbury and an affiliate of Denbury. The Lake Charles CCS Project CO_2 will be used in an

independent commercial enhanced oil recovery (EOR) project at Denbury's Hastings Field in Texas, where Denbury will implement a research monitoring, verification, and accounting (MVA) program to demonstrate the effectiveness of long-term geologic storage of the CO_2. This EIV is divided into three parts to cover each of the project components for which DOE funding is sought: Part I covers the CO_2 capture and compression facilities at the Lake Charles Gasification Facility; Part II covers the 11.6-mile Connector Pipeline; and Part III covers the MVA activities at the Hastings Field in Texas.

C1.2.2 Permits and Other Regulatory Authorizations

The status of all necessary permitted authorizations for the Lake Charles CC Project were identified as part of the EIV for each of the capture and compression, pipeline, and MVA activities.

As discussed more fully in the EIV at Part I, pp. 39-42 and below, the LCC Gasification Project has already obtained several key regulatory permits. Given the status of the LCC Gasification Project and the level of local and state support, no significant regulatory hurdles for the LCC Gasification Project are anticipated.

- **RCRA/Hazardous Materials Regulations:** The LCC Gasification Project will not require a RCRA Permit, as there will be no storage or treatment of hazardous wastes on site. It is not anticipated that any TSCA or CERCLA requirements will be applicable to the LCC Gasification Project.

- **Clean Air Act Permits:** As discussed more fully in the EIV, the LCC Gasification Project has obtained Title V and Prevention of Significant Deterioration (PSD) Air Permits for emissions associated with the production of substitute natural gas. Subsequent to the permits' issuance, it has been determined that the LCC Gasification Project will produce methanol instead of, or in addition to, SNG. Further design work is required to complete characterization of the methanol process, but the facility's emissions are not expected to vary significantly with the production of methanol. Any emission changes associated with the methanol process will be incorporated with other design clarifications in the permit modification process.

- **Clean Water Act:** The LCC Gasification Project is permitted to implement zero liquid discharge (ZLD) for the gasification process wastewater. The wastewater generated in the gasification process will be treated / recycled to achieve ZLD. Filtered solids and dewatered salts will be disposed of off-site at permitted facilities. Discharge of storm water during construction activities will require submittal of a Large Construction Notice of Intent (LCNOI) 30 days prior to start of construction.

- **United States Army Corps of Engineers (US COE):** A Section 404 permit was issued by the US COE in August 2008 supported by a 401

Water Quality Certification (WQC) issued by the LDEQ. The US COE determined that a Section 10 permit was not required. A jurisdictional wetland delineation was previously conducted by the US COE and, based on this delineation, the Port of Lake Charles mitigated 26.2 acres of the wetlands through an agreement with the US COE and Stream Wetland Services, LLC. Permitting through the US COE to develop the site has been completed and the latest permit was issued on August 18, 2008.

- **Coast Guard Review**: Due to the fact that the Calcasieu Ship Channel is a federally maintained channel, any activity within the channel, may need to undergo Coast Guard review. During the planning and design process, a description and map of the facility, including a letter of intent, would be sent to this agency for its approval and clearance. Coordination with the Coast Guard regarding the construction of the planned structures (bulkhead) will be implemented for this project to ensure that all requirements are satisfied.

- **Endangered Species Act:** Based upon information reviewed from the Louisiana Department of Wildlife and Fisheries, no rare, threatened or endangered species or critical habitats are anticipated for this proposed project. In addition, there are no state or federal parks, wildlife refuges, scenic streams, or Wildlife Management Areas at or near the proposed project site.

- **National Historic Preservation Act: A** cultural resources study has been prepared as required by the State Department of Cultural, Recreation & Tourism, Office of Cultural Development. A prior study by Earth Search, Inc. in 2001 identified a Rangia shell midden associated with Site 16CU29 that potentially extended into the southwest corner of the proposed project site. A Phase I Cultural Resources Survey was performed for this site and a report was issued to the SHPO. The SHPO reviewed this updated information and issued a letter noting that field investigations resulted in the delineation of expanded boundaries for this site and the assessment concluded that the site was not eligible for listing on the National Register of Historic Places due to a lack of depositional integrity and limited research potential. The SHPO concurred with the assessments conducted and additional assessments are not warranted.

- **Emergency Management Requirements:** The LCC Gasification Project may also be subject to certain emergency management requirements under the Emergency Planning and Community Right-to-Know Act (EPCRA) and Spill Prevention Control and Countermeasure (SPCC) requirements (40 CFR 112). Emergency response procedures will be developed for the facility in accordance with the requirements of Occupational Safety and Health Administration (OSHA), EPCRA, and CAA provisions. Such procedures will cover plant evacuation notification to local fire and law enforcement agencies, notification to state and local

officials and US EPA. Emergency response procedures will identify individuals/positions responsible for decision-making and notification and will include provisions for periodic training for plant management and employees.

- **Local Permits**: The LCC Gasification Project is anticipated to require building permits and a flood zone management permit from local regulators. Coordination on these requirements is being implemented.

The status of all necessary permitted authorizations for pipeline activities are discussed in the EIV at Part II, pp. 6-1 to 6-4. The status of all necessary permitted authorizations for MVA activities are discussed in the EIV at Part III, pp. 34.

C1.3 Site Arrangements

- Lake Charles Cogeneration LLC, an affiliate of Leucadia Energy, has signed a 40 year lease agreement with the Port of Lake Charles where the CO_2 capture and compression will take place.

- West Hastings Field Unit (WHFU) Fault Block B and C - Denbury has the right to inject CO_2 according to the terms of their mineral leases and the Texas Railroad Commission Order regarding unitization. Its CO_2 injection wells are permitted by the Railroad Commission under primacy from the Underground Injection Control regulations of the US EPA. Its oil and gas operations are regulated by the Railroad Commission, and its CO_2 pipelines are regulated by various State and Federal agencies. Thus, a complete legal and regulatory framework exists for Denbury to sequester CO_2 as part of its CO_2 EOR projects for the West Hastings Field EOR operation. Denbury purchased the West Hastings Field, a potential tertiary flood located near Houston, Texas, in February 2009 from the prior operator.

C1.4 Teaming Arrangements

Teaming arrangements have been established with key offtakers, licensors, and contractors, including the following:

- CO_2 Offtake Agreement between Denbury Onshore and Leucadia Energy.

- Memorandum of Understanding between Denbury Onshore and Leucadia Energy.

- Subcontract between Denbury and UT BEG GCCC.

- Subcontract between Leucadia Energy and Black & Veatch Special Projects Corporation.

- A license agreement between Lake Charles Cogeneration and Lurgi for the Rectisol® Unit.

- A license agreement between Lake Charles Cogeneration and GE Energy for the gasification technology.

- A construction agreement with Turner Industries.

A more extensive list of key teaming arrangements has been provided in Appendix B of the Phase 2 Renewal Application, along with support letters from key stakeholders and government officials.

C1.5 Conceptual/Preliminary Design

C1.5.1.1 Optimization Study of Rectisol® and CO_2 Compression

- The optimization study was issued in draft on February 15, 2010. Final version is attached. The three CO_2 pressure case was determined to be most economical and was subsequently utilized as the design basis.

C1.5.2.1 Preliminary Engineering of CO_2 Capture and Compression Equipment

- Based upon results of the optimization study, data sheets were issued to compressor vendors for cost and performance data. The data sheets referenced bid specification documents that were developed for Leucadia's Chicago Clean Energy Project. The Preliminary Engineering Study was issued April 14, 2010 and is attached. The report includes both capture (Rectisol) and compression data.

C1.5.2.2 Preliminary Transmission Interconnection Assessment

- The integrated gasification and CCS projects will have a single grid interconnection. The actual interconnection study will be done as part of the gasification project. There may be an incremental cost associated with the CCS project needs, but it is not included in the Phase 2 funding request. The assessment was issued April 14, 2010 and is attached.

C1.5.2.3 Optimization of CO_2 Compression Equipment

- Based upon the preliminary engineering and vendor data the type of compressor and the configuration was determined. The preferred configuration is 2 x 50 percent integrally geared multistage centrifugal compressors. The optimization was issued April 14, 2010 and is attached.

C1.5.2.4 Capture and Compression Phase 2 Application

- The Topical Reports and the Resource Loaded Schedule were relied upon to develop the Phase 2 Application

C1.5.3 Enhanced Oil Recovery /Geologic Sequestration / Injection

- In preparation for the Draft risk assessment and MVA plan, Denbury's Field Operations and Reservoir Team for Hastings Field began the planning of the injection program for WHFU Fault Block B and C. A report of the planned commercial field development was prepared and submitted to Sue Hovorka at BEG GCCC on February 26, 2010 and a formal report prepared on April 13, 2010 and is attached.

- The Preliminary CO_2 Injection Site Confirmation – West Hastings Field Unit Fault Block B and C provides detailed data on CO_2 injectivity, storage capacity, field development plans for Fault Block B and C, and characteristics of the geologic formations.

C1.5.4.1 Draft risk assessment and MVA plan

- On December 15, 2009 a review team composed of Susan Hovorka, University of Texas - Bureau of Economic Geology [BEG] and sixteen Denbury staff refined the plan for development of the Phase 1 Storage MVA plan for the capture project linked to the storage project proposed under DOE FOA 15. This prepares the way for development of detailed proposals that will be judged competitively for major funding in Phase 2.

- There were two fields that Denbury was considering as sequestration sites, namely Oyster Bayou Field and Hastings Field. Both are excellent CO_2 EOR and sequestration candidates, but a preferred field would need to be chosen as part of the Phase 1 MVA planning process on the basis of certain criteria. Environmental risks to sensitive habitats, historical sites, or populated areas were considered, as well as subsurface complexity and anticipated operational problems associated with MVA activities in each field. Uncertainties associated with the EOR process were considered, insofar as the required volume and duration of CO_2 injection – and consequent MVA activity – are concerned. The availability and quality of historical data, and additional data required prior to flood implementation was also a consideration in the field selection process, as well as the existence of existing transportation and communication infrastructure in terms of effective monitoring of the sequestered CO_2.

- After a formal review of the two fields nominated in the initial proposal the one that seemed to be most competitive in the context of the next round of proposal preparation was Hastings East Field fault block B and C. The main driver behind our choice of Hastings over Oyster Bayou had to do with contemplated development schedule, and Ms. Hvorka's perception that NETL would prefer to fund projects that are relatively "untouched" by CO_2 EOR/sequestration prior to

project startup. We expect to have initiated the CO_2 flood in both Oyster Bayou and a portion of Hastings Field prior to availability of anthropogenic CO_2 . The entirety of Oyster Bayou Field will be developed at about the same time, with first injection in 2010 or 2011. The main fault block in Hastings (Fault Block A) will be developed at about the same time, but there are two other fault blocks to the south that will take additional time to develop, and we envision that the commencement of injection in these portions of Hastings will coincide with first deliveries of anthropogenic CO_2.

- We then discussed the separation of monitoring activities into (1) those conducted commercially as part of a "Best Practices" approach for an effective EOR flood or to meet current regulatory requirements (these are not subject to NEPA) and (2) those that are surface and sub-surface research-oriented monitoring, verification, and accounting (MVA) activities that will be conducted to further demonstrate the effectiveness of storage and monitoring currently standard procedure for Denbury. This report proposes a draft research MVA program. It is intended that this draft will discuss a broad scope of all the activities that might be selected for the Phase 2 proposal. This broad scope will help us focus further cost/feasibility/optimization discussion as well as allow preparation of the EIV.

C1.5.4.2 Site-specific MVA options evaluations

- Site-specific MVA options review started on January 6, 2010 between Sue Hovorka of BEG GCCC and Denbury Onshore's Business Development Team, Field Operations Team and Reservoir Team. A report of the proposed MVA options was prepared and submitted by Sue Hovorka of BEG GCCC on February 22, 2010 and a formal report prepared on April 11, 2010 is attached.

- The Site-specific MVA options evaluation for West Hastings Field Unit Fault Block B and C provides detailed recommendation on how to document commercial CO_2 EOR field development practices and the proposed research MVA program that will prove the confidence level of the commercial practices. Research MVA options evaluated were broken down into four categories: Flood Conformance, Fault Monitoring, Well Integrity and Above-Zone Monitoring. These items were planned to include feasibility tests and risk assessments in Phase 2A; well preparation and baseline testing in Phase 2B; and time lapse testing in 2C. The BEG is also proposing a predictive reservoir model of the CO_2 plume that is injected during the Denbury Onshore commercial EOR process.

C1.5.4.3 Final MVA plan and detailed budget

- The Final MVA plan and detailed budget planning started on February 1, 2010 by Sue Hovorka of BEG GCCC in consultation with Denbury Onshore and Sandia Laboratories. A report of the proposed MVA plan and detailed budget was prepared and submitted by Sue Hovorka of BEG GCC on March 15, 2010. After

several revisions the Final MVA plan and detailed budget were completed April 11, 2010 and is attached.

- The Final MVA plan and detailed budget includes : (1) the schedule of activities; (2) the current state of site characterization and capacity assessment; (3) the current assessment of uncertainties that lead to assessment of risks and guide the research MVA plan; (4) the commercial monitoring activities that provides the standard for the research MVA plan; and (5) the research MVA plan that tests the effectiveness of the commercial plan and several novel approaches that may extend the level of confidence beyond the commercial activities. This is followed by a scope of work detail in the tasks divided by project phase and task number with a reporting plan, a cost justification, experience of key participants, and budget.

C1.6 Phase 2 Project Description and SOPO

- A Phase 2 Project Description and SOPO covering all activities associated with capture, compression, transport, and MVA was prepared and included in the Phase 2 Renewal Application.

C1.7 Intellectual Property

- A revised Intellectual Properties Form covering all Phase 1 and Phase 2 activities was submitted to NETL on April 13, 2010.

C1.8 Phase 2 Project Costs, Funding and Budget

- Technology Cost Data was submitted with the Phase 2 Renewal Application and is attached as an Appendix to this Topical Report.

- A Project Financial Plan was developed and submitted with the Phase 2 Renewal Application.

- Budget Details and Monthly Spend Plans were developed for all Phase 2 capture, compression, pipeline and MVA tasks. These were also submitted with the Phase 2 Renewal Application.

C1.9 Phase 2 Renewal Application

- A Phase 2 Renewal Application was prepared for submission on April 16, 2010.

C1.10 Phase 2 Topical Report

- This Phase 1 Topical Report was prepared as an attachment to the Phase 2 Renewal Application for submission on April 16, 2010.

List of Acronyms and Abbreviations

ARRA ..... American Recovery and Reinvestment Act
AZMI ..... Above Zone Monitoring Interval
BEG ..... Bureau of Economic Geology
CCS ..... Carbon Capture and Sequestration
CCP ..... Carbon Capture Project
CO_2 ..... Carbon Dioxide
CO ..... Carbon Monoxide
COP ..... ConocoPhillips
COS ..... Carbonyl Sulfide
DOE ..... U.S. Department of Energy
EOR ..... Enhanced Oil Recovery
GCCC ..... Bureau of Economic Geology Gulf Coast Carbon Center
GE ..... General Electric
H_2 ..... Hydrogen
HCPV ..... Hydrocarbon Pore Volume
H_2SO_4 ..... Sulfuric Acid
H_2S ..... Hydrogen Sulfide
IWR ..... Injection/Withdrawal Ratios
MP ..... Medium-Pressure
MVA ..... Monitoring, Verification and Accounting Plan
NETL ..... National Energy Technology Laboratory
NO_x ..... Nitrogen Oxide
P&A ..... Plugged and Abandoned
PSIG ..... Pounds Per Square Inch Gauge
RCSP ..... Regional Carbon Sequestration Partnerships
SO_2 ..... Sulfur Dioxide
SO_3 ..... Sulfur Trioxide
SNG ..... Synthetic Natural Gas
SOPO ..... Statement of Project Objectives
STPD ..... Short Tons Per Day
USDW ..... Underground Sources of Drinking Water

WSA.....Wet Sulfuric Acid Unit

THE LAKE CHARLES CCS PROJECT
PHASE 1 TOPICAL REPORT

APPENDIX 1

Phase 1 SOPO Task 1.5.1.1
Rectisol and CO_2 Compression Opitimization Study

APPENDIX 1.0 CO_2 COMPRESSION OPTIMIZATION STUDY

This appendix provides the results of a CO_2 compression optimization study carried out in order to determine the optimum Rectisol configuration for the Lake Charles CCS Project. The details and results of the study are provided in the attached report conducted by Black & Veatch.

LAKE CHARLES CCS PROJECT

PETROLEUM COKE GASIFICATION TO CRUDE METHANOL PROJECT

Rectisol and CO_2 COMPRESSION OPTIMIZATION STUDY

REV.	DATE	DESCRIPTION	BY	CHECKED	APPROVED
C	2/18/2010	Incorporated Leucadia Comments	GPG	GPG	RAS
B	2/15/2010	Incorporated Leucadia Comments	GPG	GPG	RAS
A	2/10/2010	Issued for Review	WLB/MJC/GPG	GPG	RAS

Table of Contents

1.0 Summary 1-1
2.0 Background 2-1
2.1 Scope of Work and Deliverables 2-1
2.2 Methanol Production and CCS Project Boundaries 2-1
2.3 CCS Project Inputs 2-2
3.0 Project Configuration 3-1
3.1 Rectisol Selective Acid Gas Removal Process Configurations 3-2
3.2 CO_2 Compression 3-4
3.3 Optimization Study Results 3-5
4.0 Conclusions 4-1

Tables

Table 1-1 Optimization Study Results Summary 1-2
Table 3-1 Rectisol Feed Gas 3-6
Table 3-2 Optimization Study Process Data 3-7
Table 3-3 Specific Energy Use 3-8
Table 3-4 Differential Capital and Operating Cost Estimates 3-9

Figures

Figure 3-1 Block Flow Diagram 3-11
Figure 3-2 Selective CO_2 and Sulfur Removal 3-12

1.0 Summary

At the request of Leucadia Energy, LLC, Black & Veatch performed an optimization study that evaluated potential Rectisol® configuration impacts on the overall cost and energy efficiency of the Lake Charles Petroleum Coke Gasification to Methanol Plant. Three Rectisol configurations were evaluated, in which one, two, and three carbon dioxide (CO_2) streams were produced at varying pressures and purities. The one CO_2 stream case includes a large vacuum flash compressor, which is replaced by additional CO_2 flash equipment in the two and three CO_2 stream cases.

Based on the available information, Black & Veatch determined that the Rectisol configuration producing three CO_2 streams would have the lowest cost, highest CO_2 recovery, and lowest specific energy use. The results are summarized in Table 1-1.

Capital cost includes Rectisol, CO_2 compression, and the wet sulfuric acid unit (WSA), which is affected by the volumetric acid gas flow. The WSA nitrogen oxide (NO_x) and sulfur dioxide (SO_2) emissions are proportional to the volumetric acid gas flow; however, the cost impact of higher emissions was not included. The three CO_2 streams case also has the lowest acid gas flow.

The CO_2 purity for the three CO_2 streams case is well within Denbury's specifications for enhanced oil recovery. In the one CO_2 stream case, the CO_2 purity just met the hydrogen sulfide (H_2S) specification; the two CO_2 streams case did not meet the combined H_2S and carbonyl sulfide (COS) specification.

The CO_2 recovery and hydrogen (H_2) and carbon monoxide (CO) loss are essentially the same for the three and one CO_2 stream cases. Cost and CO_2 recovery are much closer for the three and one CO_2 stream cases than for the two CO_2 streams case.

Table 1-1
Optimization Study Results Summary

Parameter Units		Denbury CO_2 Spec	One CO_2 Stream	Two CO_2 Streams	Three CO_2 Streams
CO_2 Pressure(s)	psia		29	17.4 48.6	23 40 60.7
CO_2 Purity	%v CO_2 97.0		99.2	98.0	99.1
CO_2 Purity	ppmv H_2S 20		20	7	1
CO_2 Purity	ppmv H_2S+COS	35	33	42	3
CO_2 Recovered (NOC)	stpd CO_2		12,577	11,967	12,591
CO_2 Recovered (NOC)	stpd total		12,619	12,069	12,660
Acid Gas to Wet Sulfuric Acid Unit (WSA)	MMscfd		24.7	34.2	23.5
Acid Gas to WSA	%v CO_2		52.9	67.8	52.7
CO_2 Lost in Acid Gas	%		5.2	9.5	5.1
H_2 and CO Loss to CO_2 and Acid Gas	MMscfd		1.9	4.1	2.0
Electricity Use	MW		1.5	-4.9	Base
Cooling Water Heat Rejection	MBtu/h		-53	-35	Base
Steam Use	MBtu/h		6.8	26.3	Base
Specific Energy Use	MBtu/ton recovered CO_2	0.78	3	0.818	0.759
Operating Cost at 90% Capacity Factor	$ millions/year		0.77	-1.35	Base
Product Credit at 90% Capacity Factor	$ millions/year		-0.44	-44.88	Base
Capital Cost	$ millions		0.8	6.3	Base

NOC = Normal Operating Case of 6.3%w S in petroleum coke feed to gasification.

2.0 Background

2.1 Scope of Work and Deliverables

This report fulfills the objectives of Item C1.5.1.1 - Optimization Study of the Statement of Project Objectives (SOPO) in the Cooperative Agreement for the Lake Charles CCS Project.

Engineer will perform an optimization study for the combined cost and energy consumption of Rectisol and CO_2 compression. A critical review of the integration between the Lake Charles Chemical Project Rectisol unit and the CO_2 compression design will be performed to optimize the design between the two facilities. Design configurations will be evaluated regarding reducing CO_2 compression power. Capital and operating costs for several cases will be evaluated to determine the Rectisol design that optimizes the combined costs of Rectisol and CO_2 compression. Cooling and water requirements for the compressors will be integrated with the cooling and water requirements for the chemical plant.

The deliverable to the Client for this subtask is an engineering report that describes the results of the optimization study. The report will include (1) design recommendations for integration of compression equipment with Rectisol, (2) a discussion of the design elements that minimize the power requirements of the system, (3) a summary of capital and operating cost estimates of the cases evaluated, and (4) an overall design recommendation, including the expected capital and operating costs of the recommended design.

2.2 Methanol Production and CCS Project Boundaries

Lake Charles Cogeneration, LLC has been developing a petroleum coke (petcoke) gasification project near Lake Charles, Louisiana for several years. Configurations that have been investigated include the cogeneration of electricity, H_2, and steam; synthetic natural gas (SNG) production with and without H_2 production; and most recently, methanol production. The SNG, H_2, and methanol projects included CO_2 capture and compression.

Leucadia Energy, LLC has entered into a Cooperative Agreement (Award No. DE-FE0002314), effective November 16, 2009, with the United States Department of Energy/NETL Pittsburgh Campus for the Lake Charles CCS Project. The scope of this agreement is CO_2 capture and sequestration (CCS).

The interface between the methanol production facility and the CCS facility is the CO_2 transfer piping at the Rectisol unit battery limits.

2.3 CCS Project Inputs

Black & Veatch is relying upon data provided by others (including Rectisol data) for the methanol production facility. The work performed on the methanol production facility can be characterized as feasibility level and will be further refined as the project is developed. Lurgi provided Rectisol information for both SNG and H_2 production. Black & Veatch adjusted this data for the methanol production.

3.0 Project Configuration

The Lake Charles CCS Project will gasify approximately 7,400 short tons per day (stpd) of petcoke to produce 6,890 stpd of crude methanol, with a methanol concentration of 94.1 percent weight (%w). Byproducts will include sulfuric acid (H_2SO_4), CO_2, argon, and electricity. Sulfuric acid production will range from 830 to 1,972 stpd of 97.5%w sulfuric acid for petcoke sulfur contents of 3.5 to 8%w, dry basis. Normal sulfuric acid production will be 1,339 stpd for 6.3%w sulfur petcoke. CO_2 production will be approximately 12,600 stpd. Argon production will be approximately 373 stpd. The gross electricity production will range from 200 to 213 MW at design methanol production. This electricity will normally be produced from process generated steam in a steam turbine generator. The plant will typically consume approximately 260 MW, which includes 40 MW for CO_2 compression. The net electricity import to the plant will be 47 to 60 MW at design methanol production conditions.

The plant configuration is shown on Figure 3-1 (included at the end of this section). Key aspects are highlighted in this section.

The plant will consist of five General Electric (GE) Quench gasifiers and two trains of syngas processing, including sour shift conversion, Lurgi Rectisol selective acid gas removal, methanol synthesis and stabilization, and Haldor Topsoe wet sulfuric acid production. At design plant capacity, four GE Quench gasifiers will operate at their design rate, which allows one gasifier to be on hot standby or shut down for maintenance. Gasifiers will be started up using natural gas to minimize the SO_2 emissions.

About 63 percent of the raw syngas will flow through two shift conversion trains, where nearly all of the CO will be reacted with water vapor over a catalyst to produce H_2 and CO_2. The flow through shift conversion will be controlled to produce the following required methanol syngas feed stoichiometric ratio:

$$(H_2\text{-}CO_2) / (CO+CO_2) = 2.05$$

H_2S, COS, and CO_2 will be selectively removed from the sour syngas in the Rectisol unit using cold methanol as a physical solvent. The Rectisol unit will produce syngas containing less than 0.1 ppmv total sulfur compounds and 2.8 percent volume (%v) CO_2 for feed to methanol synthesis. The sweet syngas from the Rectisol unit will be compressed, combined with recycle syngas, and reacted over a catalyst to produce methanol.

The Rectisol unit will produce an acid gas stream that contains H_2S and COS for feed to the WSA process. The acid gas H_2S and COS concentrations will vary with their concentrations in the sour syngas to the Rectisol unit, which will vary with the petcoke sulfur concentration. The acid gas stream will be combusted to produce SO_2, which will be catalytically oxidized to sulfur trioxide (SO_3) and then reacted with condensing water to produce 97.5%w sulfuric acid.

The Rectisol unit will also produce CO_2 suitable for enhanced oil recovery. The CO_2 concentration will be higher than 98%v. The CO_2 pressure will depend on the Rectisol configuration and can vary from a single stream at 29 pounds per square inch absolute (psia) to multiple streams ranging from 17.4 to 60.4 psia. The CO_2 from the Rectisol unit will be compressed to 2,250 psia.

3.1 Rectisol Selective Acid Gas Removal Process Configurations

The following three Rectisol configurations were evaluated:

1. Single CO_2 stream at 29 psia, with a single reabsorber column with a vacuum flash compressor.
2. Two CO_2 streams at 17.4 and 48.6 psia, with a single reabsorber column without a vacuum flash compressor.
3. Three CO_2 streams at 23, 40, and 60.7 psia, with two reabsorber columns and a hot flash column without a vacuum flash compressor.

The single CO_2 stream Rectisol design has been the most common and typically most if not all of the CO_2 is vented. The two CO2 stream Rectisol design reduces the total electricity use for Rectisol and compression of all of the CO_2 The three CO_2 stream Rectisol design futher reduces the total electricity use for Rectisol and compression of all of the CO_2 and increases CO2 recovery and purity. Lurgi developed the three CO_2 stream Rectisol design for the Lake Charles Cogeneration Coke Gasification to SNG Project. The three CO_2 stream pressures were optimized to further minimize the total electricity use for Rectisol and CO_2 compression. Lurgi did not perform an economic assessment including capital cost. So prior to this study the relative overall economic performance of these three Rectisol configurations was unknown.

The Lurgi Rectisol flow diagram for the single CO_2 stream case is shown on Figure 3-2. The gas feed to the Rectisol unit will be chilled to 50° F and passed through an ammonia scrubber. The mixed syngas will then be contacted with CO_2 rich methanol in the prewash section at the bottom of the absorber to remove any remaining ammonia and hydrogen cyanide. After that, H_2S and COS will be removed in the H_2S absorption section of the absorber. CO_2 will then be removed in the CO_2 absorption section of the

absorber. The temperature of the methanol to the absorber will be approximately -30° F. This temperature will increase with the heat of absorption, requiring additional methanol chilling at intermediate absorber locations.

CO_2 laden methanol from the absorber will be flashed in the medium-pressure (MP) flash column to remove dissolved hydrogen and CO. The flash gas will then be compressed and recycled back to the feed to the absorber.

The sulfur rich methanol will be flashed in the bottom of the MP stripper to remove dissolve hydrogen and CO. This flash gas will also be compressed and recycled back to the absorber.

The CO_2 rich methanol from the MP flash column will be subcooled in a chiller and then flashed in the reabsorber column(s). The sulfur rich methanol from the MP stripper will be flashed in the reabsorber(s) to remove CO_2. This flash gas will be washed with methanol from the CO_2 flash section at the top of the reabsorber(s) to reabsorb H_2S and COS. The methanol will be flashed to successively lower pressures. The methanol capacity to hold dissolved gas will decrease with decreasing pressure. As the pressure is reduced, the methanol temperature will be decreased by the refrigeration produced from desorption. In the single CO_2 stream case, the methanol will be flashed to a vacuum and the resulting flash gas will be compressed and added back to the higher pressure flash gas in the reabsorber. The two and three CO_2 stream cases do not have the flash gas compressor.

Ammonia and hydrogen cyanide laden methanol from the prewash section of the absorber will be fed to the top of the hot regenerator. Sulfur rich methanol from the reabsorber will be fed to a lower section of the hot regenerator. Methanol at the bottom of the hot regenerator will be indirectly heated to its boiling point by condensing 60 pounds per square inch gauge (psig) steam in reboilers. H_2S, COS, and CO_2 will then be released from the boiling methanol. Methanol removed from the bottom of the hot regenerator will be fully regenerated and returned to the absorber after cooling and chilling. The acid gas from the hot regenerator will be cooled to condense water vapor. The cooled acid gas will be fed to the WSA.

A methanol-water side stream from the hot regenerator will be fed to the methanol water column. Water at the bottom of the methanol water column will be indirectly heated to its boiling point by condensing 140 psig steam. Methanol has a lower vapor pressure than water and will be preferentially vaporized. The methanol vapor will be fed to the hot regenerator. An impure water stream will be taken from the bottom of the methanol water column, where it will be used for coke slurry makeup water. Methanol will also be purged as needed to control ammonia and hydrogen cyanide buildup. The methanol purge stream will be used as fuel in the WSA furnaces.

3.2 CO_2 Compression

The Rectisol CO_2 streams will be compressed to 2,150 psia and cooled to 90° F. At these conditions, CO_2 is a supercritical fluid. The compressed CO_2 will flow through a metering station and will be analyzed before custody transfer to the Denbury pipeline at a minimum pressure of 2,100 psig.

The optiminum number of CO_2 compressors is two each with a capacity of 50% of the total CO2 flow. This matches the two 50% capacity gas processing trains which is an optimum combination of equipment size, process availability/operating flexibility, and

cost. Each gas processing train will be shutdown once a year for preventative maintenance. One of the CO_2 compressors will also be shutdown at the same time for preventative maintenance.

Two types of compressors are commercially available for this service: between bearings and integrally geared multistage centrifugal compressors. Dresser, Elliot, GE-Nuovo Pignone, and MHI, offer between the bearings multistage centrifugal compressors, either on one shaft driven by a single motor or with separate motors for the low-pressure and high-pressure casings. These compressors have four stages with three stages of intercooling. MAN and Siemens offer integrally geared multistage centrifugal compressors with eight stages and six stages of intercooling. MAN integrally geared centrifugal compressors have been operating for 10 years in a similar CO_2 compression service at the Great Plains Synfuels Plant.

Black & Veatch recently obtained CO_2 compressor budget pricing and performance data from Dresser, GE-Nuovo Pignone, MAN, MHI, and Siemens for several projects. The polytropic stage efficiencies for the between the bearings compressors ranged from 84 to 64 percent. The polytropic stage efficiencies for the MAN compressors were all 85 percent, which makes it the most efficient machine. The more efficient MAN compressors were also the most economical. Polytropic stage efficiencies of 85 percent were used in this optimization study.

3.3 Optimization Study Results

The Rectisol data supplied by Lurgi for the Lake Charles coke gasification to SNG and H_2 projects were adjusted by Black & Veatch for coke gasification to crude methanol. Lean methanol solvent rates were estimated by adjusting for CO_2 and H_2S rates and partial pressures in the feed gas to the Rectisol unit. Tower sizes were adjusted to maintain constant superficial gas velocities. Heat duties were adjusted for methanol circulation rates. Pump and compressor horsepower values were estimated for the adjusted liquid and gas rates. The stream rate and composition data and the adjusted equipment size data were used to estimate capital and operating costs.

The Rectisol feed gas study basis is presented in Table 3-1.

Table 3-1 **Rectisol Feed Gas**		
Syngas Feed Gas Flow Rate	lb-moles/hr	83,036
Syngas Feed Gas H_2+CO Flow Rate	lb-moles/hr	54,416
Operating Pressure	psia	850
CO_2 Concentration	%vol dry	32.28%
CO_2 Partial Pressure	psia	274
H_2S Concentration	%vol dry	1.41%
COS Concentration	%vol dry	0.04%

A detailed summary of the study process data is presented in Table 3-2. Utilities consumptions for the one and two CO_2 streams cases are listed as the difference from the three CO_2 streams base case.

Table 3-2
Optimization Study Process Data

Parameter Units		Denbury CO_2 Spec	One CO_2 Stream	Two CO_2 Streams	Three CO_2 Streams
Treated Syngas from Rectisol Unit					
Treated Syngas Flow Rate	lb-moles/hr total		56,293	56,051	56,379
Treated Syngas Flow Rate	lb-moles/hr H_2+CO	54,2	10	53,968	54,200
CO_2 Concentration	%vol		2.81%	2.81%	2.81%
Operating Pressure	psia		810	810	810
CO_2 Absorbed, per train	lb-moles/hr		12,612	12,615	12,611
Product CO_2 from Rectisol Unit					
CO_2 Pressure(s)	psia		29.0	17.4 48.6	23.0 40.0 60.7
CO_2 Purity	%v CO_2 97.0		99.2	98.0	99.1
CO_2 Purity	ppmv H_2S 20		20	7	1
CO_2 Purity	ppmv H_2S +COS	35	33	42	3
CO_2 Recovered (NOC)	stpd CO_2		12,577	11,967	12,591
CO_2 Recovered (NOC)	stpd total		12,619	12,069	12,660
Acid Gas from Rectisol Unit					
Acid Gas to WSA	MMscfd		24.7	34.2	23.5
Acid Gas to WSA	%v CO_2		52.9	67.8	52.7
CO_2 Lost in Acid Gas	%		5.2	9.5	5.1
Rectisol General					
Lean Methanol Rate	gpm at 60° F	5,85	8	6,648	5,580
H_2 & CO Loss to CO_2 & Acid Gas	MMscfd		1.9	4.1	2.0

Table 3-2 (Continued)
Optimization Study Process Data

Parameter Units		Denbury CO_2 Spec	One CO_2 Stream	Two CO_2 Streams	Three CO_2 Streams
Electricity Use					
Pumps MW			0.0	-1.2	Base
Recycle Gas Comp	MW		0.1	0.1	Base
Flash Vacuum Comp	MW		5.9	0.0	Base
Refrigeration Comp	MW		-6.7	-5.9	Base
CO_2 Compression	MW		2.3	2.2	Base
Cooling Water	MW		-0.2	-0.1	Base
Total	MW		1.5	-4.9	Base
Cooling Water Duty					
Rectisol Process	MBtu/h		2.7	24.0	Base
Rectisol Refrigeration	MBtu/h		-62.4	-59.3	Base
CO_2 Compression	MBtu/h		6.8	0.7	Base
Total MBtu/h			-52.9	-34.6	Base
Steam Use					
140 psig	1,000 lb/h		2.8	10.7	Base
60 psig	1,000 lb/h		4.9	18.8	Base
Total MBtu/h			6.8	26.3	Base

Energy use is summarized in Table 3-3.

Table 3-3
Specific Energy Use

Parameter Units		One CO_2 Stream	Two CO_2 Streams	Three CO_2 Streams
Electricity and Steam	MBtu/h	412	409	400
CO_2 Recovered	stph CO_2 524		499	525
Specific Energy Use	MBtu/ton recovered CO_2 0.78	3	0.818	0.759

The three CO_2 streams case uses the least electricity and steam energy per ton of CO_2 recovered. The specific energy use of the one CO_2 stream and two CO_2 streams cases are 3.1 percent and 7.7 percent higher than the three CO_2 streams case, respectively.

Capital and operating cost estimates are summarized in Table 3-4 as the differences between the one and two CO_2 streams cases and the three CO_2 streams base case. The two CO_2 streams case has the lowest Rectisol capital cost because it uses less equipment, which is why it has lower CO_2 recovery and higher CO and H_2 losses. Lower CO_2 recovery increases the CO_2 level in the acid gas to the WSA, which increases the WSA cost. Lower CO_2 recovery increases the CO_2 level in the acid gas to the WSA, which increases the WSA cost. The WSA NO_x and SO_2 emissions are proportional to the volumetric acid gas flow; however, the cost impact of higher emissions was not included. The three CO_2 streams case also has the lowest acid gas flow.

Table 3-4
Differential Capital and Operating Cost Estimates

Parameter Units		One CO_2 Stream	Two CO_2 Streams	Three CO_2 Streams	Unit Costs
Capital Costs					
Rectisol $	millions	-4.3	-15	Base	
CO_2 Compression	$ millions	6.9	6.6	Base	
WSA $	millions	-1.8	4.7	Base	
Total $	millions	0.8	6.3	Base	
Operating Costs at 90% Capacity Factor					
Electricity $	millions/yr	0.87	-2.55	Base	$0.067/kWh
140 psig Steam	$ millions/yr	0.22 0.85		Base	$10.00/1,000 lb
60 psig Steam	$ millions/yr	0.17	0.67	Base	$4.50/1,000 lb
Cooling Water	$ millions/yr	-0.42	-0.7	Base	$1/MBtu
Makeup Methanol	$ millions/yr	0.00	0.01	Base	$1/gallon
Total $	millions/yr	0.85	-1.30	Base	
Production Credits at 90% Capacity Factor					
Methanol Production	$ millions/yr 0.12		-2.65	Base	$1/gallon
CO_2 Production	$ millions/yr	-0.80	-36.93	Base	$7.5/ton
Total $	millions/yr	-0.68	-39.58	Base	

The three CO_2 streams case has the lowest capital cost and highest production credits. The two CO_2 streams case has the lowest operating cost, but the operating cost savings are overwhelmed by higher capital cost and lower production credits. Overall, the economics for the three CO_2 streams case and the one CO_2 stream case are close, with the three CO_2 streams case being the most economical. The three CO_2 streams case will also be more reliable than the single CO_2 stream case, because it does not have the flash gas compressor.

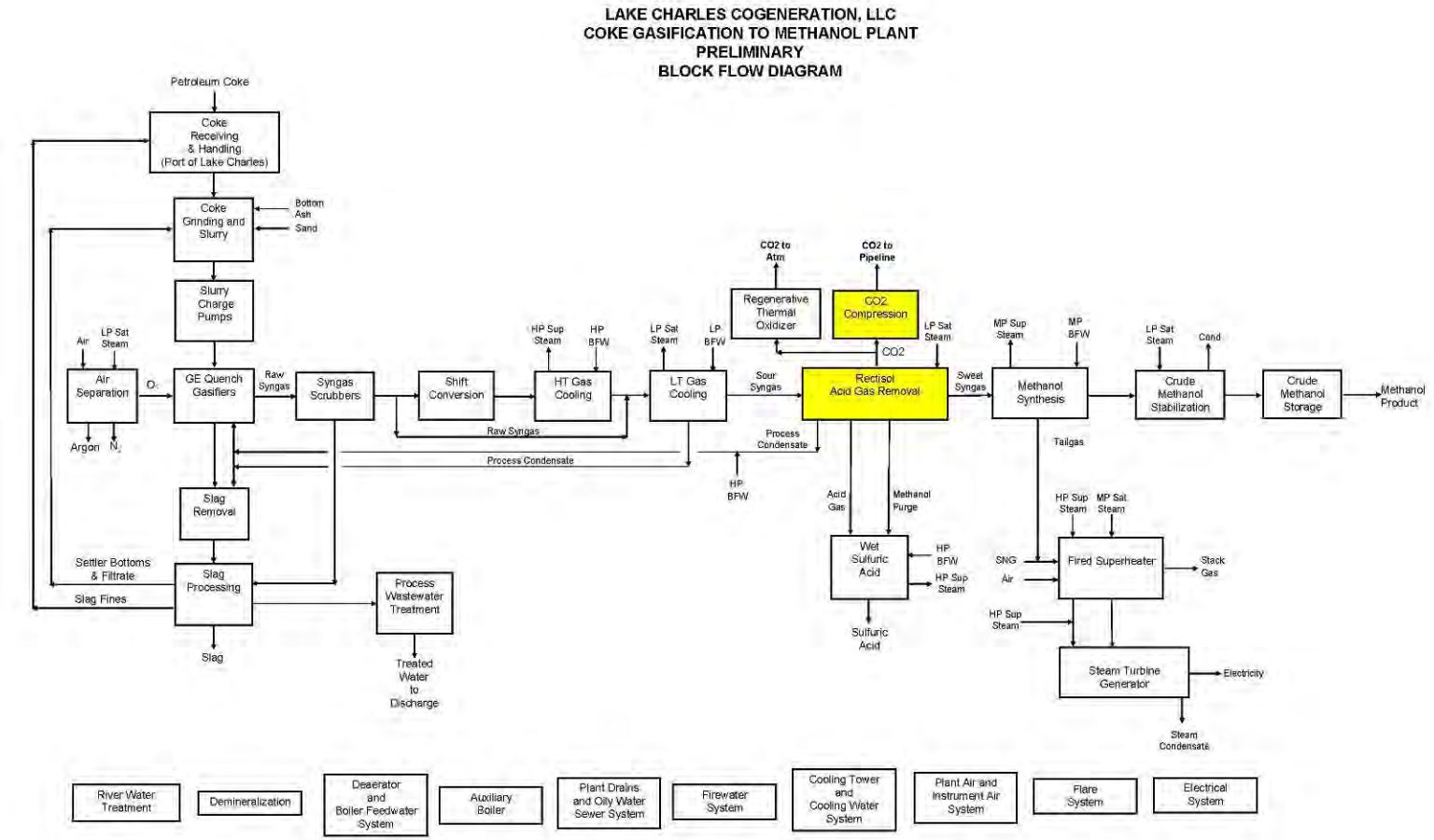


Figure 3-1
Block Flow Diagram

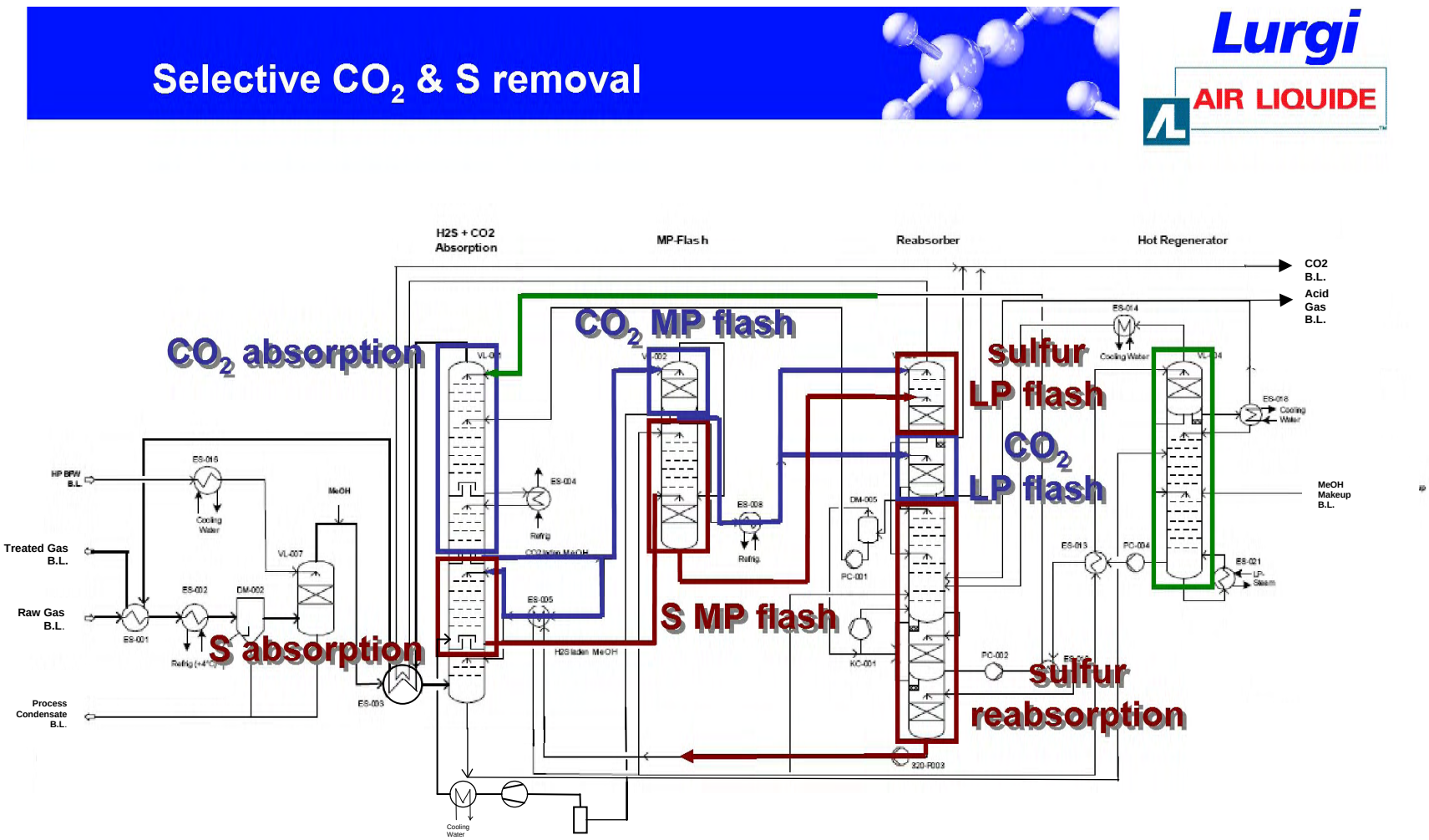


Figure 3-2
Selective CO_2 and Sulfur Removal

4.0 Conclusions

The three CO_2 streams case is optimum because it has the lowest capital cost, highest CO_2 recovery, and lowest specific energy use per ton of CO_2 recovered. The three CO_2 streams case should be used for inquiring the CO_2 compressors.

THE LAKE CHARLES CCS PROJECT
PHASE 1 TOPICAL REPORT

APPENDIX 2

Phase 1 SOPO Task 1.5.2.1
CO_2 Capture and Compression Equipment
Preliminary Engineering

APPENDIX 2.0 CO_2 CAPTURE AND COMPRESSION EQUIPMENT PRELIMINARY ENGINEERING

This appendix provides a preliminary plant arrangement, system definition, and material balances for the Lake Charles CCS Project's CO_2 capture and compression systems.

2.1 General Project Background

The Lake Charles CCS Project will gasify approximately 8,810 short tons per day (STPD) of petcoke to produce approximately 7,284 STPD of Methanol. Byproducts will include sulfuric acid (H_2SO_4), CO_2, argon, and electricity.

The plant will consist of five General Electric (GE) Quench gasifiers and two trains of syngas processing, including sour shift conversion, Lurgi Rectisol® selective acid gas removal, methanol synthesis and stabilization, and Haldor Topsoe wet sulfuric acid (WSA) production. At design plant capacity, four GE Quench gasifiers will operate at their design rate, which allows one gasifier to be on hot standby or shut down for maintenance. Gasifiers will be started up using natural gas to minimize the SO_2 emissions.

The Rectisol unit will produce approximately 237 MMSCFD of CO_2 suitable for enhanced oil recovery. The CO_2 concentration will be more than 99 percent by volume. The Rectisol unit will produce CO_2 at three different pressures that will subsequently be forwarded to the CO_2 compression system. A general block flow diagram of the gasification, CO_2 capture, and CO_2 compression system is shown on Figure 2-1.

2.2 Plant Arrangement

A conceptual layout of the CO_2 capture and compression equipment is shown on Figure 2-2 and drawing 162882-1000-X1000.

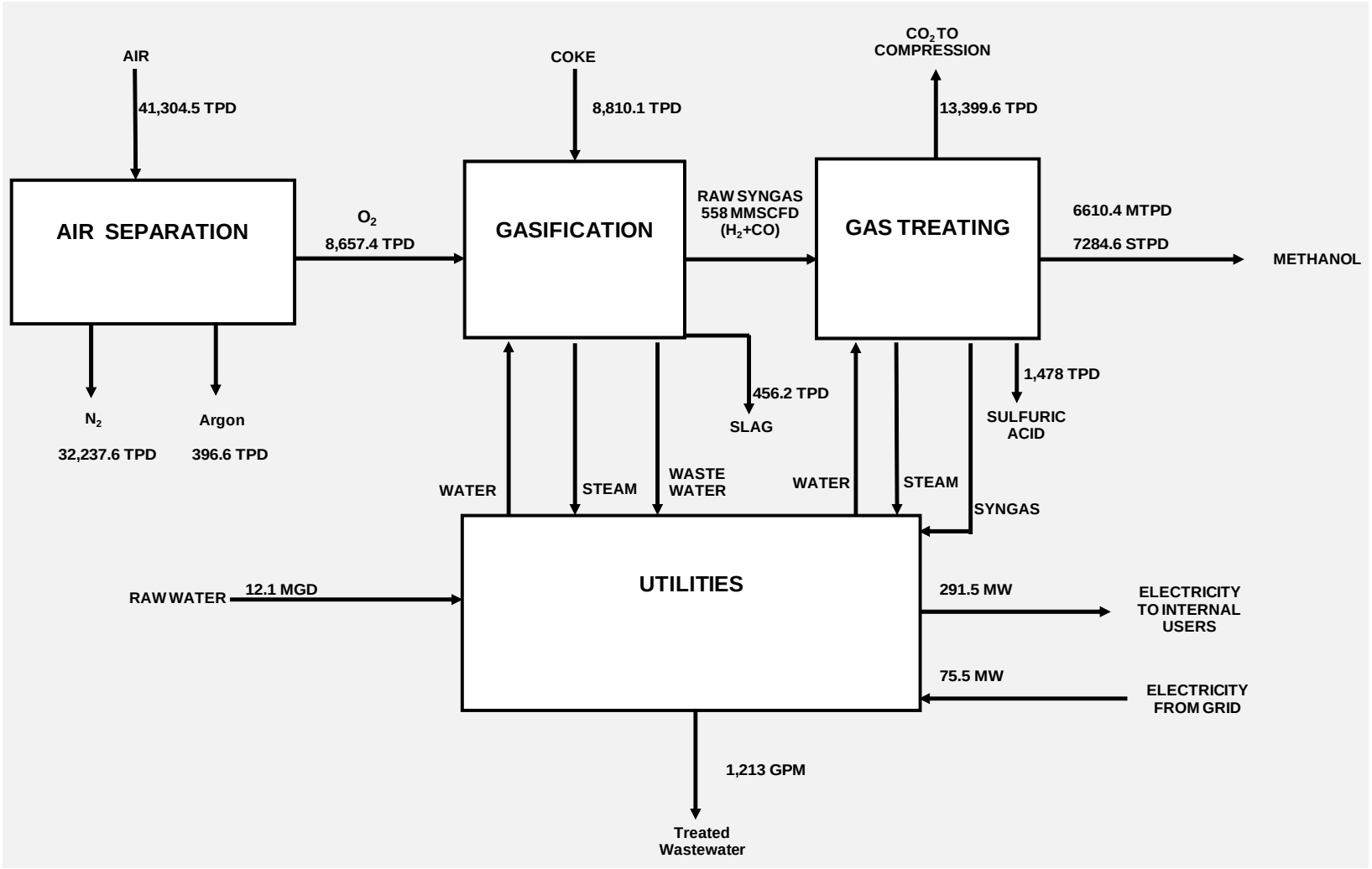


Figure 2-1. Gasification and CO_2 Capture and Compression Block Flow Diagram

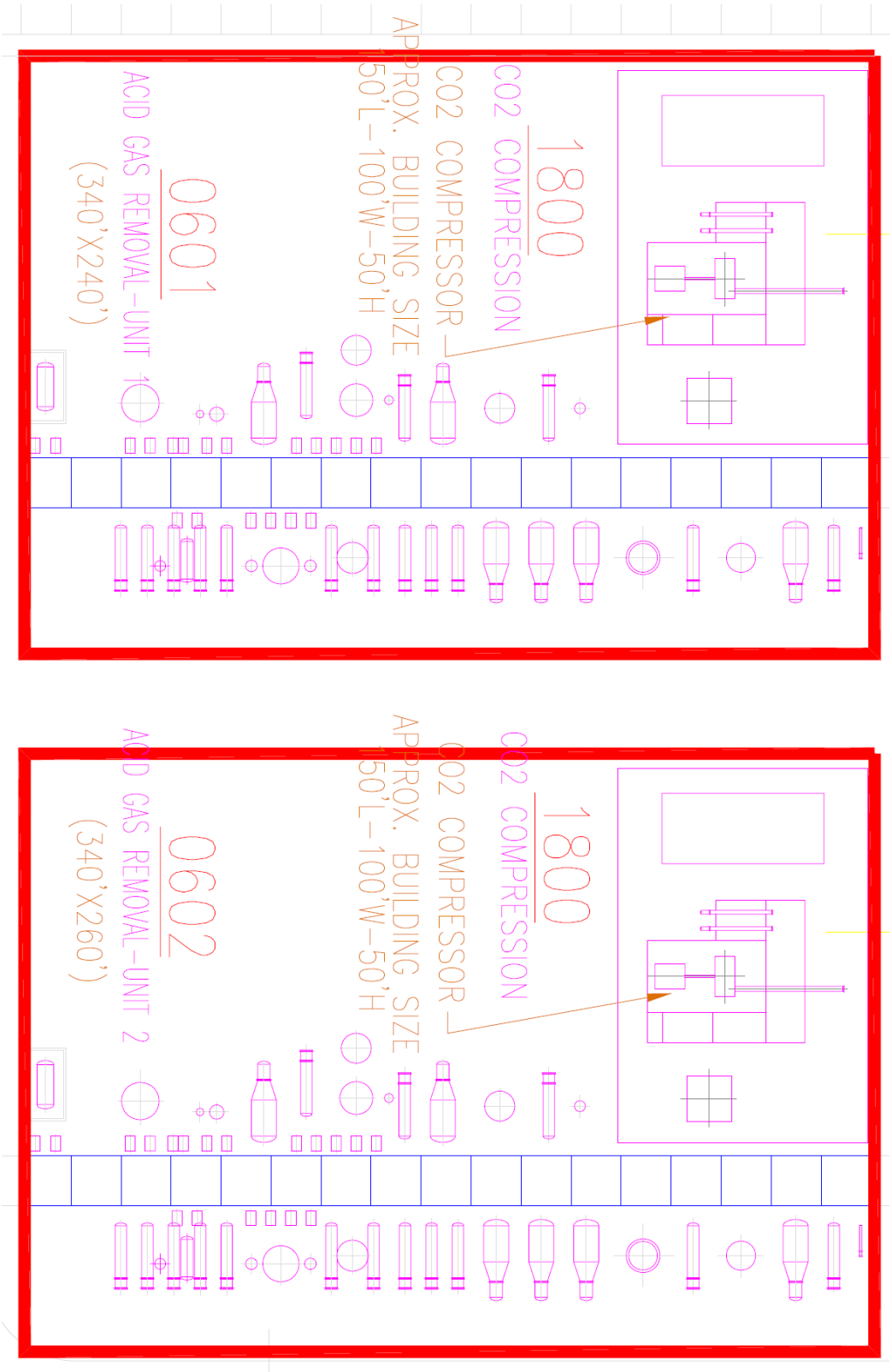
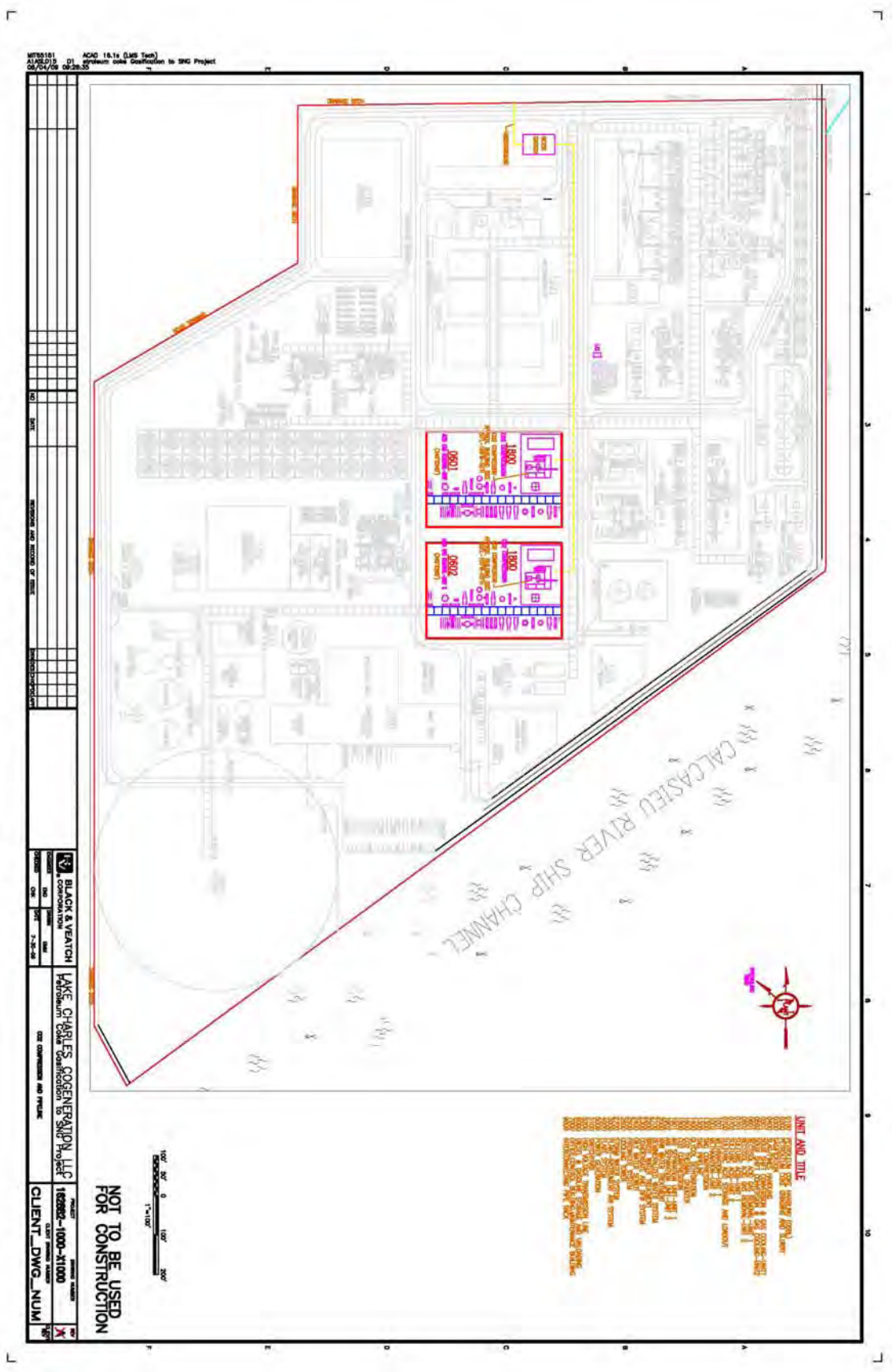


Figure 2-2. CO_2 Capture and Compression Equipment Layout (Refer to drawing 162882-1000-X1000 for scale)


NOT TO BE USED FOR CONSTRUCTION
LAKE CHARLES COGENERATION, LLC
Petroleum Coke Gasification to SNG Project
BLACK & VEATCH CORPORATION
CALCASIEU RIVER SHIP CHANNEL

General CO_2 Capture System Definition

Process flow diagrams of a single Rectisol train are shown on drawings 042152-0601-P1001 though 042152-0601-P1007. The gas feed to the Rectisol unit will be chilled to 50° F and passed through an ammonia scrubber. The mixed syngas will then be contacted with CO_2 rich methanol in the prewash section at the bottom of the absorber to remove any remaining ammonia and hydrogen cyanide. After that, H_2S and COS will be removed in the H_2S absorption section of the absorber. CO_2 will then be removed in the CO_2 absorption section of the absorber. The temperature of the methanol to the absorber will be approximately -42° F. This temperature will increase with the heat of absorption, requiring additional methanol chilling at intermediate absorber locations.

CO_2 laden methanol from the absorber will be flashed in the medium-pressure (MP) flash column to remove dissolved hydrogen and CO. The flash gas will then be compressed and recycled back to the feed to the absorber.

The sulfur rich methanol will be flashed in the bottom of the MP stripper to remove dissolve hydrogen and CO. This flash gas will also be compressed and recycled back to the absorber.

The CO_2 rich methanol from the MP flash column will be subcooled in a chiller and then flashed in the reabsorber column(s). The sulfur rich methanol from the MP stripper will be flashed in the reabsorber(s) to remove CO_2. This flash gas will be washed with methanol from the CO_2 flash section at the top of the reabsorber(s) to reabsorb H_2S and COS. The methanol will be flashed to successively lower pressures. The methanol capacity to hold dissolved gas will decrease with decreasing pressure. As the pressure is reduced, the methanol temperature will be decreased by the refrigeration produced from desorption.

Ammonia and hydrogen cyanide laden methanol from the prewash section of the absorber will be fed to the top of the hot regenerator. Sulfur rich methanol from the reabsorber will be fed to a lower section of the hot regenerator. Methanol at the bottom of the hot regenerator will be indirectly heated to its boiling point by condensing 70 pounds per square inch gauge (psig) steam in reboilers. H_2S, COS, and CO_2 will then be released from the boiling methanol. Methanol removed from the bottom of the hot regenerator will be fully regenerated and returned to the absorber after cooling and chilling. The acid gas from the hot regenerator will be cooled to condense water vapor. The cooled acid gas will be fed to the WSA.

A methanol-water side stream from the hot regenerator will be fed to the methanol water column. Water at the bottom of the methanol water column will be indirectly heated to its boiling point by condensing 200 psig steam. Methanol has a lower vapor pressure than water and will be preferentially vaporized. The methanol vapor will

be fed to the hot regenerator. An impure water stream will be taken from the bottom of the methanol water column, where it will be used for coke slurry makeup water. Methanol will also be purged as needed to control ammonia and hydrogen cyanide buildup. The methanol purge stream will be used as fuel in the WSA furnaces.

The Rectisol unit will require approximately 42.3 MW during normal operation.

2.3 General CO_2 Compression System Definition

The CO_2 Compression System compresses all of the flashed CO_2 from Rectisol unit into a sendout CO_2 pipeline for enhanced oil recovery use. A process flow diagram of a single compressor is shown on drawing 042152-1801-P1001. CO_2 will be produced from two trains of Rectisol and supplied to 2 x 50 percent electric motor driven integrally geared compressors CO_2 compressors at a total rate of approximately 237 MMSCFD.

The compressor units are comprised of a low speed gear and multiple high speed pinions which are contained within the compressor body. The impellers are mounted on the high speed pinions which allow selection of impellers operating at different speeds and diameters which allow for a more optimum aerodynamic selection. Eight impellers (stages) are required for the stated pressure ratio with intercooling as required. The compressor package will also consist of all requisite intercoolers and suction scrubbers. There will be suction scrubbers after the 5th and 6th stages of compression to protect against liquid formation at those conditions. All intercoolers use cooling water as the cooling medium.

The compressors are completely packaged by the vendor and includes motor, coupling, compressor, lube oil system, intercoolers, aftercooler and interstage piping.

CO_2 is produced at three different pressure levels in Rectisol®: ~23 psia (LP3), ~40 psia (LP2), and ~60.7 psia (LP3). Each stream is supplied to each of the first 3 stages of compression as shown on drawing 042152-1801-P1001.

The CO_2 compression will require roughly 42.9 MW of power to deliver the 237 MMSCFD of CO_2 to custody transfer metering at a pressure of 2,165 psia. The compressed CO_2 gas is cooled to 100º F in the HP CO_2 Aftercooler (18-E-0107) using cooling water prior to leaving the compressor package battery limits. The combined CO_2 stream purity will be greater than 99 percent by volume.

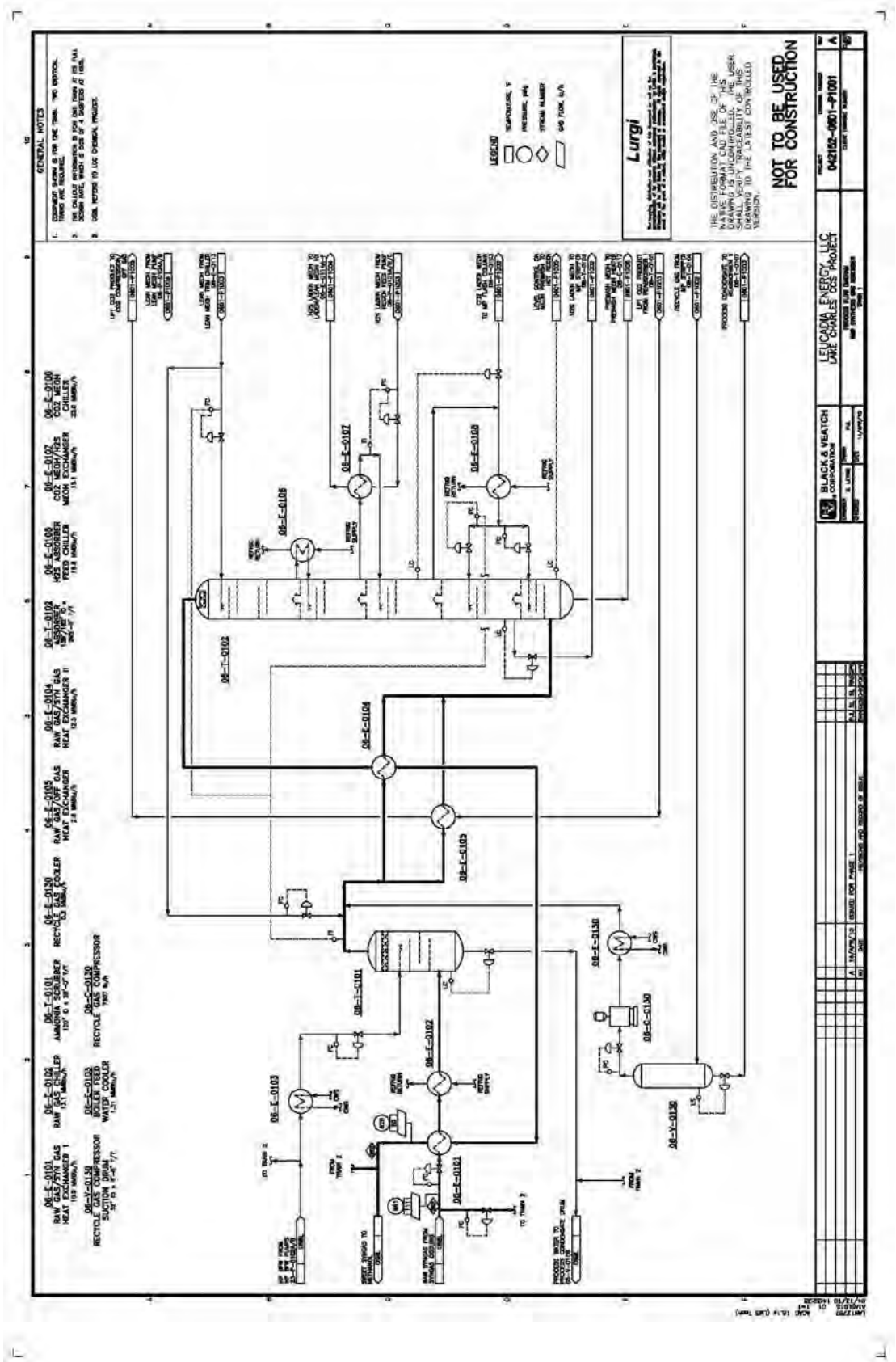
The high pressure CO_2 enters a custody transfer metering station (described below) before leaving the plant battery limit and going into the CO_2 pipeline.

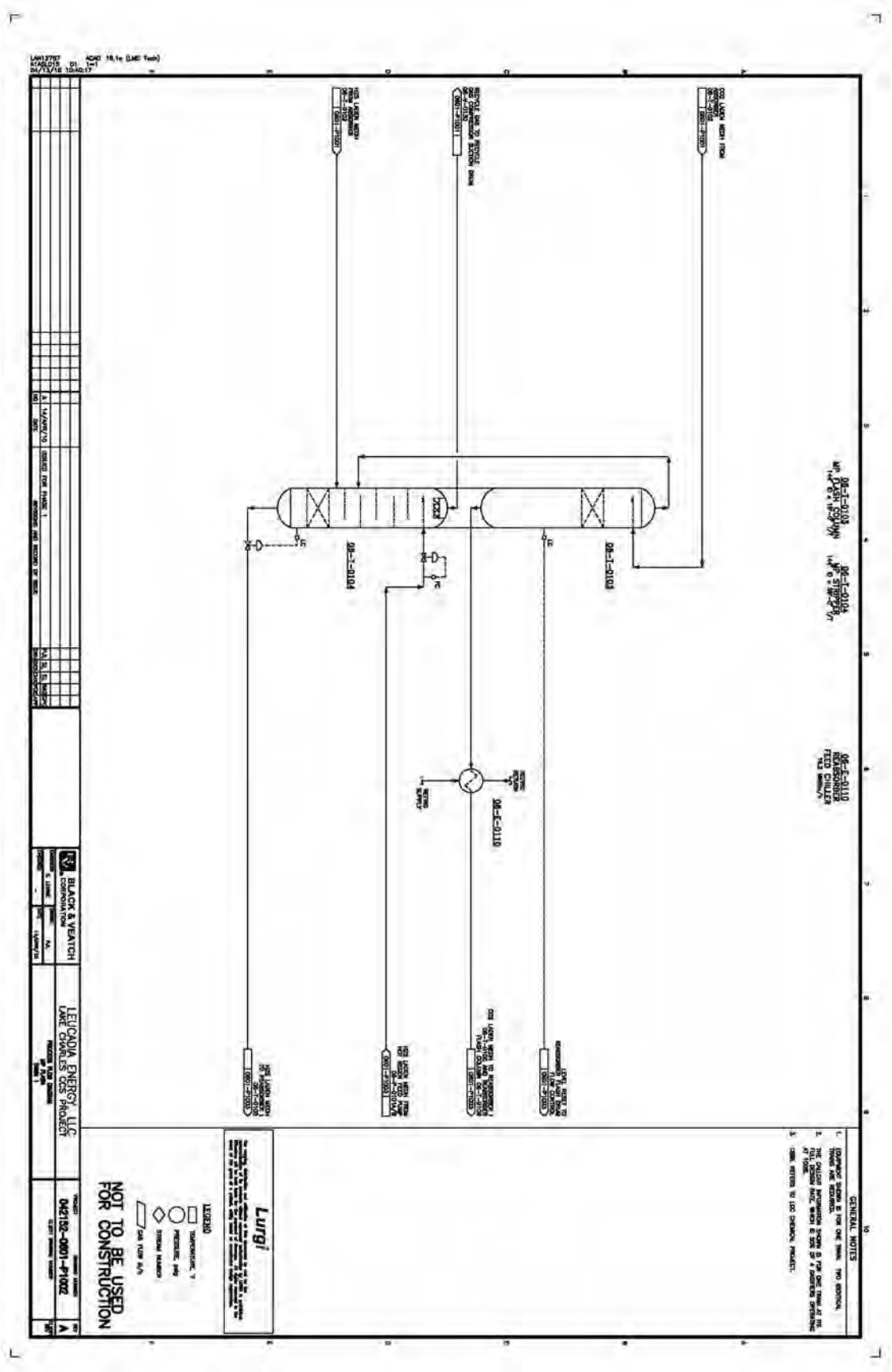
2.3.1 CO_2 Custody Metering

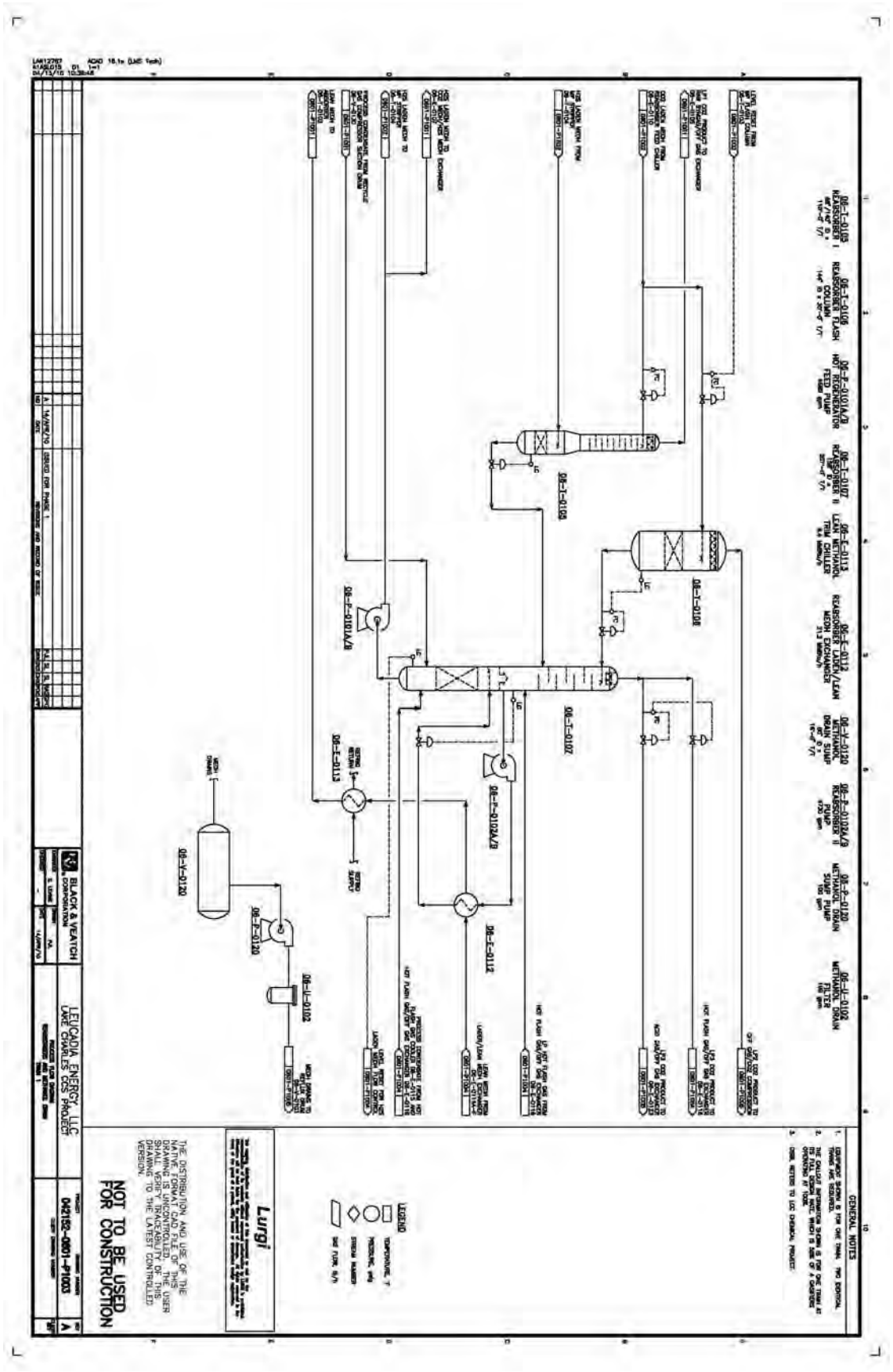
The CO_2 will flow through a two-tube custody meter system as it leaves the plant site. This system shall qualify for custody transfer (volume flow rate accuracy not exceeding +/- 1.0%), consisting of the following components:

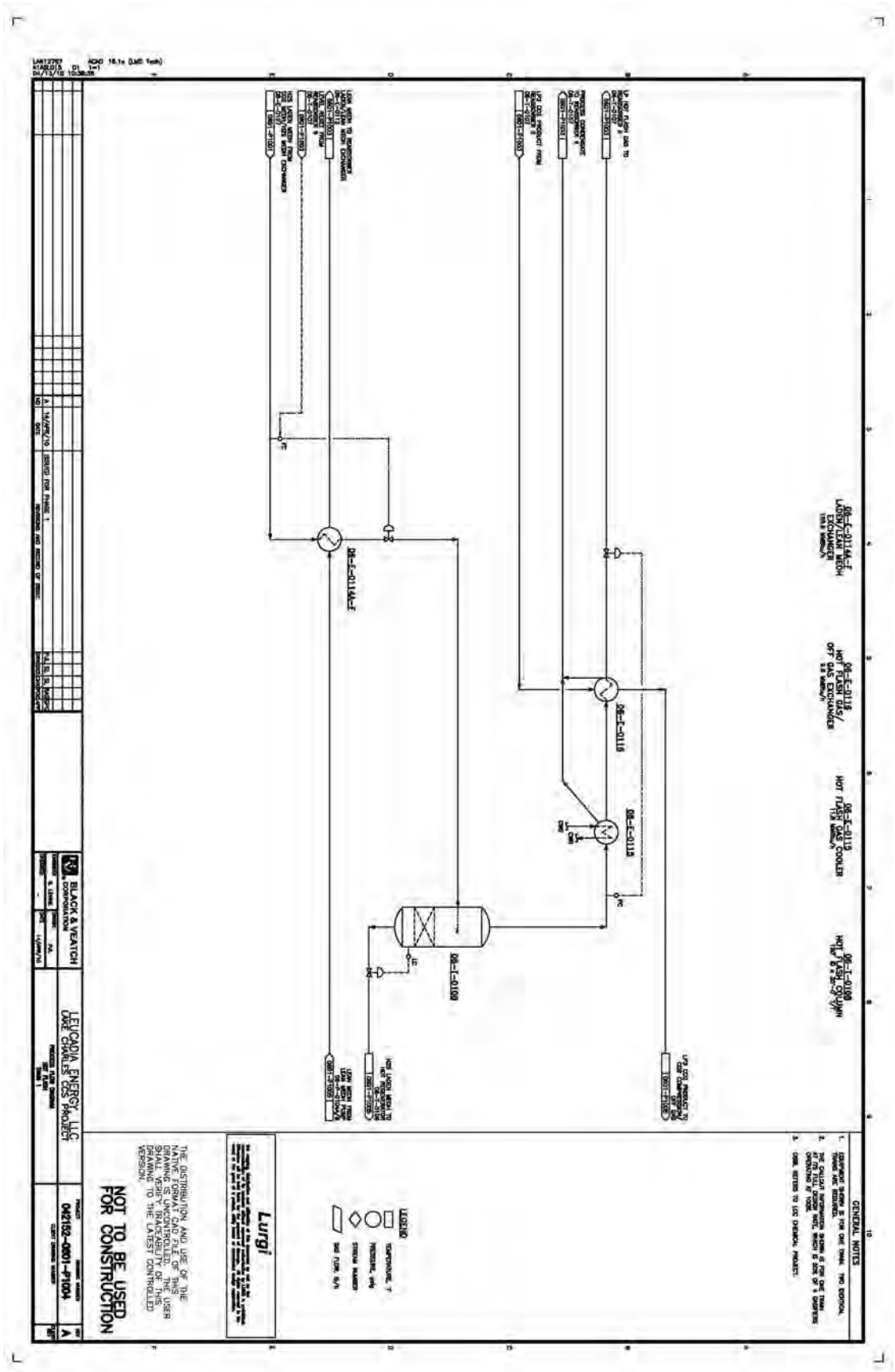
- 2 ea. 12" 2500# meter runs each with switching valves; flow, pressure, and temperature transmitters, and analyzer probes. The 2 meter runs shall be configured in a 1 + 1 configuration, with the second stream used as a spare meter stream.
- 2 ea Multi-path Ultrasonic flow meters, 1 in each run.
- 2 Flow computers (in the Meter house) with serial communication to the DCS. The flow computers correct the flow with pressure and temperature values, and using the gas composition from the chromatograph, calculate volume, mass, and energy flows.
- 2 metering panels (in the Meter house).
- Gas Chromatograph (in the Meter house) with sample probes for each meter run, and sample system and serial communication to the DCS.
- Meter house approved for the Electrical Hazardous Area Classification, including an HVAC and purge system with fresh air intake stack if required.

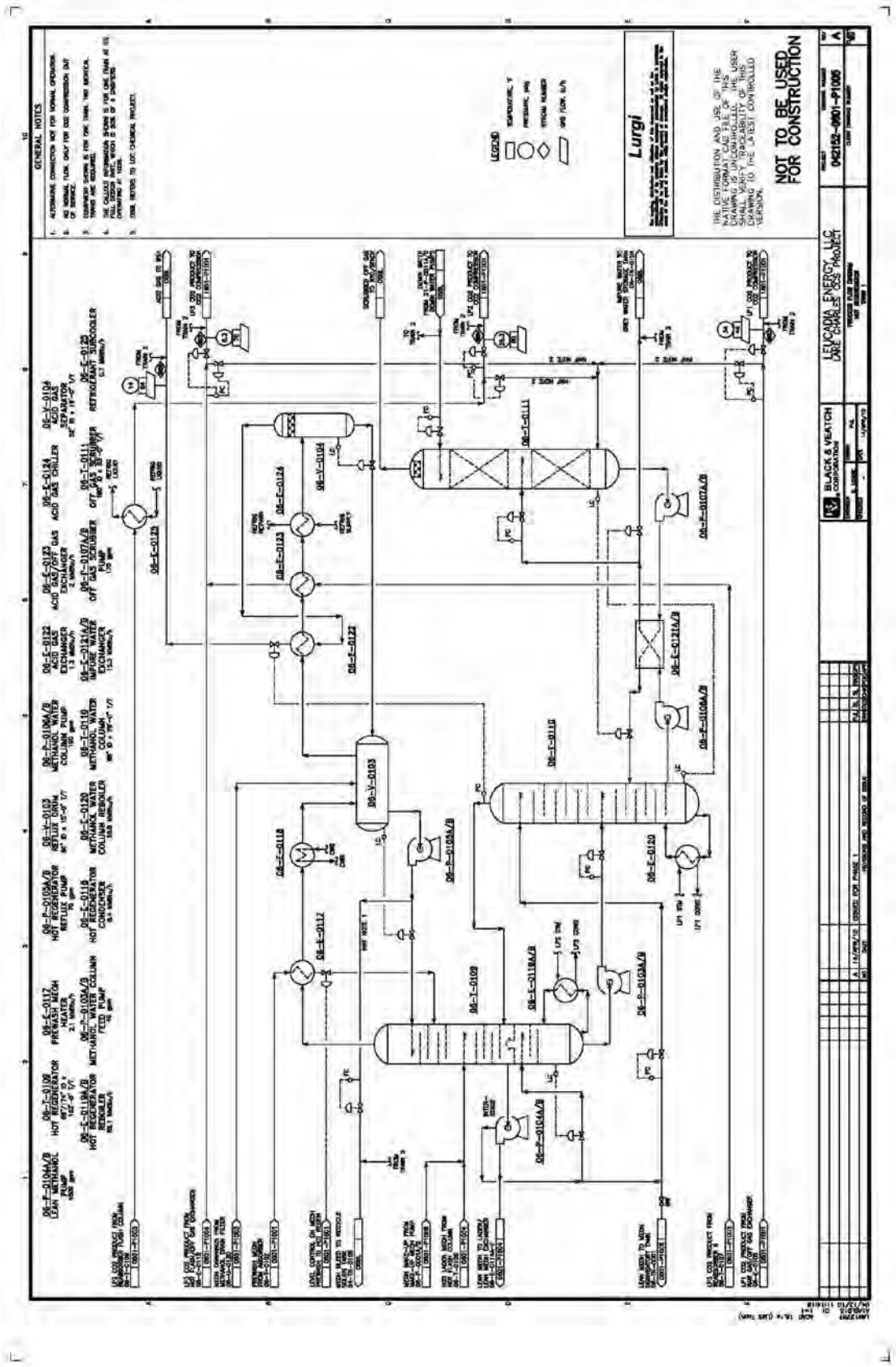
Periodically one of the ultrasonic flow meters will be sent for re-calibration and validation.

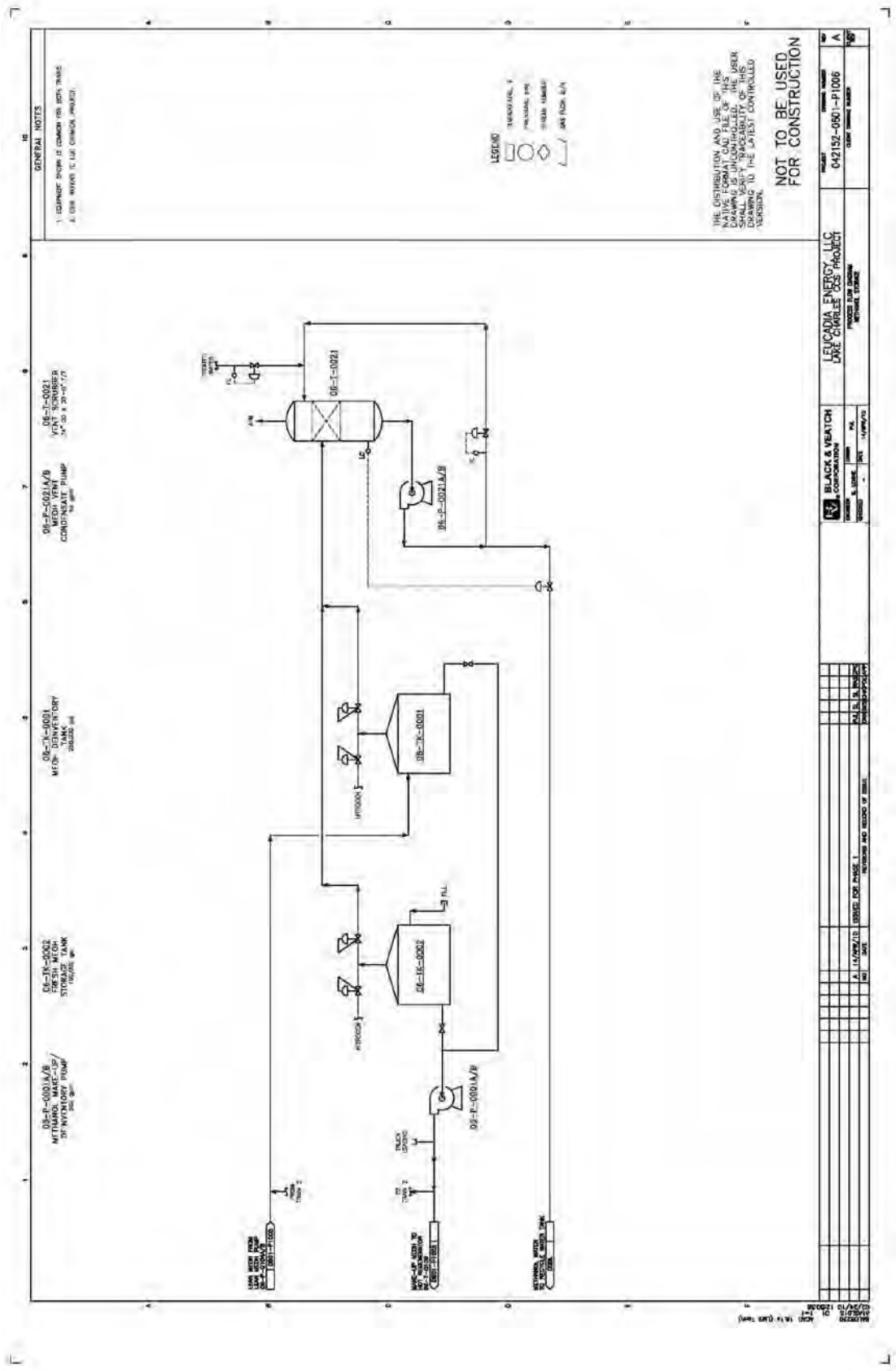

GENERAL NOTES
LEGEND
Lurgi
NOT TO BE USED FOR CONSTRUCTION
LEUCADIA ENERGY, LLC
LAKE CHARLES CCS PROJECT
BLACK & VEATCH CORPORATION
042152-0001-P1001
THE DISTRIBUTION AND USE OF THE NATIVE FORMAT CAD FILE OF THIS DRAWING IS UNCONTROLLED. THE USER SHALL VERIFY TRACEABILITY OF THIS DRAWING TO THE LATEST CONTROLLED VERSION.
04-T-0102
04-E-0102
04-E-0103
04-E-0105
04-E-0106
04-E-0107
04-E-0108
04-E-0130
04-T-0101
04-T-0130
04-C-0130
04-P-0130

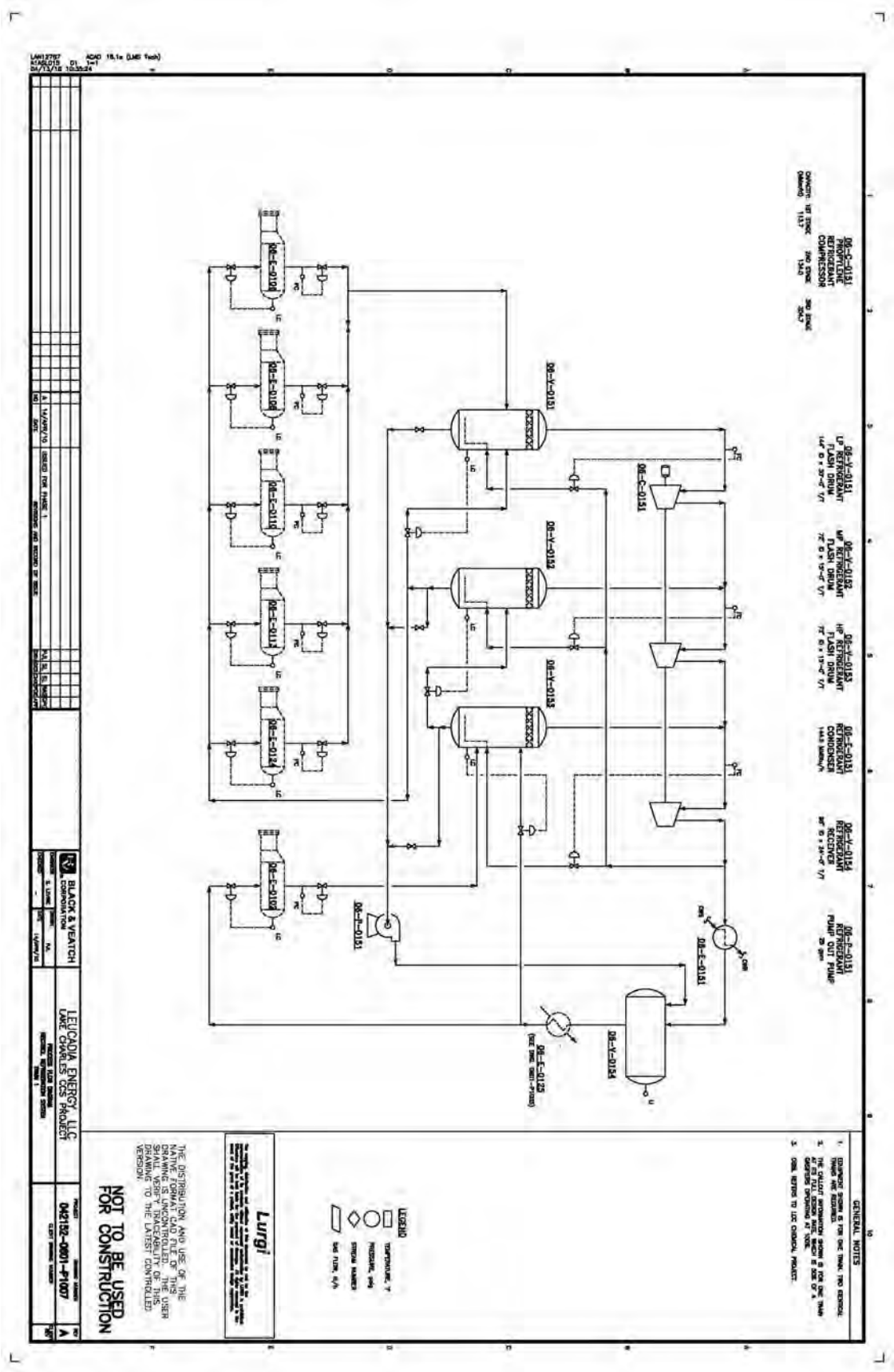

NOT TO BE USED FOR CONSTRUCTION
LEUCADIA ENERGY, LLC
LAKE CHARLES CCS PROJECT
BLACK & VEATCH
042152-0001-P1002
GENERAL NOTES
LEGEND

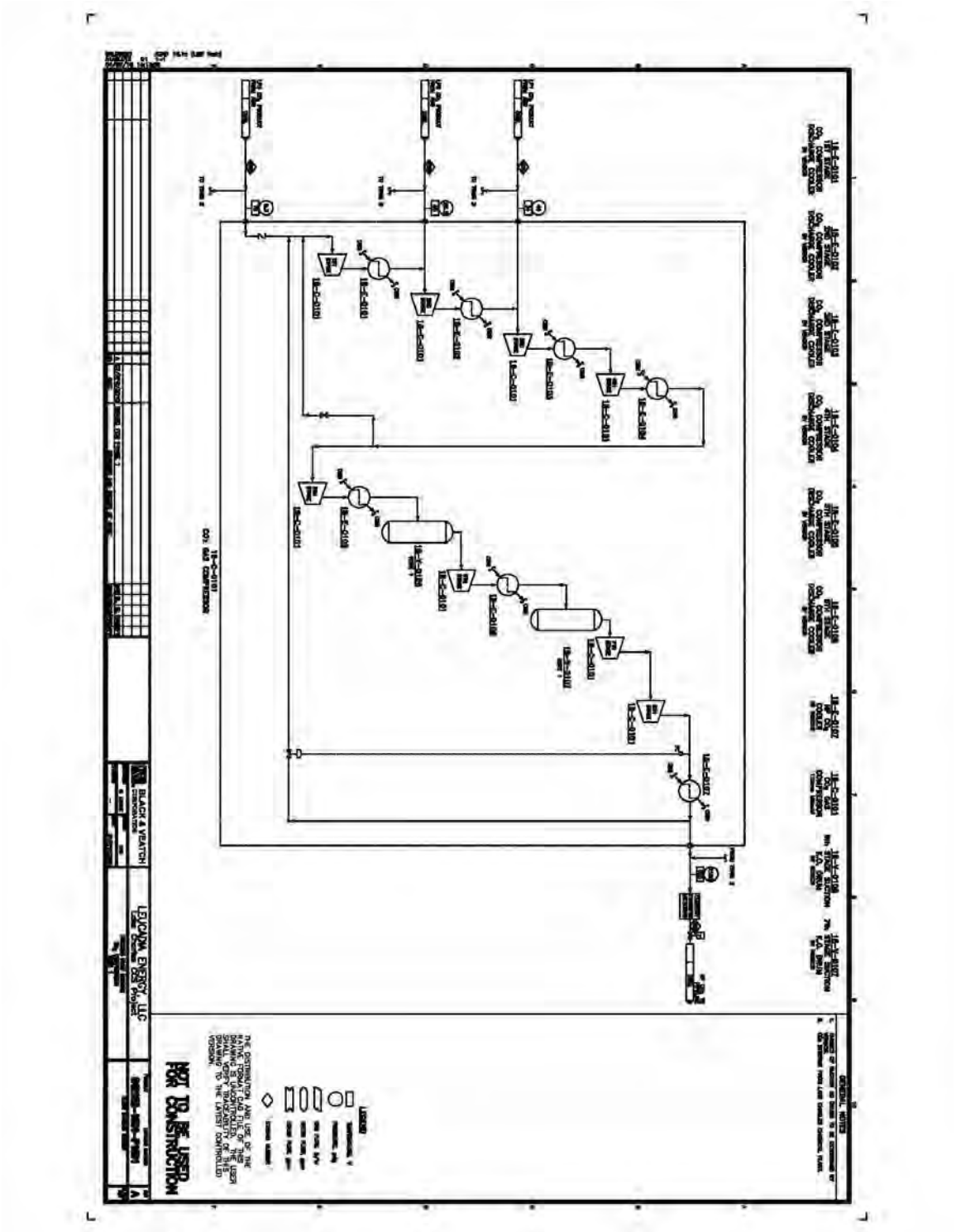

LEUCADIA ENERGY, LLC
LAKE CHARLES CCS PROJECT
BLACK & VEATCH
Lurgi
NOT TO BE USED FOR CONSTRUCTION
THE DISTRIBUTION AND USE OF THE NATIVE FORMAT CAD FILE OF THIS DRAWING IS UNCONTROLLED. THE USER SHALL VERIFY THE CONTROLLED DRAWING TO THE LATEST CONTROLLED VERSION.
042152-0001-P1003
GENERAL NOTES
LEGEND
06-T-0103
06-E-0108
06-P-0101A/B
06-T-0107
06-E-0113
06-E-0112
06-H-0130
06-P-0102A/B
06-P-0130
06-H-0100
06-T-0109
06-T-0106
06-T-0102
06-V-0120
06-P-0120
06-H-0102


NOT TO BE USED FOR CONSTRUCTION
LEUCADIA ENERGY, LLC
LAKE CHARLES CCS PROJECT
BLACK & VEATCH
Lurgi
LEGEND
GENERAL NOTES


GENERAL NOTES
LEGEND
Lurgi
NOT TO BE USED FOR CONSTRUCTION
LEUCADIA ENERGY, LLC
LAKE CHARLES CCS PROJECT
BLACK & VEATCH CORPORATION
042152-0001-P1005
THE DISTRIBUTION AND USE OF THE NATIVE FORMAT CAD FILE OF THIS DRAWING IS UNCONTROLLED. THE USER SHALL VERIFY TRACEABILITY OF THIS DRAWING TO THE LATEST CONTROLLED VERSION.
06-E-0123
06-E-0124
06-E-0122
06-E-0121A/B
06-E-0120
06-E-0119A/B
06-E-0118
06-E-0117
06-E-0116
06-E-0122
06-T-0108
06-T-0109
06-T-0111
06-V-0103
06-P-0107A/B
06-P-0106A/B
06-P-0105A/B
06-P-0104A/B
06-P-0103A/B
06-P-0102A/B
06-P-0101A/B


GENERAL NOTES
LEGEND
NOT TO BE USED FOR CONSTRUCTION
LEUCADIA ENERGY, LLC
LAKE CHARLES CCS PROJECT
BLACK & VEATCH CORPORATION
042152-0501-P1006
06-T-0021
06-P-0021A/B
06-T-0001
06-P-0001A/B
06-TK-0001
06-TK-0002
06-E-0002


NOT TO BE USED FOR CONSTRUCTION
LEUCADIA ENERGY, LLC
LAKE CHARLES CCS PROJECT
BLACK & VEATCH
042152-0001-P1007
GENERAL NOTES
LEGEND


BLACK & VEATCH
LEUCADIA ENERGY, LLC
LCE CCUS Project
NOT TO BE USED FOR CONSTRUCTION
THE DISTRIBUTION AND USE OF THE RAWING CONTAINED HEREIN BY THE USER SHALL KEEP TRACEABILITY OF THIS DRAWING TO THE LATEST CONTROLLED VERSION
GENERAL NOTES
LEGEND

2.4 CO_2 Capture Mass and Energy Balance

A mass and energy balance for the Lake Charles CCS Project's CO_2 capture system is provided in Table 2-1 for reference steams shown on the process flow diagrams 042152-0601-P1001 though 042152-0601-P1007.

2.5 CO_2 Compression Mass and Energy Balance

A mass and energy balance for the Lake Charles CCS Project's CO_2 compression system is provided in Table 2-2 for reference steams shown on the process flow diagram 042152-1801-P1001.

Table 2-1
CO_2 Capture Mass and Energy Balance

Plant:	Lake Charles CCS Project	Material Balance	B&V Project:	042152
Location:	Sulfur, LA	Expected Figures	Date:	April 13, 2010
Case:	GE Gasification, Target Values			

Gas Streams

Stream:		0601	0602	0603	0604	0605	0606
Medium:		SOUR SYNGAS	SWEET SYNGAS	LP1CO2	LP2CO2	LP3CO2	ACID GAS
From:		SYNGAS COOLING	AGR	AGR	AGR	AGR	AGR
To:		AGR	METHANOL	CO2 COMPRESSION	CO2 COMPRESSION	CO2 COMPRESSION	WET SULFURIC ACID
Mole-flow	lbmol/hr	87,744	58,968	6,042	1,400	15,752	2,721
Mass-flow	Mlb/hr	1,873.47	627.35	263.02	59.69	693.10	107.56
Mass-flow	st/hr	936.74	313.67	131.51	29.84	346.55	53.78
Vol.-flow, gas	MMSCFD	799.15	537.06	55.03	12.75	143.46	24.78
Pressure	psia	875	843	60.7	40.0	23	28.7
Temperature	°F	111	86	34	60	70	84
LHV, gas	BTU/scf	197.77	281.11	6.16	16.75	0.23	276.95
LHV, gas	BTU/lb	3,515.01	10,027.27	53.68	149.04	2.01	2,658.43
HHV, gas	BTU/lb	3,939.33	11,256.85	56.86	157.91	2.17	2,880.96
LHV, stream	MMBTU/h	6,585.28	6,290.59	14.12	8.90	1.39	285.95
HHV, stream	MMBTU/h	7,380.22	7,061.96	14.95	9.43	1.51	309.88
Composition							
H2	%mole	45.7950	68.0070	0.6459	1.8866	0.0044	0.2187
CO	%mole	19.7386	29.1177	1.2718	3.4941	0.0279	0.1278
CO2	%mole	32.2455	1.8383	98.0367	94.5496	99.9506	52.7325
CH4	%mole	0.0470	0.0666	0.0095	0.0236	0.0006	0.0319
H2S	%mole	1.4148	0.0000	0.0001	0.0001	0.0001	45.6273
COS	%mole	0.0363	0.0000	0.0003	0.0001	0.0002	1.1672
NH3	%mole	0.0449	0.0000	0.0000	0.0000	0.0000	0.0000
HCN	%mole	0.0006	0.0008	0.0000	0.0000	0.0000	0.0010
HCL	%mole	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
AR	%mole	0.0869	0.1287	0.0022	0.0079	0.0000	0.0016
O2	%mole	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
N2	%mole	0.4804	0.7138	0.0043	0.0160	0.0000	0.0030
H2O	%mole	0.1100	0.0000	0.0000	0.0000	0.0000	0.0000
SO2	%mole	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Methanol	%mole	0.0000	0.1270	0.0292	0.0220	0.0162	0.0889
Total	%mole	100.0000	100.0000	100.0000	100.0000	100.0000	100.0000
MW							
Molar Flow							
H2	lbmol/h	40,182.23	40,102.14	39.03	26.41	0.69	5.95
CO	lbmol/h	17,319.39	17,170.01	76.85	48.90	4.39	3.48
CO2	lbmol/h	28,293.38	1,084.00	5,923.86	1,323.33	15,743.98	1,434.68
CH4	lbmol/h	41.25	39.27	0.57	0.33	0.09	0.87
H2S	lbmol/h	1,241.41	0.01	0.01	0.00	0.02	1,241.37
COS	lbmol/h	31.83	0.02	0.02	0.00	0.03	31.75
NH3	lbmol/h	39.43	0.00	0.00	0.00	0.00	0.00
HCN	lbmol/h	0.53	0.50	0.00	0.00	0.00	0.03
HCl	lbmol/h	0.00	0.00	0.00	0.00	0.00	0.00
AR	lbmol/h	76.21	75.89	0.13	0.11	0.00	0.04
O2	lbmol/h	0.00	0.00	0.00	0.00	0.00	0.00
N2	lbmol/h	421.53	420.91	0.26	0.22	0.00	0.08
H2O	lbmol/h	96.52	0.00	0.00	0.00	0.00	0.00
SO2	lbmol/h	0.00	0.00	0.00	0.00	0.00	0.00
Methanol	lbmol/h	0.00	74.89	1.76	0.31	2.55	2.42
Total	lbmol/h	87,743.70	58,967.64	6,042.49	1,399.61	15,751.77	2,720.68
Mass Flow							
H2	klb/hr	81.0033	80.84	0.08	0.05	0.00	0.01
CO	klb/hr	485.1162	480.93	2.15	1.37	0.12	0.10
CO2	klb/hr	1245.1916	47.71	260.71	58.24	692.89	63.14
CH4	klb/hr	0.6618	0.63	0.01	0.01	0.00	0.01
H2S	klb/hr	42.3098	0.00	0.00	0.00	0.00	42.31
COS	klb/hr	1.9120	0.00	0.00	0.00	0.00	1.91
NH3	klb/hr	0.6714	0.00	0.00	0.00	0.00	0.00
HCN	klb/hr	0.0142	0.01	0.00	0.00	0.00	0.00
HCl	klb/hr	0.0000	0.00	0.00	0.00	0.00	0.00
AR	klb/hr	3.0444	3.03	0.01	0.00	0.00	0.00
O2	klb/hr	0.0000	0.00	0.00	0.00	0.00	0.00
N2	klb/hr	11.8084	11.79	0.01	0.01	0.00	0.00
H2O	klb/hr	1.7388	0.00	0.00	0.00	0.00	0.00
SO2	klb/hr	0.0000	0.00	0.00	0.00	0.00	0.00
Methanol	klb/hr	0.0000	2.40	0.06	0.01	0.08	0.08
Total	klb/hr	1873.47	627.35	263.02	59.69	693.10	107.56

Table 2-2
CO_2 Compression Mass and Energy Balance

Plant:	Lake Charles CCS Project	Material Balance		B&V Project:	042152
Location:	Sulfur, LA	Expected Figures		Date:	April 13, 2010
Case:	GE Gasification, Target Values				

Gas Streams

Stream:		0603	0604	0605	1801
Medium:		LP1CO2	LP2CO2	LP3CO2	HPCO2
From:		AGR	AGR	AGR	CO2 COMPRESSION
To:		CO2 COMPRESSION	CO2 COMPRESSION	CO2 COMPRESSION	CO2 PIPELINE
Mole-flow	lbmol/hr	6,774	1,569	17,659	26,002
Mass-flow	Mlb/hr	295	67	777	1,139
Mass-flow	st/hr	147	33	389	569.40
Vol.-flow, gas	MMSCFD	62	14	161	237
Pressure	psia	60.7	40.0	23	2165
Temperature	°F	34	60	70	100
LHV, gas	BTU/scf	6.16	16.75	0.23	2.77
LHV, gas	BTU/lb	53.68	149.04	2.01	24.03
HHV, gas	BTU/lb	56.86	157.91	2.17	25.48
LHV, stream	MMBTU/h	15.83	9.97	1.56	27.36
HHV, stream	MMBTU/h	16.77	10.57	1.69	29.02
Composition					
H2	%mole	0.6459	1.8866	0.0044	0.2851
CO	%mole	1.2718	3.4941	0.0279	0.5611
CO2	%mole	98.0367	94.5496	99.9506	99.1261
CH4	%mole	0.0095	0.0236	0.0006	0.0043
H2S	%mole	0.0001	0.0001	0.0001	0.0001
COS	%mole	0.0003	0.0001	0.0002	0.0002
NH3	%mole	0.0000	0.0000	0.0000	0.0000
HCN	%mole	0.0000	0.0000	0.0000	0.0000
HCL	%mole	0.0000	0.0000	0.0000	0.0000
AR	%mole	0.0022	0.0079	0.0000	0.0010
O2	%mole	0.0000	0.0000	0.0000	0.0000
N2	%mole	0.0043	0.0160	0.0000	0.0021
H2O	%mole	0.0000	0.0000	0.0000	0.0000
SO2	%mole	0.0000	0.0000	0.0000	0.0000
Methanol	%mole	0.0292	0.0220	0.0162	0.0199
Total	%mole	100.0000	100.0000	100.0000	100.0000
MW					
Molar Flow					
H2	lbmol/h	43.75	29.60	0.78	74.13
CO	lbmol/h	86.15	54.82	4.93	145.90
CO2	lbmol/h	6,641.06	1,483.54	17,650.10	25,774.69
CH4	lbmol/h	0.64	0.37	0.11	1.12
H2S	lbmol/h	0.01	0.00	0.02	0.03
COS	lbmol/h	0.02	0.00	0.04	0.06
NH3	lbmol/h	0.00	0.00	0.00	0.00
HCN	lbmol/h	0.00	0.00	0.00	0.00
HCl	lbmol/h	0.00	0.00	0.00	0.00
AR	lbmol/h	0.15	0.12	0.00	0.27
O2	lbmol/h	0.00	0.00	0.00	0.00
N2	lbmol/h	0.29	0.25	0.00	0.54
H2O	lbmol/h	0.00	0.00	0.00	0.00
SO2	lbmol/h	0.00	0.00	0.00	0.00
Methanol	lbmol/h	1.98	0.35	2.86	5.18
Total	lbmol/h	6774.05	1569.06	17658.82	26001.93
Mass Flow					
H2	klb/hr	0.09	0.06	0.00	0.15
CO	klb/hr	2.41	1.54	0.14	4.09
CO2	klb/hr	292.27	65.29	776.78	1134.34
CH4	klb/hr	0.01	0.01	0.00	0.02
H2S	klb/hr	0.00	0.00	0.00	0.00
COS	klb/hr	0.00	0.00	0.00	0.00
NH3	klb/hr	0.00	0.00	0.00	0.00
HCN	klb/hr	0.00	0.00	0.00	0.00
HCl	klb/hr	0.00	0.00	0.00	0.00
AR	klb/hr	0.01	0.00	0.00	0.01
O2	klb/hr	0.00	0.00	0.00	0.00
N2	klb/hr	0.01	0.01	0.00	0.02
H2O	klb/hr	0.00	0.00	0.00	0.00
SO2	klb/hr	0.00	0.00	0.00	0.00
Methanol	klb/hr	0.06	0.01	0.09	0.17
Total	klb/hr	294.86	66.92	777.02	1138.79

THE LAKE CHARLES CCS PROJECT
PHASE 1 TOPICAL REPORT

APPENDIX 3

Phase 1 SOPO Task 1.5.2.2
Preliminary Transmission Interconnection Assessment

APPENDIX 3.0 PRELIMINARY TRANSMISSION INTERCONNECTION ASSESSMENT

The integrated LLC Gasification and Lake Charles CCS Projects will require a net import of electrical capacity in the estimated amount of 75.5 MW. A summary breakdown of the electrical capacities for both projects is provided in Table 3-1 below.

Table 3-1
LLC Gasification and Lake Charles CCS Electrical Load Summary

LLC Gasification Project	**Value**	
Power Generated by Steam Turbine, MW	216.05	[A]
Balance of Plant Auxiliary Load, MW	206.35	[B]
Lake Charles CCS Project		
CO_2 Capture Load (Rectisol), MW	42.3	[C]
CO_2 Compression Load, MW	42.9	[D]
Load Summary		
Net Electrical Power Import from Grid with CO_2 Capture Only, MW	32.6	[B] + [C] – [A]
Net Electrical Power Import from Grid with CO_2 Capture + Compression, MW	75.5	[B] + [C] + [D] - [A]

To support the project's electrical demands, power will need to be sourced though a grid interconnect.

Key parameters for a preliminary assessment of grid interconnect options include:

- Load flows from and into the grid.
- High voltage level for the interconnect.
- Distance between plant substation/switchyard and the interconnection point.
- Start-up transients for large motors.

The transmission lines in proximity to the sites were reviewed for their capacity and use status. Load flow information is not available in the public domain post 9-11 due to security reasons. A formal request for an interconnection study has to be made to the utility who will put the request in a queue per FERC regulation and who will perform load flow analyses. A short analysis of potential interconnects are as follows:

- Transmission lines could possibly be connected to the Bayou D' Indie substation, located approximately 3 miles from the project site.

- Electrical interconnect could potentially be achieved by tapping into the following transmission lines:
    - A 138 kV line connecting Bayou D'Indie substation and Mossville has a rating of 282 MW. This transmission line is approximately 1.8 miles from the site.
    - A 138 kV line connecting between Bayou D'Indie substation and Polycit has a rating of 288 MW. This transmission line is located approximately 2 miles from the site.
    - A 230 kV line connecting Lake Charles and Gillis which is rated for 462 MW and is approximately 0.25 miles from the site.

Based on this preliminary assessment, it is expected that the electrical grid within the surrounding vicinity of the site will support the 75.5 MW load requirement. Since the cost of interconnection is substantial at any high voltage level, the LLC Gasification and Lake Charles CCS Projects would likely have a single high voltage connection through a switchyard/substation and multiple secondary unit substations that would feed auxiliary loads at 13.8 kV, 4.16 kV and 480 V via transformers, switchgear and motor control centers.

The switchyard/substation will be a design consideration for the LLC Gasification Project.

A 13.8 kV auxiliary system has been assumed for the Lake Charles CCS Project.

THE LAKE CHARLES CCS PROJECT
PHASE 1 TOPICAL REPORT

APPENDIX 4

Phase 1 SOPO Task 1.5.2.3
Optimization of the CO_2 Compression Equipment Selection

APPENDIX 4.0 OPTIMIZATION OF THE CO_2 COMPRESSION EQUIPMENT SELECTION

This appendix provides the background information to support the compressor configuration and technology selected for the Lake Charles CCS Project.

4.1 Background

CO_2 streams captured from the Lake Charles CCS Project's Rectisol units will require the CO_2 to be compressed to 2,165 psia and cooled to 100° F. Both reciprocating and centrifugal compressors are commercially available and capable providing the above-mentioned CO_2 stream requirements. The following provides general compressor configuration and technology comparisons that were used to determine the compressor configuration and technology used for the Lake Charles CCS CO_2 compression system.

4.2 Compressor Configuration

To determine the optimum compressor configuration to be used for CO_2 compression, order of magnitude capital cost estimates for 2 x 50% (two 50% capacity trains), and 3 x 33% configurations were developed for centrifugal compressors. The order of magnitude installed costs, estimated in first quarter 2010 dollars, are provided below:

	Configuration	
	2 x 50% Trains	**3 x 33% Trains**
Total Installed Cost Estimate, 2010$ million	**81.9**	**104.0**

A 2 x 50% configuration was selected as the preferred arrangement for the Lake Charles CCS Project compressors because of the expected capital cost savings compared to a 3 x 33% configuration. This configuration also corresponds to each compressor train compressing CO_2 from an associated Rectisol unit train; allowing one Rectisol unit train to be shut down for maintenance while another one remains in operation.

A 1 x 100 % compressor train configuration was not considered since such a configuration would require CO_2 recirculation in the event of a Rectisol train shutdown (e.g. for maintenance); conceding to wasted compression energy and associated compression costs. In addition, CO_2 compression system availability for a 1 x 100% compressor unit train configuration will be less than a 2 x 50% compressor unit train configuration.

4.3 Compressor Technology

Pressure requirements for screw compressors will be too demanding; as a result, screw compressors are not considered a viable option for the CO_2 compression system.

Because of capacity limitations, the use of reciprocating compressors would require multiple compressor units operating in parallel; hence, based on past experience, capital and operations and maintenance costs for reciprocating compressors are expected to be prohibitively expensive. For these reasons, reciprocating compressors were not considered a viable option for this project.

Centrifugal compressors are considered to be the most viable type of compressor for the CO_2 compression requirements for this project. Two types of centrifugal compressors are commercially available for this service; namely between bearings and integrally geared multistage centrifugal compressors. Dresser, Elliot, GE-Nuovo Pignone, MHI, and Siemens offer between the bearings multistage centrifugal compressors, either on one shaft driven by a single motor or with separate motors for the low-pressure and high-pressure casings. These compressors have four stages with three stages of intercooling. MAN offers integrally geared multistage centrifugal compressors with eight stages of compression and six stages of intercooling. MAN integrally geared centrifugal compressors have been operating for 10 years in a similar CO_2 compression service at the Great Plains Synfuels Plant.

Black & Veatch recently obtained CO_2 compressor budget pricing and performance data from Dresser, GE-Nuovo Pignone, MAN, MHI, and Siemens for several projects. The polytropic stage efficiencies for the Dresser, Elliot, GE-Nuovo Pignone, MHI, and Siemens compressors ranged from 84 to 64 percent. The polytropic stage efficiencies for the MAN compressors were all 85 percent, which makes it the most efficient machine.

To support a centrifugal compressor selection for the Lake Charles CCS Project's CO_2 compression system, data sheets (attached to this appendix) were sent to MAN, Dresser-Rand and Elliot for budgetary pricing. The following table summarizes the pricing that was obtained.

Vendor	MANN-TURBO	DRESSER-RAND	ELLIOT
Price	$21,570,000	$30,000,000	$28,600,000

Based on expected efficiencies and costs presented above, MAN integrally geared multistage centrifugal compressors with eight stages of compression and six stages of intercooling were selected as a basis for the Lake Charles CCS Project's CO_2 compression system.

BLACK & VEATCH

CENTRIFUGAL AND AXIAL COMPRESSOR DATA SHEET (API 617-7TH Chapter 2)
U.S. CUSTOMARY UNITS (1-1.6.5)

JOB NO. **166376** ITEM NO. **18-C-0101 / 0201**
PURCHASE ORDER NO.
INQUIRY NO. **67.9373**
REVISION NO. **A** DATE **19-Feb-10**
PAGE **1** OF **7** BY **CWG**

APPLICABLE TO: ● PROPOSAL ○ PURCHASE ○ AS BUILT ○ STUDY

FOR **LAKE CHARLES COGENERATION INC** UNIT **CO_2 COMPRESSION**
SITE **LAKE CHARLES, LOUISIANA** SERIAL NO.
SERVICE **CO_2 COMPRESSOR** NO. REQUIRED **TWO COMPRESSOR TRAINS**
MANUFACTURER DRIVER TYPE (1-3.1.1) **ELECTRIC MOTOR**
MODEL DRIVER ITEM NO.

INFORMATION TO BE COMPLETED: ○ BY PURCHASER ☐ BY MANUFACTURER △ MUTUAL AGREEMENT (PRIOR TO PURCHASE)

OPERATING CONDITIONS

(ALL DATA ON PER UNIT BASIS)

	STREAM 1	STREAM 2	STREAM 3			
● GAS HANDLED (ALSO SEE PAGE 2)	CO_2	CO_2	CO_2			
△ GAS PROPERTIES (1-2.1.1.4)						
○ MMSCFD/~~SCFM~~ (14.7 PSIA & 60 °F DRY)						
● WEIGHT FLOW, LBM/MIN (WET)	6,588	568	2,500			
INLET CONDITIONS						
● PRESSURE (PSIA)	22.5	39.5	60.2			
● TEMPERATURE (°F)	70	60	34			
○ RELATIVE HUMIDITY %						
● MOLECULAR WEIGHT	44.00	42.65	43.53			
☐ Cp/Cv (K_{AVG})						
☐ COMPRESSIBILITY (Z_1)						
☐ INLET VOLUME, (CFM) (WET / DRY)						
DISCHARGE CONDITIONS						
● PRESSURE (PSIA)				2165		
☐ TEMPERATURE (°F)						
☐ Cp/Cv (K_{AVG}) (NOTE 1)						
☐ COMPRESSIBILITY (Z_2)						
☐ GHP REQUIRED						
☐ TRAIN BHP REQUIRED						
☐ BHP REQUIRED AT DRIVER INCL. EXT. LOSSES (GEAR, ETC.)						
☐ SPEED (RPM)						
☐ TURNDOWN (%)						
☐ POLYTROPHIC HEAD (FT-LB / LB)						
☐ POLYTROPHIC EFFICIENCY (%)						
○ CERTIFIED POINT						
○ EXPECTED OPERATION AT EACH CONDITION (%)						
☐ PERFORMANCE CURVE NUMBER						

PROCESS CONTROL (1-3.4.2.1)

METHOD ○ SUCTION THROTTLING FROM PSIA TO PSIA
○ VARIABLE INLET GUIDE VANES (2-2.4.1) FROM % TO %
○ SPEED VARIATION
○ DISCHARGE BLOWOFF TO
○ COOLED BYPASS FROM TO

SIGNAL ● SOURCE (1-3.4.2.1)
TYPE ● ELECTRONIC ○ PNEUMATIC ○ OTHER
RANGE MA PSIG

REMARKS:
(1) There are three separate inlet streams each containing dry CO2 gas.
(2) The discharge pressure given is for the total combined flow out of the compressor package.
(3) The number of compressor sections and casing nozzles shall be determined by Supplier based on compression process resulting in balance of lowest installed cost and most efficient compressor operation.
(4) The Supplier shall advise pressure and temperature between the sections. Process intercoolers and, if required, liquid knock-out drums, shall be provided by Purch.
(5) Pressure drop between sections shall be kept to minimum (2-3 psi between low pressure sections, not to exceed 15 psi between any section).
(6) Process gas between sections will be cooled to 100°F.

THE LAKE CHARLES CCS PROJECT
PHASE 1 TOPICAL REPORT

APPENDIX 5

Phase 1 SOPO Task 1.5.3
CO_2 Injection Site Confirmation

Report to Bureau of Economic Geology on EOR/Geologic Sequestration/Injection at West Hasting Field Unit Fault Block B and C for FOA 15

Report Type:	Report and documentation of milestone completion
Report Number:	C1.5.3
Report Title:	Preliminary CO2 injection site confirmation
Completion Date:	February 26, 2010
Report Issue Date:	April 13, 2010
Submitting Organization:	Steve Upp, Darrell Davis & Trevor Richards Denbury Resources Inc. Plano, Texas

Phase 1 Task C1.5.3

Preliminary CO2 injection site confirmation – West Hastings Field Unit Fault Block B and C

Prepared for:
Susan Hovorka of Gulf Coast Carbon Center

Report by Denbury Resources

April 11, 2010

Bureau of Economic Geology
John A. and Katherine G. Jackson School of Geosciences
The University of Texas at Austin
Austin, Texas 78713-8924

Hastings DOE Proposal

The Hastings field is a planned CO_2 EOR project in the Frio formation. CO2 injection is scheduled to begin during December, 2010 into the northernmost Fault Block A (see Figure 4) using naturally occurring CO2 from Denbury's Jackson Dome CO2 supply (Norphlet and Smackover reservoirs). To supplement this naturally occurring CO2 supply, Denbury will utilize anthropogenic CO2 (ACO2) supplies to meet its rising CO2 purchase requirements. It is anticipated that ACO2 will be available for development of Fault Blocks B & C at Hastings beginning 2013, therefore a preliminary design has been made and estimates of the CO2 storage capacity for the reservoir determined. Information gained from actual injection into Fault Block A will be utilized to finalize the Fault Blocks B & C design during 2011-2012, however this will not dramatically impact the pore volume available for CO2 storage.

Injectivity - The injectivity of CO_2 can be estimated from current water injection rates on existing Frio injectors. Water injection into the Frio of ~180,000 BWPD is being accomplished with 20 wells, an average of 9000 BWPD per well. Based on a CO_2 formation volume factor of 2 MCF/bbl, this would equate to 18 MMCFD (~1050 tons per day) CO_2 per well. This rate is also consistent with the maximum erosional velocity limit of CO2 down 2-7/8" tubing, thus establishing a target injection per injector. Insuring high injection rates into each pattern maximizes the rate at which oil is recovered, therefore improving project economics.

Storage Capacity - The storage capacity for reservoirs to be flooded in Fault Blocks B&C is shown in Table 3.1. The original oil-in-place was approximately 237 million barrels and maximum CO2 storage capacity is estimated at 568 BCF. The 237 million barrels oil occupied 284 million reservoir barrels (1.2 RB/STB) and based upon 2 MCF CO2 per reservoir barrel at 160 degrees F and 3000 psi, the CO2 volume to completely displace the original hydrocarbon pore volume will be 568 BCF (33,000 tons). Areal and vertical sweep efficiency will reduce this number, as will the residual oil saturation to CO2 injection.

The Hastings Development team recently cored a well in Fault Block A (WHU-3706) to determine reservoir properties for the five (5) major sands (A1-A5) of the Upper Frio reservoir. Smaller plugs are currently being cut from the core and measurements will soon be made to determine porosity and permeability of each plug. Additional tests will also be performed to determine connate water and residual oil saturation endpoints on approximately 5 plugs, along with oil/water and gas/oil relative permeability curves. This information will be used to guide in the selection of perforated intervals and to better understand the vertical sweep efficiency expected during the CO2 flooding process.

In general, the Frio sands of Hastings are typical of most sandstones along the Texas and Louisiana Gulf Coast, where porosities are in the 28-32% range and permeabilities are high, in the 200-2000 md range. With initial oil saturation of approximately 80%, this suggests high storage capacity for the reservoir rock. The Hastings Frio reservoir is an excellent reservoir for CO2-EOR recovery as well as CO2 storage. High primary (water drive) recoveries indicate that the areal and vertical sweep efficiencies should be excellent.

Table 3.1
Field Storage Capacity (Fault Blocks B & C)

Upper Frio	Sand	Area (acres)	Thickness (feet)	Net-to-Gross (decimal)	Porosity (decimal)	Swi (decimal)	Boi (RB/STB)	OOIP (bbls)	CO2 Capacity (MMCF)
	A1	700	20	0.61	0.3	0.8	1.2	13,350,940	32,042
	A2	675	30	0.61	0.3	0.8	1.2	19,311,181	46,347
	A3	650	50	0.61	0.3	0.8	1.2	30,993,253	74,384
	A4	625	40	0.61	0.3	0.8	1.2	23,840,964	57,218
	A5	600	20	0.61	0.3	0.8	1.2	11,443,663	27,465
	A - Total		**160**					**98,940,000**	**237,456**
Lower Frio	**Sand**	**Acres (acres)**	**Thickness (feet)**	**Net-to-Gross (decimal)**	**Porosity (decimal)**	**Swi (decimal)**	**Boi (RB/STB)**	**OOIP (bbls)**	**CO2 Capacity (MMCF)**
	B1	360	5	0.59	0.3	0.8	1.2	1,642,128	3,941
	B2	360	30	0.59	0.3	0.8	1.2	9,852,768	23,647
	B3	360	5	0.59	0.3	0.8	1.2	1,642,128	3,941
	B - Total							**13,137,024**	**31,529**
	C1	300	5	0.87	0.3	0.8	1.2	2,016,919	4,841
	C2	300	20	0.87	0.3	0.8	1.2	8,067,675	19,362
	C3	300	20	0.87	0.3	0.8	1.2	8,067,675	19,362
	C - Total							**18,152,269**	**43,565**
	D1	250	20	0.87	0.3	0.8	1.2	6,723,063	16,135
	D2	250	20	0.87	0.3	0.8	1.2	6,723,063	16,135
	D3	250	20	0.87	0.3	0.8	1.2	6,723,063	16,135
	D4	250	20	0.87	0.3	0.8	1.2	6,723,063	16,135
	D - Total							**26,892,251**	**64,541**
	E1	200	25	1.00	0.3	0.8	1.2	7,758,000	18,619
	E2	200	25	1.00	0.3	0.8	1.2	7,758,000	18,619
	E - Total							**15,516,000**	**37,238**
	F1	175	30	1.00	0.3	0.8	1.2	8,145,900	19,550
	F2	175	35	1.00	0.3	0.8	1.2	9,503,550	22,809
	F3	175	30	1.00	0.3	0.8	1.2	8,145,900	19,550
	F4	175	11	1.00	0.3	0.8	1.2	3,095,442	7,429
	F - Total							**28,890,792**	**69,338**
	G1	150	30	0.92	0.3	0.8	1.2	6,389,545	15,335
	G2	150	20	0.92	0.3	0.8	1.2	4,259,696	10,223
	G3	150	30	0.92	0.3	0.8	1.2	6,389,545	15,335
	G4	150	10	0.92	0.3	0.8	1.2	2,129,848	5,112
	G - Total							**19,168,634**	**46,005**
	H1	92	40	0.93	0.3	0.8	1.2	5,283,563	12,681
	H2	92	15	0.93	0.3	0.8	1.2	1,981,336	4,755
	H3	92	15	0.93	0.3	0.8	1.2	1,981,336	4,755
	H4	92	50	0.93	0.3	0.8	1.2	6,604,454	15,851
	H - Total							**15,850,689**	**38,042**
	Total							**137,607,659**	**330,258**
	Grand Total							**236,547,659**	**567,714**

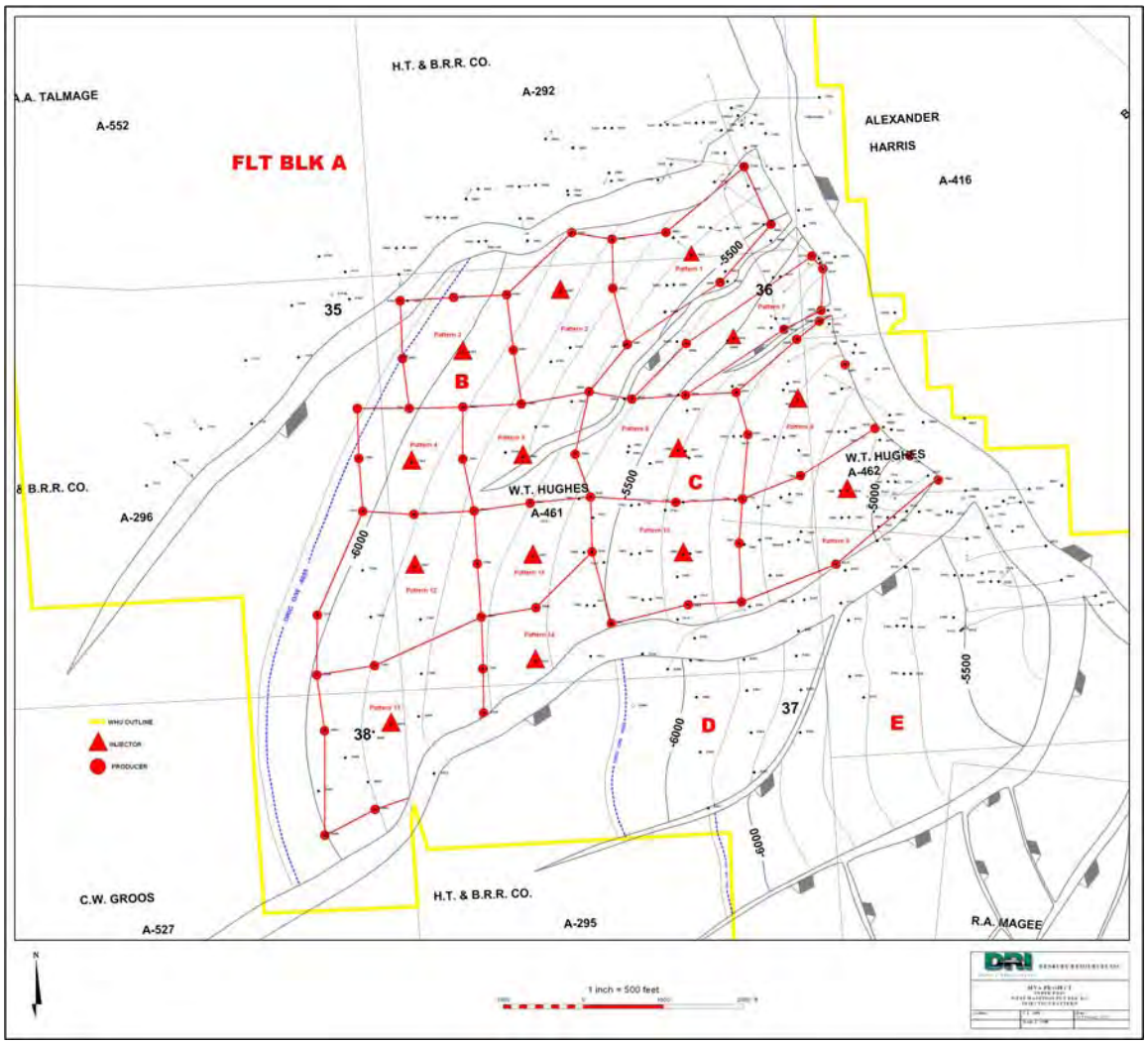
Pattern Selection **- Upper Frio**

The pattern design selected for Fault Blocks B & C is different than the one used for Fault Block A, as the existing well configuration in B & C indicated that smaller patterns (~40 acres each) with larger completion intervals (~100-150 feet) would make most efficient use of existing wellbores, limiting the number of new wells which would have to be drilled. Fault Block A, on the other hand, is planning to use larger patterns (~140 acres) with smaller completion intervals (~50-75 feet). The Fault Block A pattern

required that one set of patterns be used for the A1 & A2 sand, and another set for the A3, A4, and A5 sands. If this approach was utilized in Fault Blocks B & C, it is likely that over 20 wells would have to be drilled to accommodate the multiple pattern scenario. The current design requires that less than 5 wells be drilled.

Below is the pattern design for the Upper Frio. In addition to the 14 CO2 injectors and 61 producers, downdip water injection will be required to create a high pressure barrier between the residual oil zone and the large aquifer downdip. Reservoir modeling indicates that the high permeability sands will not pressure up easily due to leakoff of the CO2 (or water) into the aquifer. By utilizing the 4 most downdip CO2 injection wells as water injectors initially, pressure can be raised from 2200 psi to 3100 psi in the updip patterns when CO2 injection begins. As a result, expenditures on water injection is required during 2013 prior to CO2 injection.

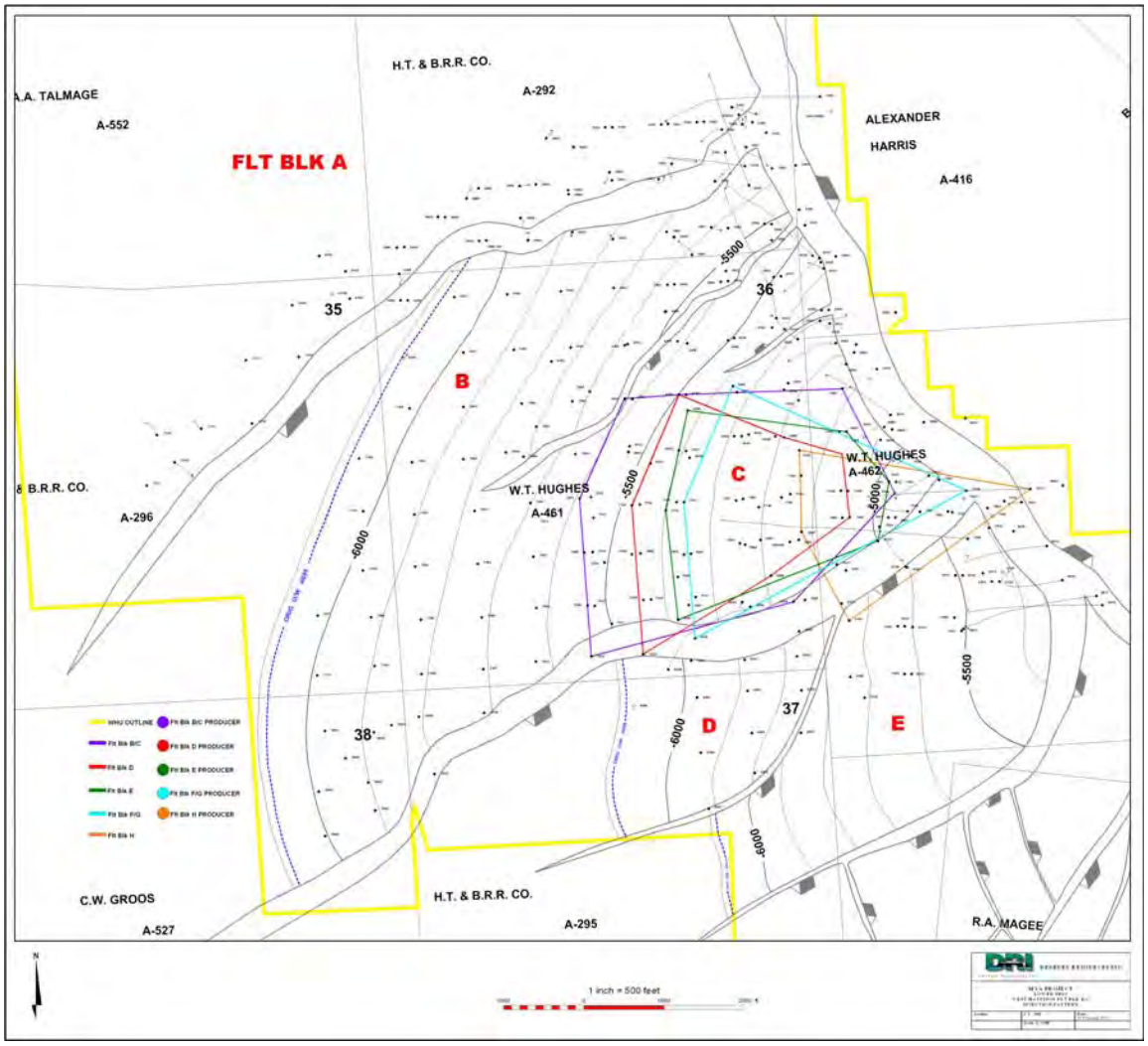
UPPER FRIO – FAULT BLOCKS B & C DEVELOPMENT



***Pattern Selection* - Lower Frio**

Unlike Fault Block A which only required two patterns in the Lower Frio to develop a majority of the reserves, Fault Block C requires a minimum of 5 patterns to recovery the CO2 target oil. As was shown in Table 3.1, the Lower Frio contained 138 million barrels original oil-in-place versus 99 million barrels in the Upper Frio, a 39% increase. Since the patterns are relatively small due to the oil-water contact being close in to the major growth fault, downdip CO2 injection is shown as the preferred design. The plan currently calls for patterns in the (1) B/C, (2) D, (3) E, (4) F/G, and (5) H, with 3 CO2 injectors downdip for each pattern. In addition to the 15 CO2 injectors and 18 producers shown for development, downdip water injection will also be required for the Lower Frio development. Strategically placed wells downdip of the B sand original oil-water contact should allow for all of the Lower Frio sands to be pressured up.

LOWER FRIO – FAULT BLOCKS B & C DEVELOPMENT



Production Forecast

Since a geologic model and compositional reservoir simulation model is not available for Fault Blocks B & C, CO_2 purchase and recycle volumes were forecasted using dimensionless curves obtained from an analogous field and verified by modeling work performed for Fault Block A. We therefore have confidence that they can be applied to Fault Blocks B & C.

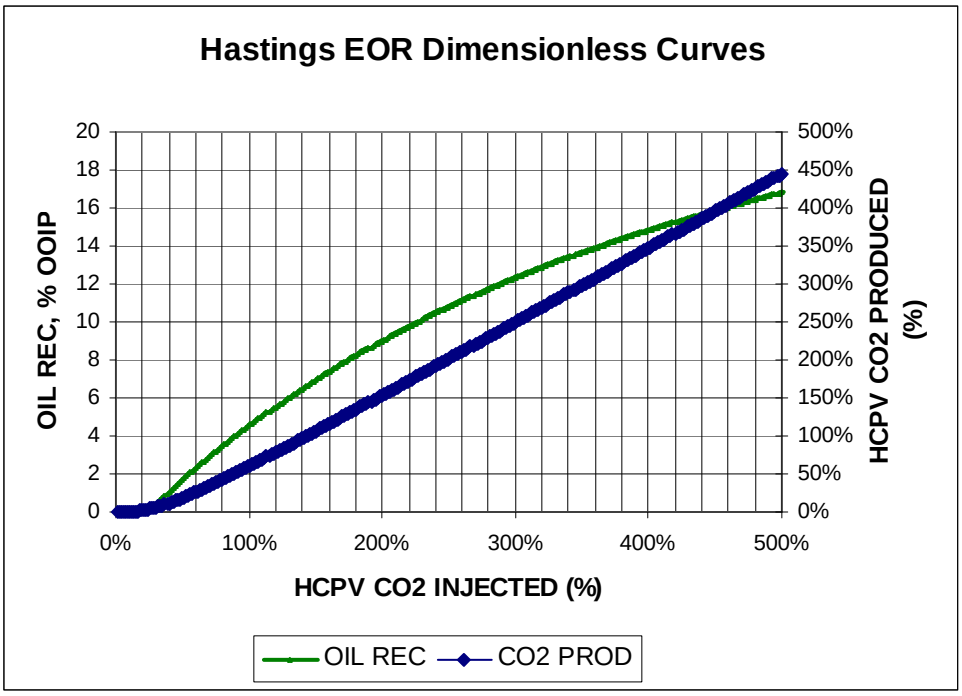


Figure 3.4 – EOR Dimensionless Curves.

The dimensionless curves are used by converting the cumulative CO2 injected into a percent HCPV (hydrocarbon pore volume) injected and reading off the oil recovery (% OOIP) and CO2 produced (% HCPV) values. This provides the amount of oil which is produced with each increment, and also determines the incremental produced gas (CO2) volume. Spreadsheets are used to convert acres and reservoir thickness into HCPV percentages. A summary of the assumptions for Fault Blocks B & C are shown in Table 3.2

Table 3.2
CO2 Flood Pattern Size (Fault Blocks B & C)

Pattern	Sands	Pattern	FB	Thickness	Acreage	Start Date	CO2 Inj	Swi	Porosity	Boi	OOIP (MBO)	Inj/Yr (% HCPV/yr)
1	Upper	9	B & C	100	63	7/1/2013	18,000	20%	30%	1.2	9,719	28.2%
2	Upper	8	B & C	100	51	9/1/2013	18,000	20%	30%	1.2	7,926	34.5%
3	Lower	H	B & C	120	74	9/1/2013	18,000	20%	30%	1.2	13,778	19.9%
4	Upper	6	B & C	100	61	11/1/2013	18,000	20%	30%	1.2	9,407	29.1%
5	Lower	F/G	B & C	175	127	11/1/2013	54,000	20%	30%	1.2	34,484	23.8%
6	Upper	10	B & C	100	57	7/1/2014	18,000	20%	30%	1.2	8,852	30.9%
7	Lower	E	B & C	50	115	7/1/2014	18,000	20%	30%	1.2	8,922	30.7%
8	Upper	7	B & C	100	31	9/1/2014	18,000	20%	30%	1.2	4,770	57.4%
9	Lower	D	B & C	80	120	9/1/2014	18,000	20%	30%	1.2	14,895	18.4%
10	Upper	11	B & C	100	38	11/1/2014	18,000	20%	30%	1.2	5,933	46.1%
11	Lower	B/C	B & C	85	216	11/1/2014	36,000	20%	30%	1.2	28,487	19.2%
12	Upper	14	B & C	100	35	7/1/2015	18,000	20%	30%	1.2	5,468	50.1%
13	Upper	1	B & C	100	47	8/1/2015	18,000	20%	30%	1.2	7,336	37.3%
14	Upper	2	B & C	100	53	9/1/2015	18,000	20%	30%	1.2	8,206	33.4%
15	Upper	3	B & C	100	43	10/1/2015	18,000	20%	30%	1.2	6,714	40.8%
16	Upper	4	B & C	100	40	10/1/2015	18,000	20%	30%	1.2	6,180	44.3%
17	Upper	5	B & C	100	43	11/1/2015	18,000	20%	30%	1.2	6,641	41.2%
18	Upper	12	B & C	100	72	11/1/2015	18,000	20%	30%	1.2	11,158	24.5%
19	Upper	13	B & C	100	75	12/1/2015	18,000	20%	30%	1.2	11,592	23.6%
TOTAL							396,000				210,468	

Since the F/G sand combination is so thick, a portion of it will likely be combined with the E and/or H sands to allow for more uniform distribution. Another option is that the F & G sands may be flooded separately. Given that each of the Lower Frio sands have 3 injectors, a maximum of 54 MMCFD is achievable, so the 36 MMCFD shown for B/C and 54 MMCFD for F/G does not exceed the design limits.

The table shows that 210 million barrels OOIP (89%) will be CO2 flooded out of the total 237 million. The additional 11% of the volume is on the edges near the original oil water contact and in areas of the Lower Frio where the current configuration does not sweep. As we get closer to executing the project, slight adjustments may be made to maximize sweep.

Using this information, the CO2 purchase, recycle (produced), and injection volumes are shown in Figure 3.5. The 396 MMCFD CO2 injection is shown, with peak CO2 purchase of 211 MMCFD occurring during December, 2015.

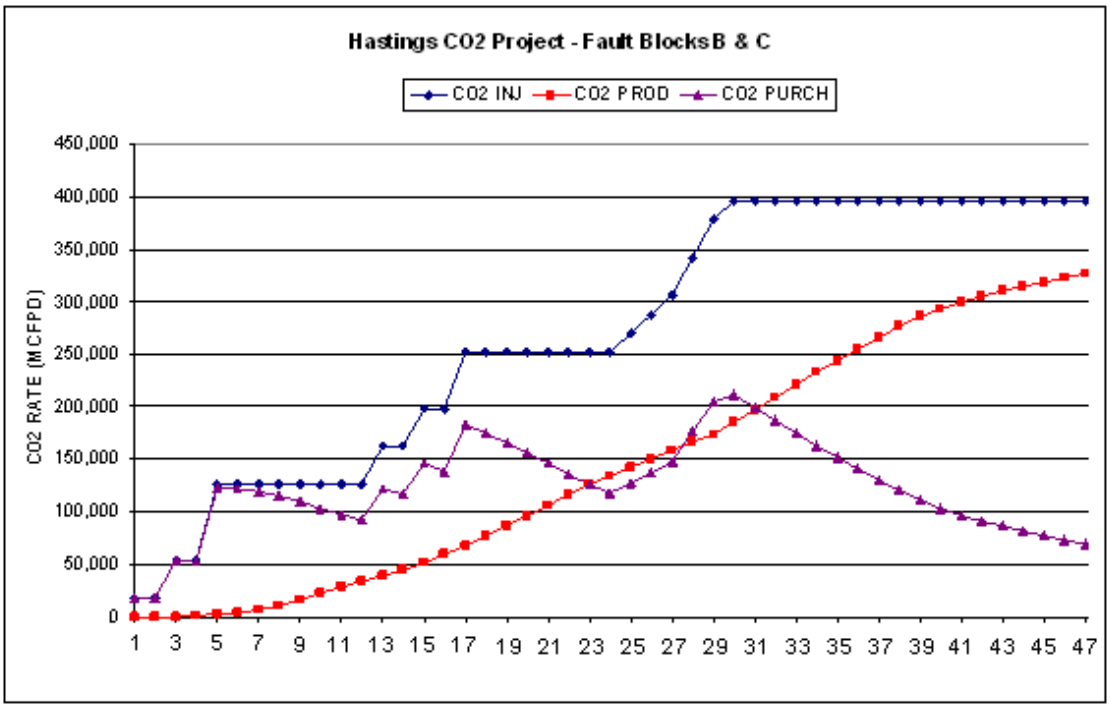


Figure 3.5

On the following page is a month by month estimate of CO2 purchase volumes, including the estimate of number of CO2 injectors and patterns developed in Fault Blocks B & C. These estimates are impacted by capital expenditure levels available for prior years, yet is felt to be a reasonable forecast. If the anthropogenic CO2 is not ready by January, 2014, CO2 from Denbury's Jackson Dome may be utilized.

The table indicates that peak purchases will be around 200 MMCFPD by month 30. A total of 145 BCF (or 8.4 million tons) will be injected over the first 3 year period.

Anticipated Hastings Fault Block B&C Development Schedule

Month	CO2 Purchased Volumes (MMCF)	CO2 Purchased Volumes (MMCF/D)	Cumulative CO2 Purchased Volumes (MMCF)	Cumulative # injectors	Cumulative # patterns	Cumulative # Upper Frio Patterns	Cumulative # Lower Frio Patterns
Jan-14	547	18	547	1	1	1	0
Feb-14	547	18	1,094	1	1	1	0
Mar-14	1,642	54	2,736	5	3	2	1
Apr-14	1,613	53	4,349	5	3	2	1
May-14	3,760	124	8,109	9	5	3	2
Jun-14	3,699	122	11,808	9	5	3	2
Jul-14	3,624	119	15,431	9	5	3	2
Aug-14	3,495	115	18,927	9	5	3	2
Sep-14	3,320	109	22,247	9	5	3	2
Oct-14	3,135	103	25,382	9	5	3	2
Nov-14	2,955	97	28,337	9	5	3	2
Dec-14	2,787	92	31,124	9	5	3	2
Jan-15	3,729	123	34,852	13	7	4	3
Feb-15	3,562	117	38,414	13	7	4	3
Mar-15	4,470	147	42,884	17	9	5	4
Apr-15	4,196	138	47,080	17	9	5	4
May-15	5,582	184	52,663	21	11	6	5
Jun-15	5,331	175	57,994	21	11	6	5
Jul-15	5,042	166	63,036	21	11	6	5
Aug-15	4,754	156	67,790	21	11	6	5
Sep-15	4,454	147	72,244	21	11	6	5
Oct-15	4,109	135	76,354	21	11	6	5
Nov-15	3,822	126	80,175	21	11	6	5
Dec-15	3,569	117	83,745	21	11	6	5
Jan-16	3,876	128	87,621	22	12	7	5
Feb-16	4,176	137	91,797	23	13	8	5
Mar-16	4,489	148	96,286	24	14	9	5
Apr-16	5,344	176	101,629	26	16	11	5
May-16	6,205	204	107,834	28	18	13	5
Jun-16	6,409	211	114,244	29	19	14	5
Jul-16	6,049	199	120,292	29	19	14	5
Aug-16	5,702	188	125,994	29	19	14	5
Sep-16	5,331	175	131,325	29	19	14	5
Oct-16	4,961	163	136,286	29	19	14	5
Nov-16	4,619	152	140,906	29	19	14	5
Dec-16	4,295	141	145,200	29	19	14	5

Descriptions of the number, type, and characteristics of wells and equipment necessary for the sequestration effort. For information not available, the approach to obtaining necessary information.

CO_2 will be injected in the Frio Formation. Currently 29 CO_2 Class II injection wells are planned for Fault Block B & C development. The CO_2 EOR project will utilize a combination of inverted 9-spots and downdip injection patterns. This phase of the project will require approximately 200 MMCFD CO2 purchases and peak CO2 injection of 400 MMCFD. Target reservoir pressure is around 3100 psi. A target injection rate of 18 MMCFD per well is planned.

All wells will be permitted as Class II injectors. A typical injection well schematic is shown in Figure 5.

Figure 1 – Stratigraphic Column for Texas and Louisiana Deposits

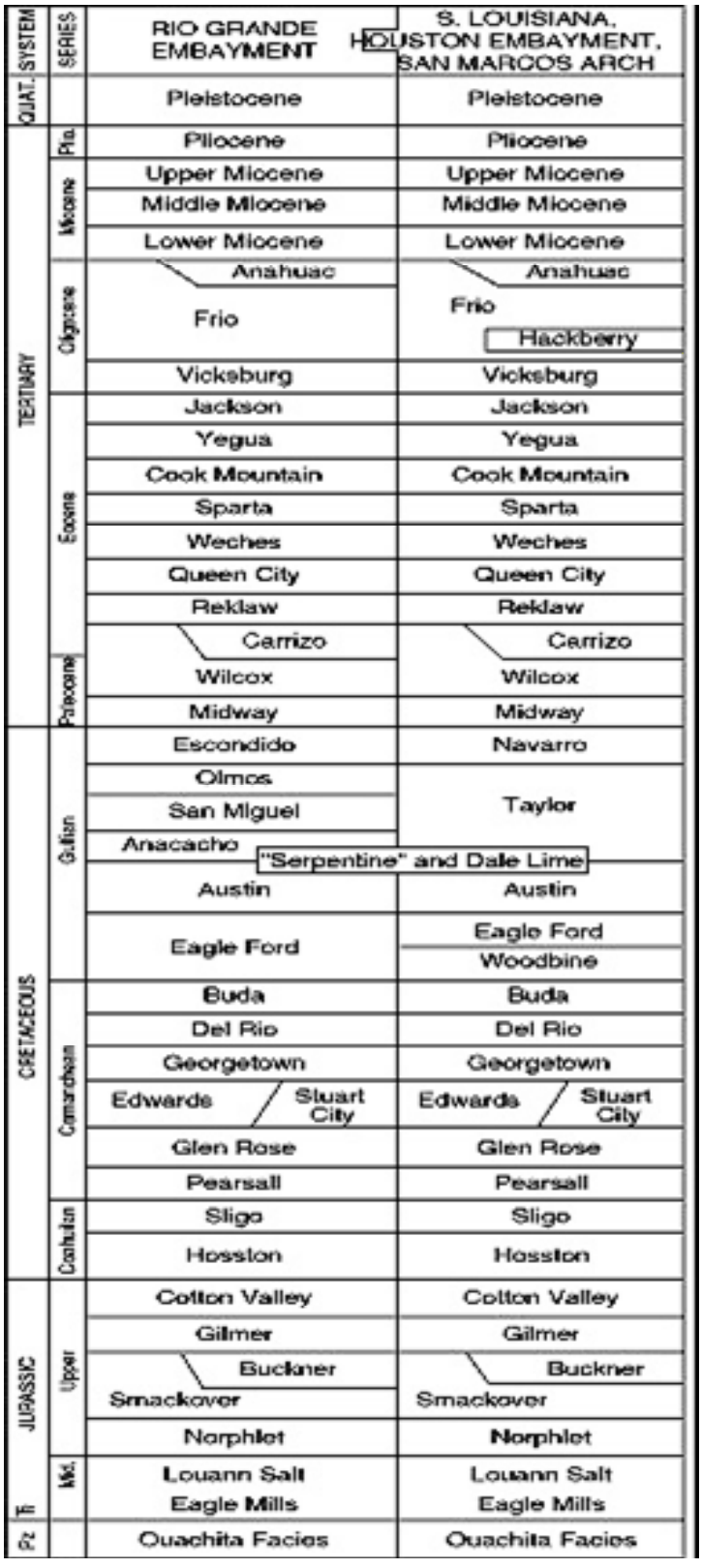


Figure 2 – Location of Hastings Field, Brazoria County, Texas

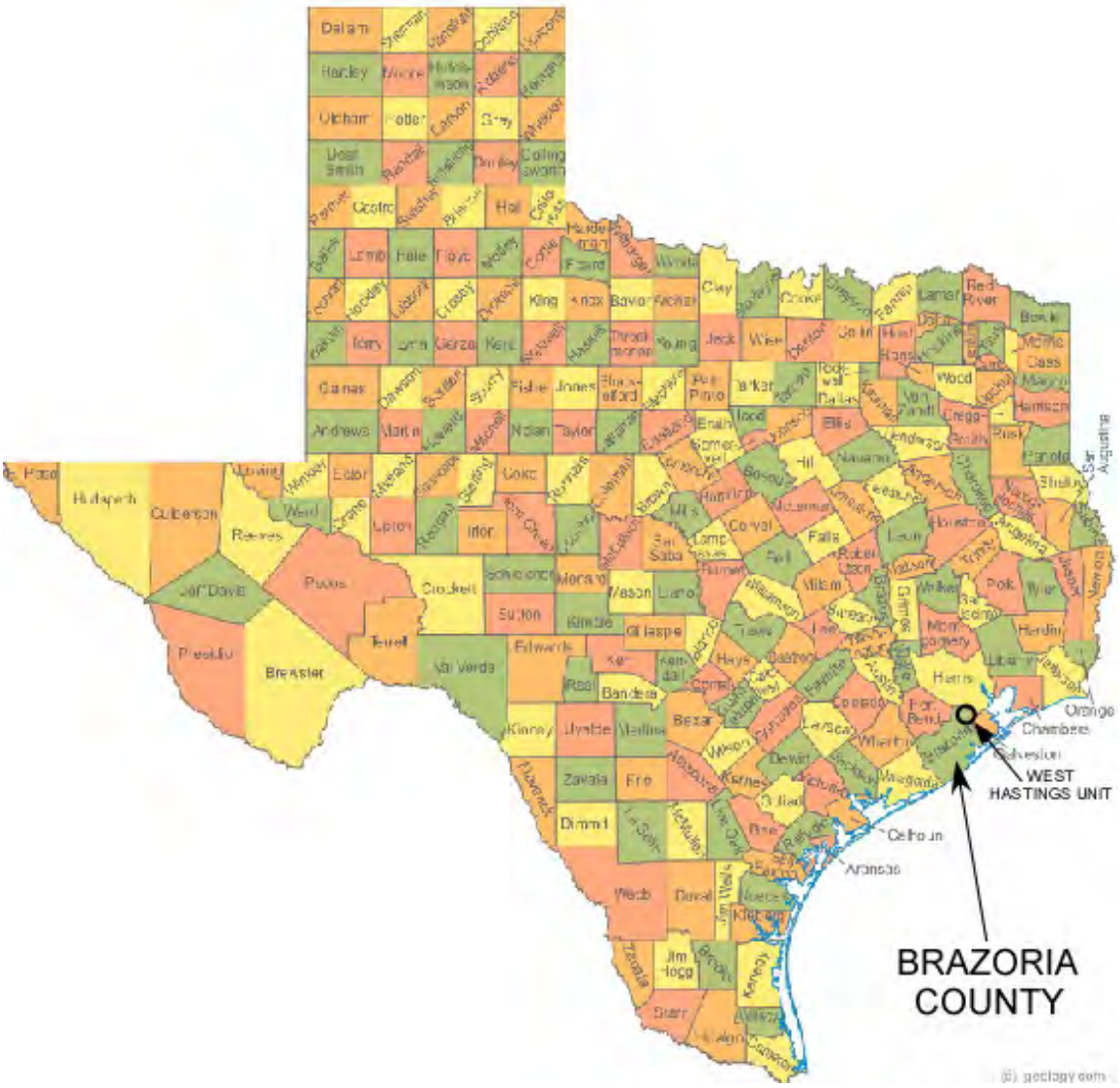


Figure 3 – Type Log for Hastings Upper Frio Reservoir

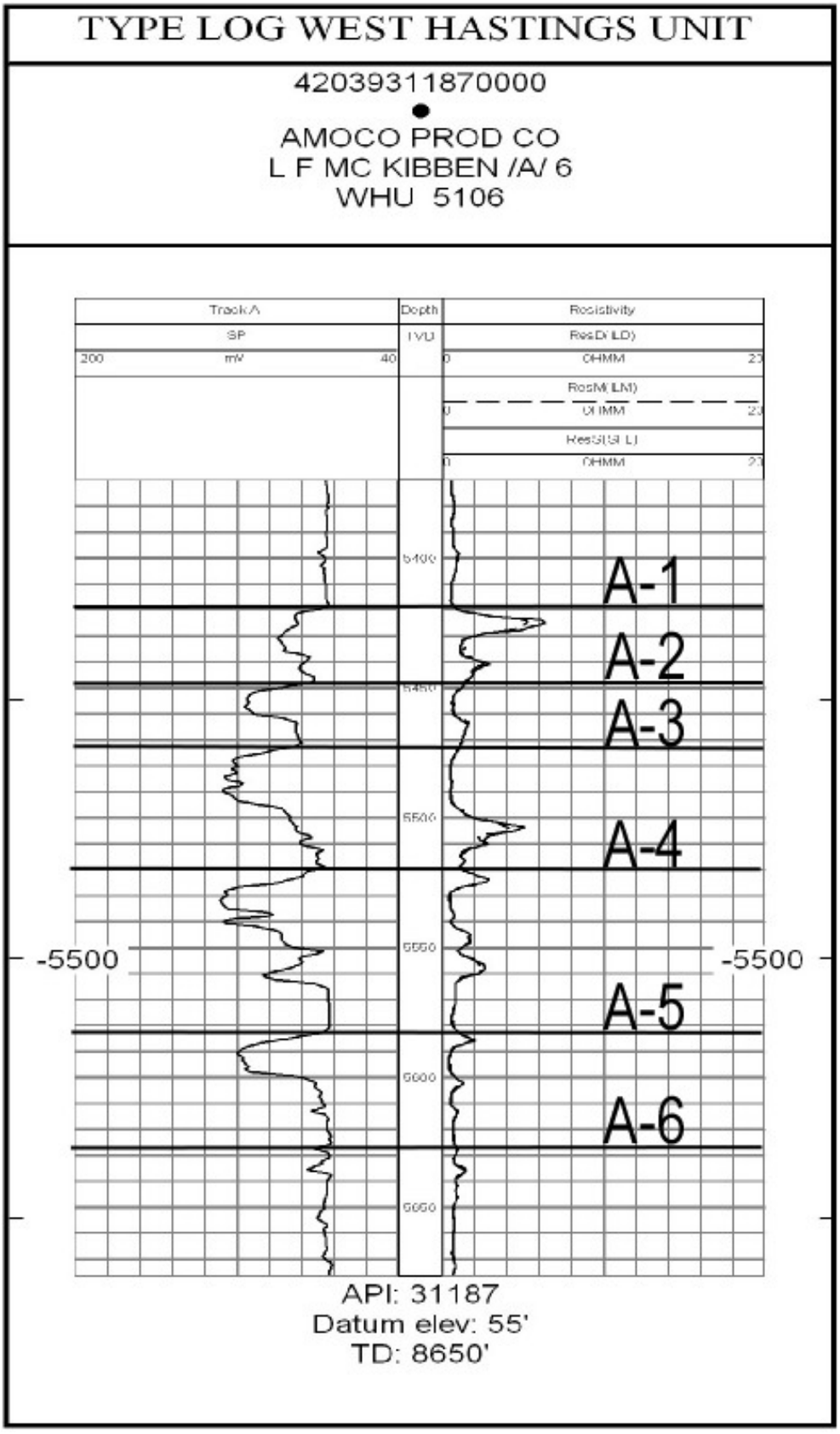


Figure 4 – Top of Structure Map – Hastings Frio Reservoir

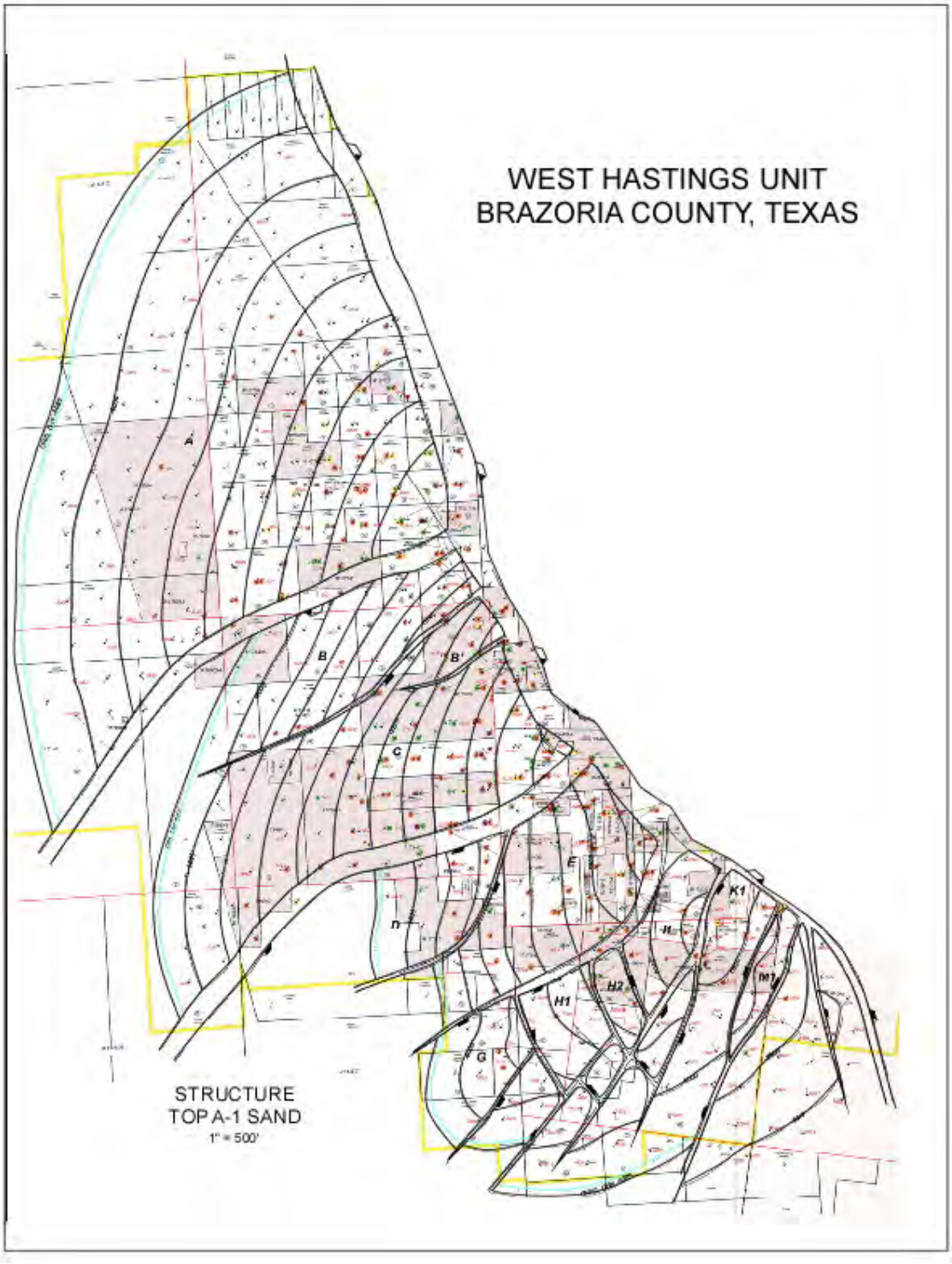
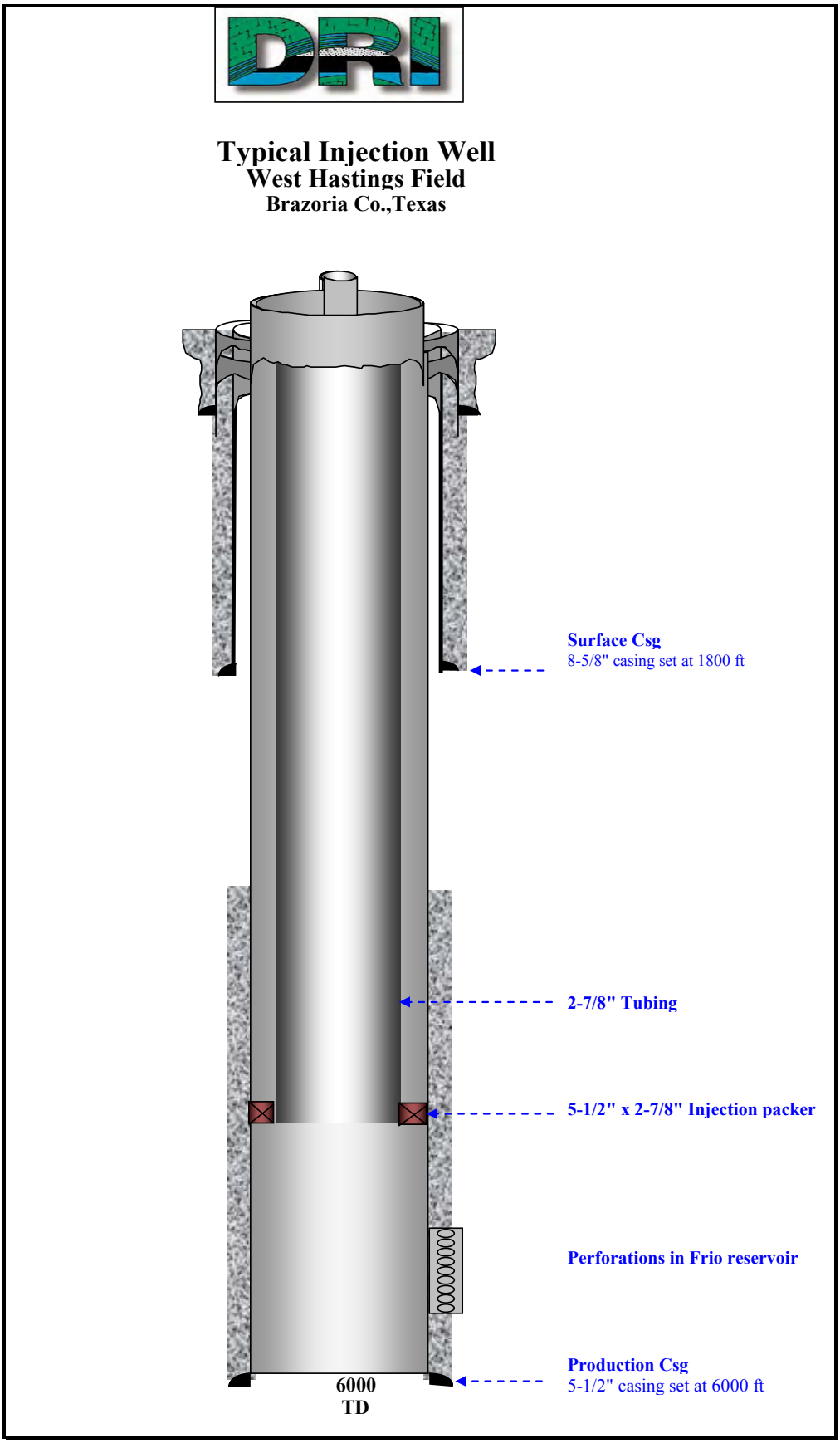


Figure 5 – Typical injection well Schematic



THE LAKE CHARLES CCS PROJECT
PHASE 1 TOPICAL REPORT

APPENDIX 6

Phase 1 SOPO Task 1.5.4.1
Draft Risk Assessment and MVA Plan

Gulf Coast Carbon Center – Report to Denbury on MVA Planning for FOA 15

Report Type:	Report and documentation of milestone completion
Report number :	C1.5.4.1
Report title:	Draft Risk Assessment and MVA plan
Completion Date:	December 15, 2009
Report Issue Date:	April 11, 2010
Submitting Organization:	Susan D. Hovorka, Principle Investigator, Gulf Coast Carbon Center Bureau of Economic Geology Jackson School of Geosciences The University of Texas at Austin

Comment: Draft risk assessment and MVA plan noting site-specific data needs prepared by GCCC based on previous experience and available site-specific data.

Phase I Task C1.5.4.1

Draft risk assessment and MVA plan

Prepared for:
Denbury Onshore, LLC

Report by Susan D. Hovorka

April 11, 2010

Bureau of Economic Geology
John A. and Katherine G. Jackson School of Geosciences
The University of Texas at Austin
Austin, Texas 78713-8924

Tables

Table 1. Proposed monitoring program options..... 7
Table 2 Sources of expertise within the project showing highlights..... 8
Table 3. Scoping spreadsheet for field selection and MVA program development …12

Introduction

This report documents the status of planning and progresses for Task C1.5.4.1, Draft risk assessment and MVA plan. GCCC has prepared a list of site-specific data needs based on previous experience and available site-specific data. This data table describes the data needs needed to design an MVA plan, and requests information from Denbury on data availability for several field in consideration. It also solicits information on how the MVA needs will be evaluated, and discusses how the data will be used for achieving storage goals.

Goals of a Monitoring, Verification and Accounting Plan (MVA)

A Monitoring, Verification and Accounting (MVA) plan for each sequestration site will focus on demonstrating that identified risks are not occurring. This assurance program includes:

(1) demonstrating that the CO_2 is contained in the designated trap (no spill out of reservoir);
(2) demonstrating that well completions have integrity to retain CO_2 over the 1000 year time frame;
(3) demonstrating that the seal and the faults and fracture systems that cut it retain confining capacity after pressure depletion during production and pressure increase during the flood;
(4) and additional observations and activities above and beyond the normal CO_2 EOR operations that will allow interpretations to be made of confinement of the CO_2 beyond the operational period.

Process for preparing MVA plan

In order to prepare a detailed plan a number of activities will be performed in Phase I of the project. An effective and efficient MVA plan has to be based on the actual field and reservoir in which the sequestration will take place.

Prior to injection, Denbury will construct a geologic model of the reservoir using available wireline logs, core, seismic, and past production data, and simulate the interaction of injected CO_2 with reservoir fluids. Reservoir characterization is undertaken to guide the flood design; this provides essential data to demonstrate that the CO_2 is effectively and efficiently contained within the reservoir (in production terms maximize sweep efficiency and oil contact area).

Well bore integrity is a major reservoir management activity. Denbury has began a comprehensive review to determine the condition of active, idle, and plugged and abandoned (P&A) wells in the area to be flooded. Scout tickets and RRC W-3A P&A records are evaluated to make sure that this process has been properly completed. Denbury will develop a plan to reenter about half of the P&A wells, that will provide an opportunity to evaluate ¾ of the penetrations using a combination of cement bond, temperature, TNT or other wireline tools to determine and remediate, if needed, casing – borehole annular cement integrity prior to or during the flood. The integrity of P&A wells will be determined by (1) comparing the P&A records for wells that were re-entered with the actual condition of the wells, to determine if records are accurate; and (2) a site specific surveillance program using migration indicators in soil and groundwater using both ambient (oil, methane, salinity) and introduced (CO_2, stable isotopic, perfluorocarbon tracers) to assure that individual wells are performing correctly. The operational period for individual wells is >15 years. At the end of useful life Denbury will P&A producers and injectors in accordance with applicable regulations.

As the flood starts, Denbury will track CO_2 via daily to weekly monitoring of well head pressure, monthly measurement of produced fluids from each well using the production test facility, and collection of additional data that are then input into reservoir models to optimize the flood. Denbury will track CO_2 for flood optimization via routine monitoring of bottom hole pressures during the initiation of the flood and routine monitoring of well head pressure to determine when to open and begin to produce the wells into the facility. Once production begins, monthly volumetric balances of produced fluids in conjunction with reservoir pressure measurements and other wireline measurements will be utilized to monitor the flood and location of the CO_2. Surveillance methods may include, flowing and shut-in bottom hole pressure measurements, TNT (neutron) logs, thermal/spinner production logging and other tools that may be developed.

A review of literature and recommendations for MVA activities will be conducted to evaluate what is recommended for each field. There are several existing publications of potential recommended MVA activities such as; IPPC Special Report on Geologic Sequestration, World Resources International CCS guidelines, CCPII's Results from the CO2 Capture Projects Vol. III, and the National Energy Technology Laboratory (NETL) http://www.netl.doe.gov/technologies/carbon_seq/core_rd/mva.html), Interstate Oil and Gas Compact Commission report "Carbon Capture and Storage: A regulatory framework for states.

The Bureau of Economic Geology Gulf Coast Carbon Center (GCCC) will work with Denbury and a number of service companies and research organizations to develop a site specific research MVA plan to augment normal commercial best practices. The MVA plan will include the extent to which normal best practices can provide this confirmation, the extent (if any) to which they need to be augmented and to recommend monitoring systems that are fit- for-purpose.

Criteria that define fit-for-purpose include

(1) definitive data that retention for storage has occurred
(2) predictive data that storage is permanent (<1% migration over 1000 years)
(3) cost effective
(4) compatible with CO_2-EOR practices
(5) durable and robust for monitoring over multi-decade time frame in active CO_2 field environment
(6) quantitative and reportable

Some of the ranges of possibilities that will be considered for the MVA plan are shown in Table 1.

Table 1. Proposed monitoring program options

Goal	MVA techniques to be considered*
Demonstrating that the CO_2 is contained in the designated trap (no spill out of reservoir)	Collection of injection data, pressure data and fluid production. History matching production data using reservoir simulator to document mass balance, pressure conformance, and maximum extent of plume. Additional data collection, such as as PFT Geochemical Tracers to show injector-producer flow and plume thickness, additional permanently installed, wireline or slickline instruments (e.g. thermal, acoustic, pulsed neutron), surface-deployed geophysical techniques including VSP azimuthal and walkaway surveys and time lapse 3-D; conformance control via CO_2 foams or other advanced reservoir management engineering
Demonstrating that well completions and P&A wells have integrity post-closure to retain CO_2 over the 1000 year time frame.	Assessment of historical well completion and P&A reports; reentry of selected wells to test accuracy of historical reports, cement bond and casing integrity logs; deconstruction and analysis of well materials (as done by Schlumberger and CCP); well surveillance during flood (noise, temperature, pressure, fluid migration); above-zone pressure, temperature, geochemical monitoring; emplaced PFT to tag CO_2 to detect above zone or at surface; time lapse 3-D survey looking for change above zone, up-gradient-down gradient groundwater monitoring, soil gas monitoring.
Demonstrating that the seal and faults and fracture systems that cut it retain confining capacity after pressure depletion during production and pressure increase during the flood.	Collection of seal and geomechanical testing and modeling to determine if either pressure drop during production or pressure increase during injection could damage seal, emplaced PFT to tag CO_2 to detect cross-fault, above zone or at surface; geochemical stability with CO_2-water-interation; evaluation of geologic and historical performance of seal and faults during charge and production; cross-faults and above-zone pressure, temperature, or geochemical monitoring; time lapse 3-D survey looking for change above zone; up-gradient-down gradient groundwater monitoring, soil gas monitoring.

* Site specific cost/value/feasibility assessment will be conducted and only a selection of techniques named above will be proposed for the final MVA plan.

As the geologic assessment, modeling, and engineering design advances, it will highlight additional uncertainties or remove potentially eliminate uncertainties that may affect storage assurance. We will use several risk assessment methods, consulting Denbury's in-house expertise, Quintessa FEPS data base (http://www.quintessa.org/CO_2fepdb/PHP/frames.php),

LBNL-UT certification framework, literature review, interview other current projects doing monitoring (e.g. Otway, Victoria, Australia, Ketzin, Potsdam, Germany, project at ADM plant Dekatur,Il, BP's Insalah Project in Algeria), and expert interviews to formally list all the factors and uncertainties that could lead to failure to attain the expected level of long-term storage. Any significant additions to the list in the table above and a list of monitoring options will be added.

GCCC will invest significant effort into evaluation of the value based on the cost versus benefit of each monitoring tool. Value includes the ability of the tools to make the needed measurements to reach project goals, sensitivity at relevant conditions, durability and cost of maintenance/replacement, frequency of repeat, density of data collection, cost of each repetition, value of information in context of history matching a model or confirming non-detect. This evaluation will make substantive use of GCCC past field monitoring experience (Frio I, Frio II, SECARB Stacked Storage at Cranfield, SECARB Early at Cranfield, and SWP Phase II at SACROC). Each of these test projects has made significant advances in monitoring and provides lessons learned that will be used to meet this project's applied objectives. In addition, the GCCC team has been involved as reviewers and collaborators in many other projects, and will continue aggressive co-ordination with other groups within the Regional Carbon Sequestration Partnerships (RCSP), the US, and worldwide to bring new results to the project. Table 2 shows some of the resources and connections that have been drawn upon to develop the MVA plan. Denbury will review the recommendations of the GCCC evaluation and during working meetings the project team will determine best value tools will be selected for proposal in the final MVA plan.

Table 2. Sources of expertise within the project showing highlights

Expertise	Source	Nature of link
Reservoir characterization	Denbury	Provided to project as in-kind contribution
Storage efficiency –best practice	Denbury	Provided to project as in-kind contribution
Storage efficiency – extended as needed for CCS	GCCC/Denbury	In-zone monitoring experience from Frio test, Phase I Cranfield enhanced reservoir surveillance program, Phase III Cranfield Field test underway. Numerous other CCS specific as well as service company approaches available, contacts through IEA GHGR&D program monitoring working group; RCSP MVA Working Group
Well-bore integrity – best practice	Denbury	Provided to project as in-kind contribution
Well-bore integrity-advanced	GCCC-Sandia Technologies	Expertise via Carbon capture Project (CCP) http://www.CO_2captureproject.org/; contacts through IEA GHGR&D program well-bore integrity working group
Above –zone Monitoring	GCCC/Sandia Technologies	Chemical monitoring –Frio, Pressure Monitoring SECARB II and III at Cranfield
Ground water monitoring	GCCC	Experience through recently completed SWP SACROC program, test at Cranfield underway.
Soil gas monitoring	Denbury, GCCC	Baseline underway at Oyster Bayou; GCCC method improvement at Brackenridge field station; Cranfield Phase III. Connection to ZERT, RCSP monitoring working group, numerous vendors

Worksheet for field and MVA selection

The mechanism for accomplishing the site selection and site specific risks will be via an in-person meeting, at which Denbury and GCCC staff will evaluate the candidate field to determine the lowest risk and highest chance of success. The evaluation table is shown in figure 3.

Figure 3. Scoping spreadsheet for field selection and MVA program development

			TX Fields	
Characteristics	**Details**	importance to success of project 5= very important to 1= not at all important	Oyster Bayou	Hastings
Match of injection area to injection volume				
Number of patterns needed for planned CO_2 A volumes				
Timing/volumes of CO_2A available				
Temporal match of CO_2 available patterns	Will CO_2 be injected in a new area? (no previous CO_2)			
CO_2 accounting				
Quantify and report CO_2 injected, recycled	Who is handing this part of MVA?			
Quantify water, oil, gas volumes extracted				
Handing CO_2 – separator efficacy, line leakage, venting during handing				
Frequency, density, quality of data for CO_2 accounting				
Potential to improve accounting data beyond current practices				
NEPA risks				

Minimum contentious or litigious public				
Wetlands				
No endangered species habitat				
No historical features, parks, residential area problems				

Model reservoir block to account for CO_2 distribution

3-D seismic				
Cores and core analysis				
Historical production data				
Good PVT data				
Detailed geologic model				
Detailed flow model				

Available MVA data to history match

Pressure data during flood				
Good access and support for surface monitoring – roads, power, cell coverage				
Can collect repeat 3-D/VSP				
Good well integrity – avoid fields with the most bad well conditions/bad well records				
Good confidence in predicting preflood fluid composition, saturation, pressure				
Minimum complexities of past production – multiple zones produced? Water flood? Past CO_2 flood, other tertiary recovery. Multiple operators in field (e.g. shallower production by another company might raise issues of contamination by CO_2 – not good to monitor and raise these issues				
minimum surface conditions that may limit monitoring options - cropped, uncooperative surface owners, wet or inaccessible, highly complex surface uses (past oil field contamination)				
Suitable probable flood geometry – area to be monitored. reservoir compartmentalization. complexity, number of faults				

Some additional questions and key points to consider as we plan MVA strategy:

Develop MVA approach - Collect data to reduce perception of risk (by CO_2 supplier & DOE)

What are the biggest unknowns? CO_2 use per pattern? Compartmentalization? Miscibility? Pressure? In DOE –speak these would be described as capacity and trapping mechanism

What shall we do to show well integrity?

How do we show faults are sealing especially over geologic time?

Monitoring should be used to confirm a model - who will do this model?

Risk Assessment approach?

How to coordinate monitoring with field development – possible dual use (future injectors/producers used as monitoring wells) to limit cost.

Dual use of water make-up wells?

Who are stakeholders and what is process by which they will provide feedback for Phase II proposal?

In Phase II budget -Who will do the monitoring field work – how much done by Denbury or other contractors?

THE LAKE CHARLES CCS PROJECT
PHASE 1 TOPICAL REPORT

APPENDIX 7

Phase 1 SOPO Task 1.5.4.2
Site-Specific MVA Options Evaluation

Gulf Coast Carbon Center – Report to Denbury on MVA Planning for FOA 15

Report Type:	Report and documentation of milestone completion
Report number :	C1.5.4.2
Report title:	C1.5.4.2 Site-specific MVA options evaluation
Completion Date:	February 22, 2010
Report Issue Date:	April 11, 2010
Submitting Organization:	Susan D. Hovorka, Principle Investigator, Gulf Coast Carbon Center Bureau of Economic Geology Jackson School of Geosciences The University of Texas at Austin

Phase I Task C1.5.4.2

Site-specific MVA options evaluation

Prepared for:
Denbury Onshore, LLC

Report by Susan D. Hovorka

April 11, 2010

Bureau of Economic Geology
John A. and Katherine G. Jackson School of Geosciences
The University of Texas at Austin
Austin, Texas 78713-8924

Introduction 1
Field Selection – West Hasting Fault Block B - C 1
MVA program 2
Non sealing well completions 3
Vertical migration up faults 4
Next actions 5
NEPA activities 5

Table 1. Commercial MVA program used for reservoir management 3

Introduction

This report documents the planning and progresses for Task C1.5.4.2, evaluation if site-specific MVA options. On December 15, 2009, a review team composed of Susan Hovorka, University of Texas, Bureau of Economic Geology (BEG) and sixteen Denbury staff refined the plan for development of the Phase I Storage MVA plan for the four capture projects linked to two storage projects proposed under DOE FOA 15. This report recounts the evaluation completed at that meeting, and identifies the field and MVA options selected for further evaluation. This prepares the way for development of detailed proposals that will be judged competitively for major funding in Phase II

The review team completed a formal review of two fields nominated in the initial proposal and selected one that seemed to be most competitive in the context of the next round of proposal preparation: West Hasting fault block B and/or C. We discussed the separation of monitoring activities into (1) those conducted commercially as part of best practices for an effective EOR flood and/or to meet current regulatory requirements (these are not subject to NEPA) and (2) those geographically and topically limited research-oriented monitoring, verification, and accounting (MVA) activities that will be conducted to further demonstrate the effectiveness of storage. Research MVA will be federally funded and will be subject to NEPA. This report proposes a draft research MVA program. It is intended that this draft discuss a broad scope of all the activities that might be selected for the phase II proposal. This broad scope will help us focus further cost/feasibility/optimization discussion as well as allow preparation of the EIV. For purposes of this MVA study, “best practices” means typical oilfield drilling and completion practices in accordance with state regulatory requirements and industry-accepted standards utilizing a well injection pattern for CO_2 intended to extract additional oil and gas from the reservoir based upon Denbury’s geological (and where appropriate, possibly seismic) and operational studies.

Field Selection – West Hasting Fault Block B - C

Two fields were proposed in the initial proposal from which one was to be selected: Oyster Bayou or Hastings. A list of competitive advantages/possible risks to consider was prepared and jointly reviewed. Issues that were judged to be significant were: temporal and volumetric match between field development and availability of captured CO_2 and possible negative implications of the public aspects of using federal funding, in particular the public information associated with NEPA.

The review team felt that a stronger proposal would result if the field expansion (additional patterns) was approximately matched to the captured CO_2 (assumed to be 1 million tons per site per year during 2014-15). Make-up CO_2 is purchased throughout the life of a field even when recycling dominates, however the possible reviewer confusion about “room for CO_2 when the field is already full” might weaken a competitive proposal. Also in fields which will be relatively mature and into recycle, the purchase volumes needed during the 2014-15 period could not be stated with high confidence in the Phase II proposal. In addition, the possibility of collecting baseline data prior to completion of the development of the flood will allow the MVA program to mirror what the DOE

program expects, which will improve its acceptability. The field in which expansions are planned in 2014 timeframe is Hastings fault block B and C (fault block A will be becoming mature).

The other factor considered a significant selection parameter is the public comment period triggered by NEPA. Public comment related to NEPA will apply only to federally funded research MVA activities, as Denbury's commercial field operations will be part of the EOR flood whether or not federal funds are applied. Rationally, research MVA activities should provide additional comfort for residents and communities, however where anxiety or hostility are involved, residents may not separate the commercial flood of Denbury from the research MVA of GCCC. Local interest could have possible negative consequences resulting in unnecessary delays for either commercial or research program, or both. We therefore ultimately recommend avoiding locations where the CO_2 enhanced recovery project may impact a larger population.

The consensus is that a strong proposal can be written for Hastings.

MVA program

The MVA program proposed will include two components: a commercial operations program and an added value research program. The commercial MVA program will be conducted as part of the EOR Operator's normal best practices, in conformance with applicable regulations. These commercial operations are not subject to NEPA review as they are independent operations which will be conducted whether or not federal funding and anthropogenic CO_2 is acquired for the EOR project. The research program is designed to test with additional rigor and available technology the extent to which a commercial operations monitoring program is adequate to assure that storage is of quality desired to obtain lasting benefit to the atmosphere. In particular the research program will test for conditions where retention of CO_2 is adequate for commercial operations benefit and duration but may not be of standards desirable for long-term sequestration. The standards desired for sequestration are not codified at this time, however the IPCC target that a well selected site should retain 99% CO_2 in the reservoir over 1000 years meets the DOE's expectations. The research portion of the MVA program will be federally funded and subject to NEPA review.

Commercial operations EOR field monitoring provides assurance to the Operator that the CO_2 flood is performing correctly via reservoir management and its oilfield development pattern. In order to create a credible MVA program, Denbury will document that these commercial activities are conducted in a manner to lend credence to the MVA research project. In some cases the applicable data are reported to the appropriate state oil and gas regulatory board, however, in other cases data is proprietary to the operator and BEG will work with Denbury to disclose that data needed for documentation to demonstrate permanent sequestration. Reservoir management goals and activities are shown in table 1.

Table 1. Commercial MVA program used for reservoir management

Goal	Methods	Remedial action if needed achieve goal
Demonstrate no migration through existing and P&A wells for protection of USDW	Examine well completion records, P&A records prior to flood, run cement bond logs, conduct mechanical integrity tests, during flood daily record of casing pressure at each well (a truly abandoned well may not have pressure recording capablility)	Re-entry and workover to repair wells if needed, includes, cement squeezes, installation of casing liners, P&A and redrill if needed.
Surveillance of the flood to demonstrate that injection is balanced (CO_2 is going into the selected area of the selected zone and driving production at selected producers, pressure is not above fracture gradient).	Daily record of tubing pressure on injectors and producers, minimum monthly inventory of fluid volumes produced at each well at test facility, intermittent bottom hole shut-in or flowing well pressures, intermittent production/injection logs.	Shut in wells that do not contribute, increase/decrease injection or production rates, modify perforated interval. Conformance treatments to alter injection and/or production zones.
Predict future performance of reservoir	History match surveillance data to predictions in reservoir model.	Correct model as needed to match history and gain confidence in future predictions

The research MVA program will focus on areas of uncertainty in retention of fluids in the injection zone. As these oil fields have retained oil and gas for geologic time, we consider that it is documented the natural seal is adequate to support a significant CO_2 column with migration occurring possibly only at diffusion rates. Risk assessment and experience indicates that the most probable migration paths are (1) non-sealing well completions; (2) vertical migration up fault when reservoir pressure exceeds original pressure (3) off-structure or out of compartment migration of CO_2 or brine as a result of elevated pressure into areas not controlled as part of the flood. An MVA program is outlined for each of these risk areas and is linked to a mitigation or management process that can be implemented to result in adequate assurance that the CO_2 injected is permanently stored.

Non sealing well completions

Wells that penetrate the seal are potential weak points, especially during injection. This occurs because older wells have been completed under older regulatory schemes. Wells that perform adequately during extraction, when they are pressure sinks, have the

possibility of becoming upwardly transmissive during injection when pressure of the reservoir is increased. Wells that are actively producing can be inspected via a logging program, however wells that have been plugged and abandoned (P&A) are prohibitively expensive to reenter to inspect and therefore do not provide viable candidates for monitoring. The research MVA program is intended to extend the commercial operations well integrity program, and test the effectiveness of the commercial operations program.

Activities that will be considered for possible inclusion in the research MVA proposal:

(1) Additional logging program (e.g. temperature, radioactive tracers, high end wireline tools)

(2) Above zone pressure monitoring – ambient and introduced fluids

(3) Well deconstruction – possibly associated with workover.

(4) Soil gas, groundwater, or other near-surface monitoring.

In Hastings, water disposal into the Miocene overlying the Frio CO_2 injection zone has elevated pressure and perturbed geochemistry. In the short term, this elevated pressure provides a barrier to upward flow. It will be interesting to assess how long this pressure barrier will be sustained with respect to long term storage goals. (it should be noted that we are making efforts to restrict or eliminate Miocene water injection as it is creating several adverse problems in the field re-development, will be interesting to monitor how quickly the Miocene "bleeds" off if any with time once injection has been curtailed). It may add difficulties to above-zone detection methods.

Possible methods for looking for flawed wellbore migration are:

- Thermal anomalies (hot fluids expelled from depth, or cold areas in shallow zones where CO_2 flashes to gas). Can be done though casing
- Noise anomalies - Can be done though casing
- Pressure anomalies - requires perforations
- Geochemical anomalies - requires perforations.
- Soil gas methods near surface (methane, CO_2)
- Augmented soil gas/aquifer surveillance methods (noble gases/isotopes, tracers)

Vertical Migration up faults

Faults related to salt structure are ubiquitous in the Gulf coast. Some faults are clearly vertically transmissive; others trap thick oil and gas columns and are therefore not transmissive at rates relevant to CO_2 storage. It is sometimes not clear how faults will perform when pressure is increased, and this uncertainty can be a block to use/storage of anthropogenic CO_2 in faulted settings. Technique development is needed to determine effective methods to document that faults are sealed to vertical flow. Hastings has a main growth fault that extends to surface as well as several cross faults. Production history suggest that cross faults maybe somewhat cross-fault transmissive, however the vertical performance has not been assessed.

Activities that will be considered for possible inclusion in the proposal:

(1) Natural fault performance - any near surface soil gas anomalies - methane , noble gasses

(2) Soil gas, groundwater, or other near-surface monitoring, same as above but focused on fault. Location - where master fault approaches surface.

(3) Logging program for wells that cut the fault (e.g. temperature, radioactive tracers, high end wireline tools) looking for changes (need before and after injection in wells that cut faults as CO_2 is injected).
(4) Above zone pressure and geochemical monitoring - any changes as CO_2 is introduced? may be impossible with water disposal in Miocene. Need to perforate one or more wells where they cut fault. Sample for PFT.
(5) Geophysical methods – design VSP or cross well acoustic array to look for changes along fault plane. Consider passive acoustic methods to determine if there is any viability in ductile rocks in Gulf Coast. Consider gravity methods.

Next actions

(1) BEG estimate sensitivity of these methods for reservoirs in question against the 99% retained over 1000 years standard. Work on concept of proving the container prior to addition of anthropogenic CO_2 – using current perturbation to assess for current migration. Feasiblity assessment for which we need basic groundwater, including depth to water and soil data.
(2) Discuss with Denbury field staff what wells could be used for above zone assessment - near reservoir depth both during early stages of development and during flood, groundwater wells. Hastings should have a significant number of wells that could be used.
(3) Resolve perspective on the soil gas in these fields.
(4) Develop a detailed "shopping list" request for Sandia to collect needed cost/vendor data
(5) Finalize plan for proposal
(6) Finalize budget for proposal

NEPA activities

This review is provided as the bounding conditions to be considered in NEPA review.

These activities are possible, and not firmly selected.

Access 1 to 10 existing wells, run various types of wireline wellbore integrity logs (temperature, noise, CBL, USIT, RAT). Select one or more wells not planned for production for plug back/set bridge plug to above-reservoir zone and perforate above zone (presumably in a permeable, "producable" oil, gas or water zone) with a workover rig, produce well with N2 lift to clean formation fluids (several hundred barrels). Completion must allow current geochemical samples and high frequency static fluid pressure. (Surface readout least expensive, downhole certainly possible, but more expensive) Consider simple (pressure transducer to measure fluctuation in static fluid column) and complex, for example Westbay sampler (http://www.slb.com/content/services/additional/water/monitoring/multilevel/westbay_multilevel_well.asp) or Ella G Lees 7 type completions. Record data via data loggers, real time phone system or satellite uplink.

Soil gas monitoring - numerous (100?) shallow (20 ft deep) boreholes below active soil zone. Install PVC pipes for soil gas wells, install weather station. Define depth the water,

may preclude this approach at Hastings. Location inside lease footprint as defined by active and P&A wells. Hastings – Add PFT's to injected CO_2, detect at surface near producers and in soil gas and groundwater wells. This would require several mobilizations because of uncertainty about transport speed.

Ground water surveillance – access to about 20 existing or new drill (100-200 ft deep) groundwater wells, cemented in PVC casing with surface protection box. Develop wells so that they can produce groundwater (100 barrels). Location inside footprint plus several up-gradient and several down gradient (off pattern) wells. Noble gas, isotope labs.

We will need to identify labs and do NEPA forms of them also.

Next actions

(1) Examine available data on wells that cut faults or could be used for cross-well geometries. Discuss with Denbury availability of well access for monitoring activities.
(2) Consider feasibility of geophysical methods.
(3) Add area where fault approaches surface to soil gas/groundwater sampling area. same techniques.
(4) Need data on Miocene water disposal and conceptual modeling.
(5) Refine approaches.
(6) Look for cost estimates.
(7) Final proposed elements.
(8) Final costs for budget.

NEPA activities

Similar to above, however add well-based geophysics to list of possible techniques. Might need kill fluids, or to plug back existing well as monitoring well (if one is available) above reservoir

Off-structure or out of compartment migration of CO_2 or brine as a result of elevated pressure into areas not controlled as part of the flood

In EOR, injection is mostly balanced by extraction, so that the area of elevated pressure is of limited size, which has not in the past been of much concern. However, the prospect of areas where injection will now be for EOR, or after EOR has ceased, (disposal only) has elevated concern within DOE and EPA about management of the size of the CO_2 plume and the size of the area of elevated pressure. It would therefore be wise in a competitive proposal to document the pressure elevation in the reservoir but outside of the flood and the maximum expected extent of CO_2 migration.

Several techniques are possible to document the two areas (elevated pressure and extent of CO_2):

(1) Direct measurement though wells. Repeat measurement of bottom hole pressure under shut in conditions and measurement of fluid saturations via sampling or (in new wells with good open hole logs) logging. This could be done by drilling one

or more future injectors early, and using them as observation wells for most of 2014-15 period before conversion to injection. (these are off structure or away from initial patterns?)

(2) Model –matching, assuring that the ultimate fate of CO_2 over 1000 years is constrained depends on good model-match during early stages of flood. Improve model – collect any needed data such as PVT, end point residual saturation, cap pressure, core porosity and permeability. (Do tar mats, ROZ areas or original water legs have a material impact on the real perm data? BEG needs to define these as part of the model when investigating plume growth beyond the original oil/gas zones) Add data needed to improve history match especially with regard to DOE expectation of tracking injected CO_2 – injection and production profiles, logging program. Update model as needed with observations during flood. (flow model only as good as the static geo model)

(3) Indirect geophysical measurements - surface deformation via, tilt, GPS and InSAR, downhole tilt, repeat VSP or surface 2-D or 3-D though transects of the plume, to document maximum lateral extent. The choices at Hastings will be limited because of previous activities. (some historical subsidence issues in Hastings as evidenced by casing collapse in its history)

Next actions

(1) Discuss with Denbury drilling short-term observation wells (future injectors drilled ahead of schedule) Possible? Need to make sure these hit the 2011 or 12 budget ahead of the planned work in 2013 or 2014, best argument is that they are accelerated wells that will be needed anyway.

(2) Discuss model situation with Denbury – What exists? Who will do this work? Ongoing deterministic model in Hastings, simplified, being developed by Denbury's Reservoir Simulation group, all in FB-A so far.

(3) Sensitivity/feasibility of using focused geophysics for plume and pressure tracking.

(4) Refine approaches

(5) Look for cost estimates

(6) Final proposed elements

(7) Final costs for budget

THE LAKE CHARLES CCS PROJECT

PHASE 1 TOPICAL REPORT

APPENDIX 8

Phase 1 SOPO Task 1.5.4.3
Final MVA Plan and Detailed Budget

Gulf Coast Carbon Center – Report to Denbury on MVA Planning for FOA 15

Report Type:	Report and documentation of milestone completion
Report number :	C1.5.4.3
Report title:	Final MVA plan and detailed budget
Completion Date:	March 22, 2010
Report Issue Date:	April 11, 2010
Submitting Organization:	Susan D. Hovorka, Principle Investigator, Gulf Coast Carbon Center Bureau of Economic Geology Jackson School of Geosciences The University of Texas at Austin
Comment:	Report presented here is after Denbury review and revision as of April4, 2010.

Phase 1 Task C1.5.4.3

Final MVA Plan and Detailed Budget

Prepared for:
Denbury Resources

Report by Susan D. Hovorka

April 11, 2010

Bureau of Economic Geology
John A. and Katherine G. Jackson School of Geosciences
The University of Texas at Austin
Austin, Texas 78713-8924

Table of contents

Phase 1 Task C1.5.4.3 3
Final MVA plan and detailed budget 3
Introduction to MVA plan 5
Schedule of Phase 2 activities 7
2A Design Phase 8
2B Construction Phase 9
2C Demonstration 9
Initial characterization and capacity assessment 9
Characteristics of the West Hastings Frio injection reservoir 10
Injectivity 14
Storage Capacity 14
Well distribution 17
Initial risk assessment linked to monitoring plans 19
Performance of wells 20
Performance of faults 20
Monitoring activities 23
Scope of Work 24

Figures

Figure 1. Stratigraphic section 6
Figure 2. West Hastings Fault Block B and C Frio type log showing multiple injection zones 8
Figure 3. Compartmentalization of the West Hastings reservoir by the main fault on the east side of the field and a series of cross faults 9
Figure 4. Development plan of CO_2 flood in West Hastings field 10
Figure 5. Upper Frio patterns in fault blocks B and C. 13
Figure 6. Estimated CO_2 purchase and recycle volumes 14

Tables

Table 1. Documents considered in preparation of the research monitoring, verification and accounting (MVA) program 1
Table 2. MVA plan responsibilities 2

Table 3. MVA project phases aligned with capture facility phases. 4
Table 3. MVA project phases aligned with capture facility phases. 4
Table 4. Field Storage Capacity (Fault block B and C) based on volume-for volume replacement of original oil-in-place by CO_2. 12
Table 5. Results of core-based permeability from fault block A. 13
Table 6. Data for modeling and likely data source 20
Table 7 Budget in Excel

I. Introduction to MVA plan

CO_2 injected for EOR is the best known and therefore the lowest risk process available for geologic sequestration. The effectiveness of the seal and trapping structure in confining the fluids (oil and gas) over geologic time has been demonstrated directly by hydrocarbon accumulation. Injectivity and effective capacity have been documented by previous fluid handling during production and water injection. Permitting and negotiation of land and pore space access follow well known processes with low risk. Injection of natural CO_2 into West Hastings field will be underway in fault block A several years prior to beginning injection of anthropogenic CO_2 (CO_2-A) injection into West Hastings fault block B and C; this will provide a strong experience base on which to rely to document CO_2 retention. Previous studies focused on sequestration in an EOR context provide precedents for MVA design. These include the Weyburn project conducted at EnCana's flood in Saskatchewan, the BEG-led study as part of the Southwest Regional Carbon Sequestration Partnership (SWP) of the results of more than 30 years of CO_2 injection from EOR at Kinder Morgan's SACROC Field in Scurry County Texas, and the currently underway BEG led multi-institutional study of large volume (>1 Million ton/year) injection at Denbury's Cranfield Field, Adams-Franklin Counties, Mississippi.

Currently, CO_2 from any source injected for CO_2 enhanced oil recovery (EOR) is regulated under UIC class II. In Texas, the Railroad Commission has primacy and requires a number of monitoring, accounting, and reporting activities to bring the field under flood and that are required periodically during the flood. Protection of groundwater resources (underground sources of drinking water [USDW]) is the main focus of the class II regulations. In addition, Denbury has developed, through a decade of experience with EOR in the Gulf Coast, a number of commercial best practices that are used to control the subsurface movement of CO_2 and manage elevated pressure in order to optimize the performance of the flood and minimize cost and risks. It is unclear if additional monitoring and reporting activities will be required for EOR in the future, or to what the extent of these activities would be. The goals of the research monitoring, verification and accounting (MVA) program proposed here are, therefore, based on uniting elements of the existing regulatory monitoring requirements and existing best practices with a number of proposed and suggested processes that are being considered for future application to CO_2 injected under various possible future regulatory or credit trading conditions. Table 1 shows documents with proposed and suggested future MVA processes reviewed during compilation of this research MVA plan.

Table 1. Documents considered in preparation of the research monitoring, verification and accounting (MVA) program

Document	Source	Status
TX RRC rules for EOR	Fluid injection into productive reservoirs TAC Title16 part1 Chapter3 Rule 3.46	in effect
Denbury Commercial Best Practices	Denbury	in effect
EPA Draft Rules	http://www.epa.gov/safewater/uic/wells_sequestration.html Comment period closed.	Proposed 2008
TX RRC draft rules for injection for the purpose of geological storage in productive formations and in formation directly above and below productive formations	TAC Chapter 16 Chapter 5 Draft Rules Released March 26, 2010 Out for comment.	Proposed 2010
World Resources Institute CCS Guidelines Report	http://www.wri.org/project/carbon-capture-sequestration	NGO overview document

The current requirements for Class II injection and commercial best practices in managing a CO_2 flood are the foundations of an MVA plan. No federal regulatory agency has proposed a change in rules for CO_2 EOR, so the current regulations that govern injection of anthropogenic CO_2 for EOR (Fluid injection into productive reservoirs under TAC Title16 part 1 Chapter3 Rule 3.46) are presumed to be those regulating the project injection. In fact, the Texas proposed rules anticipate the continued use of Class II for CO_2 EOR. It is however, possible under some scenarios that future rules for handling CO_2 could result in a change of standards for MVA applied to EOR, for example to avoid EOR counting as a source of emissions. The research goals set for this plan are (1) to test the extent to which current commercial practices (as required by regulations for fluid injection into productive reservoirs under TAC Title16 part 1 Chapter 3 Rule 3.46 plus commercial best practices) can meet possible future MVA expectations; (2) to test novel MVA approaches to see if they increase confidence and otherwise add value to an EOR + sequestration project; and (3) provide adequate budget and flexibility in case regulatory requirements change prior to the end of the project period.

A team comprised of three named groups (Table 2) will conduct the research MVA plan. Each named group will have subcontractors working for them; these subcontractors are not named in the proposal, however costs are based on quotes and extensive past experience with contracting similar services in similar settings. Costs include normal percentage of field work related costs beyond the minimum costs, and also reflect cost uncertainties in labor, fuel, commodities over the project time period.

Table 2. MVA plan responsibilities

Group	Responsibility	Reporting	Budget
Denbury	Conduct commercial MVA activities, remediation in	Report results to document the effectiveness of these	Commercial and remediation activities are done as part of

	response to any evidence of non-containment	activities	commercial project, not in proposal budget
Denbury	Support research MVA activities where these activities fit in with Denbury's core competency, for example contract geophysical activities, review BEG results prior to submission	Report results though BEG research team	20% Denbury cost 80% Federal cost. Characterization data for reservoir and fault modeling studies is provided as in kind (no cash) cost share.
Sandia Technologies LLC	Support research MVA activities where these activities require extensive supervision (e.g. specialized MVA surveys and equipment installation)	Contribute results to research plan through BEG team	20% Denbury cost 80% Federal cost
Bureau of Economic Geology	Develop reservoir and area of elevated pressure for prediction of pressure and fluid evolution during and 1000 years beyond project period, risk assessment, MVA research design, oversight of research data collection, conduct near surface data collection, integration of research results	Report results of modeling and risk assessment, submit updated MVA plans and costs at each phase, report interim results, and at project conclusion report integrated MVA. Results to be reviewed by Denbury and submitted by DOE	20% Denbury cost 80% Federal cost

In the following sections, we define: (1) the schedule of activities, (2) the current state of site characterization and capacity assessment, (3) the current assessment of uncertainties that lead to assessment of risks and guide the research MVA plan, (4) the commercial monitoring activities that provides the standard for the research MVA plan, and (5) the research MVA plan that tests the effectiveness of the commercial plan and several novel approaches that may extend the level of confidence beyond the commercial activities. This is followed by a scope of work detail in the tasks divided by project phase and task number with a reporting plan, a cost justification, experience of key participants, and budget.

II. Schedule of Phase 2 activities

MVA activities are coordinated to match the stages of development of the capture facility as shown in Table 3.

Table 3. MVA project phases aligned with capture facility phases.

Phase	Capture Facility Phase	MVA phase
2A	Design*	Site characterization including initial field measurements, predictive fluid flow and pressure modeling, risk assessment, tool down-selection, experience increase as a result of ongoing injection in fault block A and early measurements in fault blocks B and C, learning from other projects elsewhere
2A Decision	Go/No Go decision	Revised MVA conceptualization and reallocation of funds as needed to coordinate with revised build out plan
2B	Capture facility construction	Fault blocks B and C injection, production, monitoring well permitting, site preparation (roads, separation facility expansion), well workover and new drills in patterns including selected advanced patterns, baseline data on soil gas, groundwater, and subsurface pressure, fluid composition and rock property data collected, baseline geophysics and well logging, input data into predictive model, revised risk assessment.
2B Decision	Go/No Go decision	Revised MVA conceptualization and reallocation of funds as needed to coordinate with revised build out plan
2C	Demonstration CO_2 production from capture facility	Anthropogenic CO_2 injection, time-laps MVA data collection
2C Overview		Evaluation of results of MVA program, revised model runs showing model match, comparing the effectiveness of the commercial program to the research program in documenting effectiveness and permanence of storage, and recommendations for future MVA at CO_2 EOR settings.

**Commercial proprietary non-funded data utilized to refine fluid flow and pressure modeling may be withheld from public information.*

2A Design Phase

The lead tasks of the design phase are integration of commercial site characterization data followed by predictive fluid flow and pressure modeling, and improved description of stress conditions on faults, leading to an improved assessment of risk of non-retention. Denbury is already well along on commercial development of Hastings Field for CO_2 EOR flood into the northern fault block of West Hastings Field, fault block A. Prior to anthropogenic CO_2 availability, injection using natural CO_2 from Jackson Dome will be used to develop the flood into West Hastings Field fault block A. This experience will greatly decrease uncertainties in developing fault blocks B and C, which development is scheduled to begin flood at the about the same time as anthropogenic CO_2 (CO_2-A) is available. Therefore, prior to CO_2-A injection, we expect improvements in knowledge of effective ways to manage the numerous wells, pressure, and flow in the field. As part of this effort, Denbury may start brine injection into fault block B and C, allowing collection of some early measurements of connection or isolation of fault block A from fault blocks B and C. Because the West Hastings Field is an ongoing EOR operation, it is expected that a NEPA CX or a waiver will be obtained to begin tests to determine sensitivity and feasibility of proposed soil gas, groundwater, and well-bore integrity methods. BEG has planned several monitoring wells to determine the current

pressure distribution during this phase. Any adjustments needed to match commercial field development to the CO_2-A injection plan(s) will be accommodated.
In addition, learning from other projects conducted elsewhere as part of DOE's and international programs, as well as reliance on Denbury's experience in other fields will be part of the design phase. At the end of the phase, BEG, in consultation with Denbury, will prepare a report containing an updated risk assessment, modifications recommended in MVA system, and corresponding adjustments in cost.

2B Construction Phase
In this phase, preparation for injection of CO_2-A into fault blocks B and C will be completed as part of Denbury's commercial field development operations. Injection, production, and monitoring wells will be permitted through the TX RRC. Site preparation; well workovers and new drills in patterns, including selected wells in the above zone monitoring interval (AZMI) will be used as access points to monitor ahead of the active injection. Baseline data on soil gas, groundwater, and subsurface pressure, fluid composition and rock properties will be collected and input into a predictive model, allowing a revised risk assessment. Baseline geophysics and baseline well logging will be completed prior to initiation of the flood. At the end of the phase, BEG in consultation with Denbury will prepare a report containing a revised MVA conceptualization and reallocation of funds as needed to coordinate with the revised build out plan.

A. 2C Demonstration

During this phase, it is anticipated that CO_2-A will be available from the capture facility. The availability of natural CO_2 will allow flexible staging, as any source of CO_2 can be used to demonstrate containment. As injection starts, the commercial monitoring program will track the CO_2 injected, the CO_2 recycled, and the performance of the reservoir and wells in retaining CO_2. The research program will collect time-lapse data testing alternative and possibly high-resolution techniques for documenting that the CO_2 is retained in the injection zone and in the predicted flood area, and that pressure is below that determined to be safe. At the end of this phase, BEG, in consultation with Denbury, will prepare a report evaluating the results of the research MVA program, revised model runs showing model match, comparing the effectiveness of the commercial program to the research program in documenting effectiveness and permanence of storage. Recommendations for future MVA at EOR settings will be prepared.

The research monitoring program will end at the end of the demonstration phase. The objective of the research MVA program is to increase confidence in commercial monitoring programs and in the permanence of CO_2-A storage.

III. Initial characterization and capacity assessment

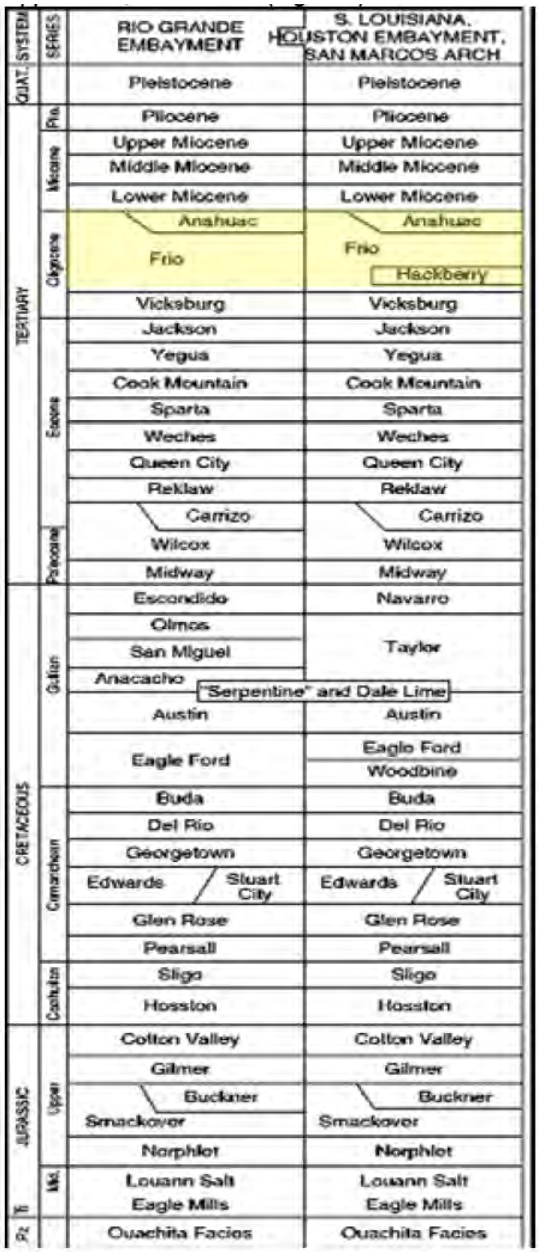
In this section we review the current state of site characterization and capacity assessment, emphasizing the current assessment of uncertainties that lead to assessment of risks and guide the research MVA plan.

A. Characteristics of the West Hastings Frio injection reservoir

The Frio Formation of West Hastings Field is well characterized as an injection zone, and sufficient data are currently available to confirm confinement, injectivity, and storage capacity. The Anahuac Formation provides confinement at the top of the reservoir (Figure 1). This unit is a regionally extensive transgressive dark mudstone > 500 ft thick. The seal properties of the Anahuac were studied as part of the Frio Brine pilot, and show that this formation is an excellent seal. Miocene strata provide redundant seals above the reservoir, which is the proposed location for the above-zone monitoring interval (AZMI). The base of the Frio Formation is defined by additional shale-sandstone sequences. Multiple sands in both the upper and lower Frio formation will be flooded as part of the Fault Block B and C development plan.

Regionally fluvial, strandplain, and deltaic sandstones of the Oligocene Frio Formation extend across the Gulf Coast Basin from the Texas–Mexico border to just west of the Texas-Louisiana border. Two sandstones of the upper Frio Formation were tested and found favorable for monitoring and for sequestration by the Bureau's Frio brine pilot test east of Houston. The Frio Formation at West Hastings field is composed of a number of sandstones separated by shales (Figure 2). Multiple sandstones are productive within the field and will serve as the injection reservoir. A major fault serves as the updip limit of the reservoir. Differences in the historic oil water-contact provide evidence that this fault is sealing. In addition, the reservoir is partly compartmentalized by cross faults (Figure 3). Fluvial sandstones of the Frio Formation, and salt deformation causing faulted structural closures are abundant along the Gulf Coast; knowledge about reservoir performance is high as is confidence in trapping. In addition to the natural trapping of large amounts of hydrocarbon beneath the Anahuac Formation, further confidence is provided by the widespread permitting of this unit as a confining system for Class I hazardous and non-hazardous permits (Kreitler, et al, 1990).

Figure 1. Stratigraphic section



SYSTEM	SERIES	RIO GRANDE EMBAYMENT	S. LOUISIANA, HOUSTON EMBAYMENT, SAN MARCOS ARCH
QUAT.		Pleistocene	Pleistocene
TERTIARY	Plio.	Pliocene	Pliocene
	Miocene	Upper Miocene	Upper Miocene
		Middle Miocene	Middle Miocene
		Lower Miocene	Lower Miocene
	Oligocene	Anahuac / Frio	Anahuac / Frio / Hackberry
		Vicksburg	Vicksburg
	Eocene	Jackson	Jackson
		Yegua	Yegua
		Cook Mountain	Cook Mountain
		Sparta	Sparta
		Weches	Weches
		Queen City	Queen City
		Reklaw	Reklaw
	Paleocene	Carrizo / Wilcox	Carrizo / Wilcox
		Midway	Midway
CRETACEOUS	Gulfian	Escondido	Navarro
		Olmos	Taylor
		San Miguel	
		Anacacho	
		"Serpentine" and Dale Lime	
		Austin	Austin
		Eagle Ford	Eagle Ford / Woodbine
	Comanchean	Buda	Buda
		Del Rio	Del Rio
		Georgetown	Georgetown
		Edwards / Stuart City	Edwards / Stuart City
		Glen Rose	Glen Rose
		Pearsall	Pearsall
	Coahuilan	Sligo	Sligo
		Hosston	Hosston
JURASSIC	Upper	Cotton Valley	Cotton Valley
		Gilmer	Gilmer
		Buckner / Smackover	Buckner / Smackover
		Norphlet	Norphlet
	Mid.	Louann Salt / Eagle Mills	Louann Salt / Eagle Mills
Pz		Ouachita Facies	Ouachita Facies

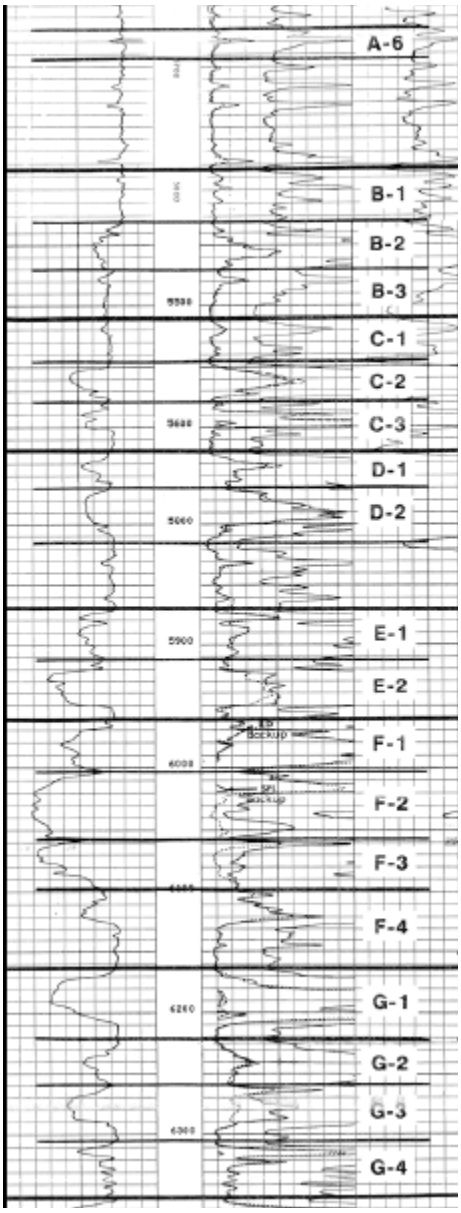
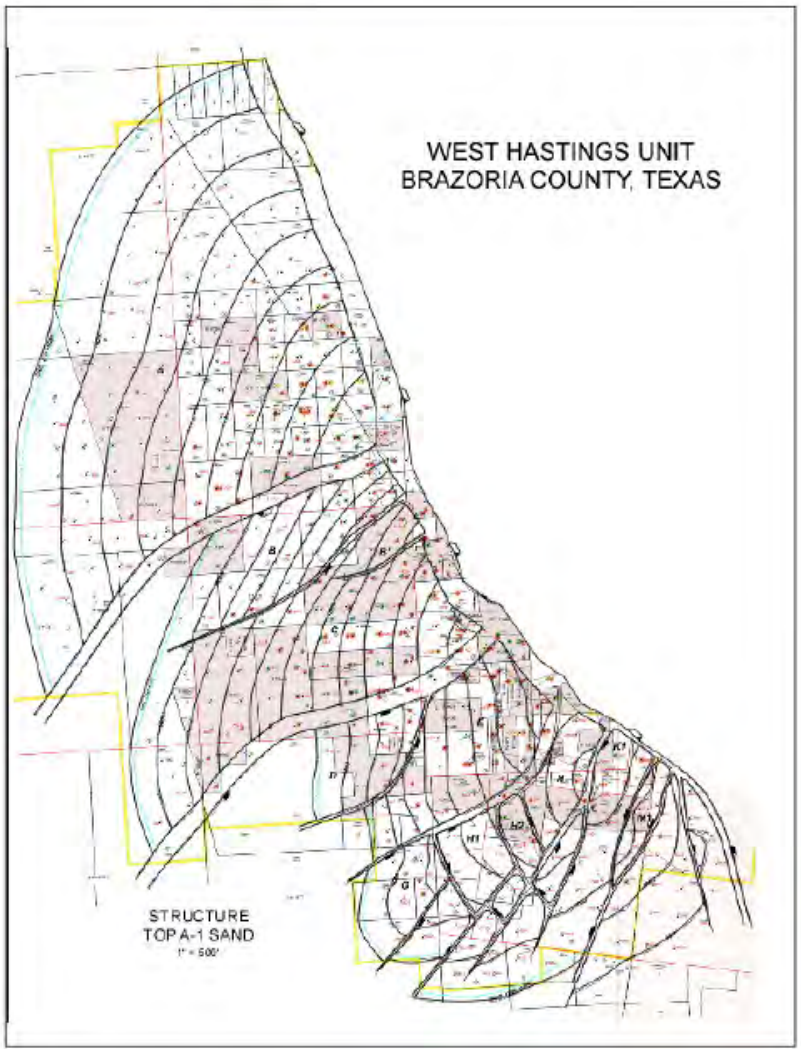
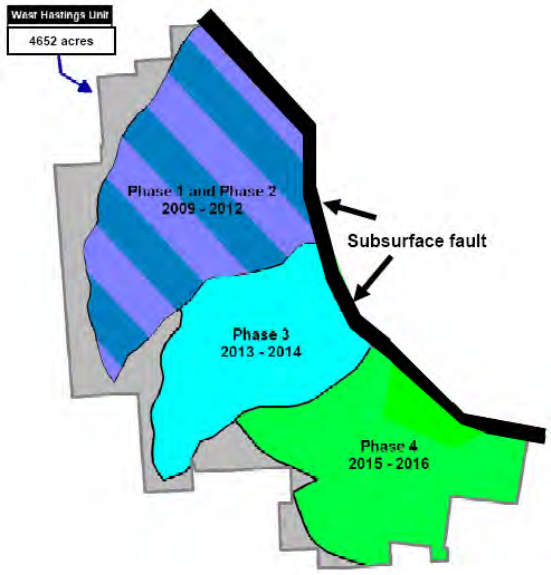

A-6
B-1
B-2
B-3
C-1
C-2
C-3
D-1
D-2
E-1
E-2
F-1
F-2
F-3
F-4
G-1
G-2
G-3
G-4

Figure 3. Compartmentalization of the West Hastings reservoir by the main fault on the east side of the field and a series of cross faults



Denbury plans to develop the field in several stages (Figure 4), starting in 2010 with block A at the north end of the field. Injection of CO_2-A is planned to be into productive intervals of the Frio Formation into the B and C fault blocks of the reservoir because that area of the field will be first undergoing injection at the time when capture is underway.

Figure 4. Development plan of CO_2 flood in West Hastings field



To supplement this naturally occurring CO_2 supply, Denbury will utilize anthropogenic CO_2 (CO_2-A) supplies to meet its rising CO_2 requirements. It is anticipated that CO_2-A will be available for development of blocks B & C at West Hastings beginning in late 2013, therefore a commercial preliminary design has been made and estimates of the CO_2 storage capacity for the reservoir determined. Information gained from actual injection into fault block A will be utilized to finalize the fault block B and C design during 2011and 2012; however, this injection will not dramatically impact the pore volume available for CO_2 storage.

B. Injectivity

The injectivity of CO_2 can be estimated from current water injection rates on existing Frio injectors. Water injection into the Frio of ~180,000 BWPD is being accomplished with 20 wells, an average of 9000 BWPD per well. Based on a CO_2 formation volume factor of 2 MCF/bbl, this would equate to 18 MMCFD (~947 metric tons per day or 0.345 million metric tons/year) CO_2 per well. This rate is also consistent with the maximum erosional velocity limit of CO_2 down 2-7/8" tubing, thus establishing a target injection per injector. The seven planned injection wells during the initial pattern development for blocks B and C will therefore demonstrate that the formation can accept the planned CO_2-A. Insuring high injection rates into each pattern maximizes the rate at which oil is recovered, therefore improving project economics.

C. Storage Capacity

The storage capacity for reservoirs to be flooded in fault blocks B and C is shown in Table 4. A simple estimate can be made by assuming the volume of original oil-in-place can be replaced on a volume per volume basis by CO_2, as done in the NATCARB atlas. The 237 million barrels oil produced occupied 284 million reservoir barrels (1.2 RB/STB) and based upon 2 MCF CO_2 per reservoir barrel at 160 degrees F and 3000 psi, the CO_2 volume to completely displace the original hydrocarbon pore volume will be 568 BCF (31 million metric tons). Inefficiencies in aerial and vertical sweep efficiency and relative permeability to CO_2 because of remaining oil will reduce this number, dissolution of CO_2 into brine and sequestration in non-productive intervals will increase this number. Because the reservoir is complex both stratigraphically, with

lateral changes in sandbody properties typical of fluvial-deltaic systems, and structurally, because of cross faulting, significant uncertainty remains in exactly how the CO_2 will spread from injection wells. Significant monitoring effort will be provided in both the commercial and research program to track the CO_2 distribution aerially and stratigraphically to reduce this uncertainty (flood conformance). Improving quantification of the storage via monitoring is one of the goals of this project.

The West Hastings Development team recently cored a well in fault block A (WHU-3706) to determine reservoir properties for the ten major sands of the upper and lower Frio reservoirs. Plugs have been cut from the core and measurements of permeability are reported in Table 5. Additional tests will also be performed to determine connate water and residual oil saturation endpoints on approximately 5 plugs, along with oil/water and gas/oil relative permeability curves. This information will be used to guide in the selection of perforated intervals and to better understand the vertical sweep efficiency expected during the CO_2 flooding process. Good water drive during production indicates that pressure increase during injection will not limit injection rates, in contrast it is expected that water injection prior to and down-dip of CO_2 injection will be required to augment CO_2 so that injection pressure can be raised from 2200 psi to 3100 psi desired for EOR.

Table 4. Field Storage Capacity (Fault block B and C) based on volume-for volume replacement of original oil-in-place by CO_2.

Upper Frio	Sand	Area (acres)	Thickness (feet)	Net-to-Gross (decimal)	Porosity (decimal)	Swi (decimal)	Boi (RB/STB)	OOIP (bbls)	CO2 Capacity (MMCF)
	A1	700	20	0.61	0.3	0.8	1.2	13,350,940	32,042
	A2	675	30	0.61	0.3	0.8	1.2	19,311,181	46,347
	A3	650	50	0.61	0.3	0.8	1.2	30,993,253	74,384
	A4	625	40	0.61	0.3	0.8	1.2	23,840,964	57,218
	A5	600	20	0.61	0.3	0.8	1.2	11,443,663	27,465
	A - Total		**160**					**98,940,000**	**237,456**
Lower Frio	**Sand**	**Acres (acres)**	**Thickness (feet)**	**Net-to-Gross (decimal)**	**Porosity (decimal)**	**Swi (decimal)**	**Boi (RB/STB)**	**OOIP (bbls)**	**CO2 Capacity (MMCF)**
	B1	360	5	0.59	0.3	0.8	1.2	1,642,128	3,941
	B2	360	30	0.59	0.3	0.8	1.2	9,852,768	23,647
	B3	360	5	0.59	0.3	0.8	1.2	1,642,128	3,941
	B - Total							**13,137,024**	**31,529**
	C1	300	5	0.87	0.3	0.8	1.2	2,016,919	4,841
	C2	300	20	0.87	0.3	0.8	1.2	8,067,675	19,362
	C3	300	20	0.87	0.3	0.8	1.2	8,067,675	19,362
	C - Total							**18,152,269**	**43,565**
	D1	250	20	0.87	0.3	0.8	1.2	6,723,063	16,135
	D2	250	20	0.87	0.3	0.8	1.2	6,723,063	16,135
	D3	250	20	0.87	0.3	0.8	1.2	6,723,063	16,135
	D4	250	20	0.87	0.3	0.8	1.2	6,723,063	16,135
	D - Total							**26,892,251**	**64,541**
	E1	200	25	1.00	0.3	0.8	1.2	7,758,000	18,619
	E2	200	25	1.00	0.3	0.8	1.2	7,758,000	18,619
	E - Total							**15,516,000**	**37,238**
	F1	175	30	1.00	0.3	0.8	1.2	8,145,900	19,550
	F2	175	35	1.00	0.3	0.8	1.2	9,503,550	22,809
	F3	175	30	1.00	0.3	0.8	1.2	8,145,900	19,550
	F4	175	11	1.00	0.3	0.8	1.2	3,095,442	7,429
	F - Total							**28,890,792**	**69,338**
	G1	150	30	0.92	0.3	0.8	1.2	6,389,545	15,335
	G2	150	20	0.92	0.3	0.8	1.2	4,259,696	10,223
	G3	150	30	0.92	0.3	0.8	1.2	6,389,545	15,335
	G4	150	10	0.92	0.3	0.8	1.2	2,129,848	5,112
	G - Total							**19,168,634**	**46,005**
	H1	92	40	0.93	0.3	0.8	1.2	5,283,563	12,681
	H2	92	15	0.93	0.3	0.8	1.2	1,981,336	4,755
	H3	92	15	0.93	0.3	0.8	1.2	1,981,336	4,755
	H4	92	50	0.93	0.3	0.8	1.2	6,604,454	15,851
	H - Total							**15,850,689**	**38,042**
	Total							**137,607,659**	**330,258**
	Grand Total							**236,547,659**	**567,714**

D.

Table 5. Results of core-based permeability from fault block A.

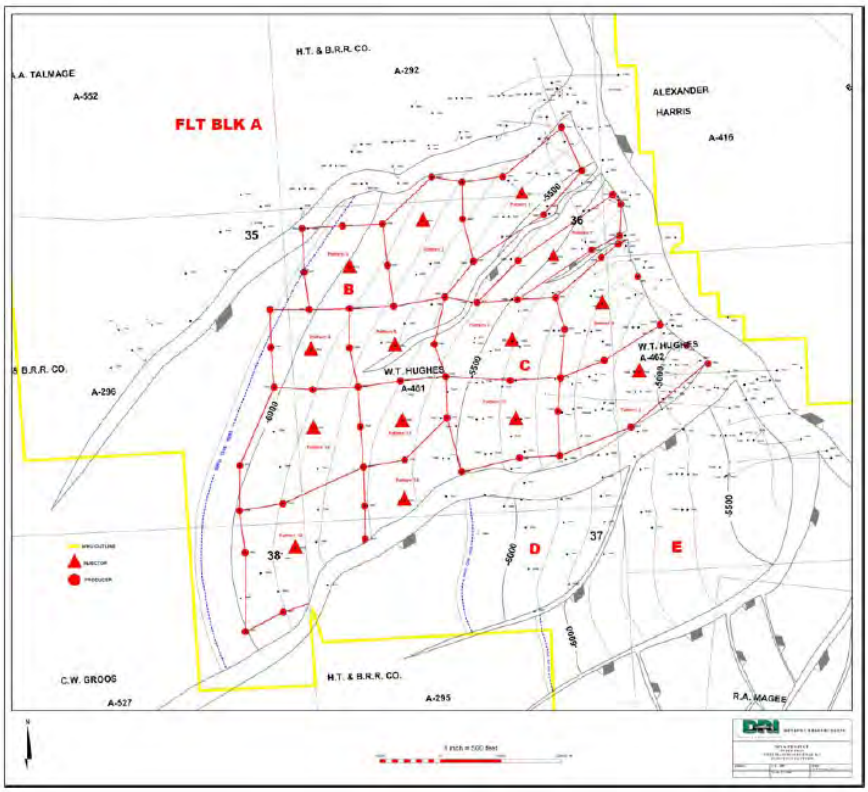
Sand	Horizontal Permeability (md)	Sand	Horizontal Permeability (md)
A1	238	D1	812
A2	199	D2	718
A3	1282	E1	60
A4	950	E2	665
A4-L	1363	F1	1160
A5	1240	F2	272
A6	7	F3	317
B1	513	F4	8
C2	515	G1	162
C3	304	G2	108
		G3	117
		G4	244

In general, the Frio sands of West Hastings Field are typical of most sandstones along the Texas and Louisiana Gulf Coast, where porosities are in the 28-32% range and permeabilities are high, in the 200-2000 md range. With initial oil saturation of approximately 80%, this suggests high storage capacity for the reservoir rock. The West Hastings Frio reservoir is an excellent reservoir for CO_2 EOR recovery as well as CO_2 storage. High primary (water drive) recoveries indicate that the aerial and vertical sweep efficiencies should be excellent.

E. Well distribution

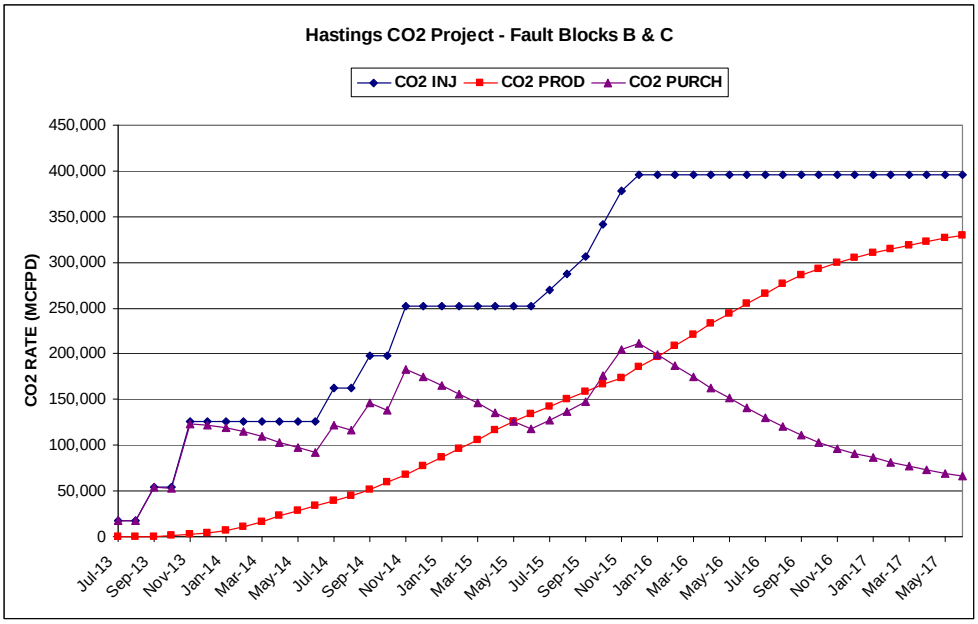
An inventory of the distribution of wells in fault blocks B and C shows 72 active wells, 113 inactive but accessible wells, 9 temporarily abandoned wells, and 110 plugged and abandoned (P&A) wells. Prior to beginning the flood, Denbury will expend significant effort as part of the commercial project (non-federal funds) reviewing well data and remediating wells as required to determine that wells are ready for pressure increase associated with injection. Denbury preliminarily plans to reenter selected wells and develop inverted 9- spot patterns(one injector surrounded by 9 producers). Initial plans are for seven (7) patterns to be developed in 2013 and seven (7) more in 2014. The pattern design selected for fault blocks B and C requires 14 CO_2 injectors and 61 producers, shown in figure 5. Numerous unused wells are therefore available for conversion into monitoring wells, where cost effective. In most cases the placement of cement is not sufficient to provide certainty of zonal isolation for wells to be completed in the AZMI.

Figure 5. Upper Frio patterns in fault blocks B and C.



As part of the field development plan, the monthly CO_2 purchase and recycle volumes were forecasted (Figure 6) using dimensionless curves obtained from an analogous field and verified by commercial modeling work performed for fault block A. If the anthropogenic CO_2 is not ready by July 2013, CO_2 from Denbury's Jackson Dome will be utilized. Peak purchases will be around 200 MMCFPD by November 2015. A total of 145 BCF (or 7.6 million metric tons) will be injected over the 3 year period.

Figure 6. Estimated CO_2 purchase and recycle volumes



IV. Initial risk assessment linked to monitoring plans

Over the past 30 years EOR projects have been conducted in the US with essentially no adverse environmental effects. Injection into known traps with well known reservoir properties greatly reduces uncertainties and resulting risk. Active management of pressure via production and operator oversight to optimize the flood also are large risk-reduction measures. CO_2 injected as part of EOR projects is not released to the atmosphere except in instances of equipment upsets or well upsets. Based on review of the data available at this time, there remain areas of uncertainty. For the purposes of this plan, BEG consider the following possible elements of future MVA expectations that might differ from or exceed the expectations of current Class II and commercial best practices:

(1) Document through characterization the geologic conditions that are expected to retain injected CO_2 for periods long enough to benefit the atmosphere. The standards desired for sequestration are not codified, however, the IPCC target that a well selected site should retain 99% CO_2 in the reservoir over 1000 years meets or exceeds DOE's expectations. The atmospheric benefit is not a requirement of the proposed rules of the Texas Railroad Commission.
(2) Execute a formal assessment of areas of uncertainty through a process such as Risk Assessment. This write up reviews the results of the initial risk assessment.

The research MVA program will focus on areas of uncertainty in retention of fluids in the injection zone. As this oil field has retained oil and gas for geologic time, BEG considers that it documents that the natural seal is adequate to support a significant CO_2 column with migration only at diffusion rates. Risk Assessment and experience indicates that the most probable migration paths are (1) non-sealing well completions because of undetected construction flaws or damage; (2) unexpected vertical migration up the main fault when reservoir pressure exceeds original pressure, and (3) off-structure or out of

compartment migration of CO_2 or brine as a result of elevated pressure into areas not controlled as part of the flood. An MVA program is outlined for each of these risk areas and is linked to a mitigation or management process that will document that the CO_2 injected is permanently stored.

A. Performance of wells

As part of Denbury's commercial operations, prior to the start of the flood, every active, inactive and plugged and abandoned well will have its mechanical status defined prior to the start of the flood. Wells deemed as unable to contain the injected CO_2 in the reservoir will be remediated by Denbury prior to initiating CO_2 injection.

After CO_2 injection starts, both the commercial and research activities defined in the MVA program will be used to monitor the mechanical integrity of each well. The commercial activities of the MVA program include monitoring the surface pressures of injectors and producers frequently, as well as, each inactive well. Wells that have significant changes in surface pressures, will have bottom-hole pressure surveys taken. If the pressure data suggests that a well may have a mechanical integrity problem, a profile survey will be run in the well. A tracer survey and temperature log will be run in an injector. A temperature log, spinner survey and capacitance log will be run in a producer. These surveys will be run in each active well every 6 months regardless of the pressure data to confirm that there is no migration of CO_2 from the reservoir via the wellbore. Surveys will be run in the inactive wells less often. However, as mentioned above, surface pressures will be monitored frequently in these wells.

Injection and production rates will also be monitored as part of commercial activities. Daily rates will be measured for each injector and test rates will be taken for each producer at least once a month. A significant change in rates may indicate a wellbore integrity issue. Logs, as defined above, will be run in a potential problem well. If a problem is identified, then the well will be remediated.

Each pattern will also have IWR's (injection to withdrawal ratios on a reservoir barrel basis) calculated monthly to help define a problem well which requires remediation. The targeted IWR for every pattern is a 1:1 ratio. If a pattern has had such a ratio of several months and the ratio suddenly changes to 2:1 or 3:1 for example, then one of the wells in the pattern has a mechanical integrity issue. The problem well will be identified using the commercial activities described above and remediated.

The task for the research program is to independently test the performance of wells to determine if the commercial approaches are adequate for purposes of storage. The research plan includes surveillance of all wells via monitoring for changes in pressure or chemistry in the above zone monitoring interval (AZMI), monitoring for changes in underground sources of drinking water (USDW – defined as above 1650' per the Texas Railroad Commission in the West Hastings Field), and monitoring for changes in soil gas above plugged and abandoned (P&A) wells.

B. Performance of faults

Faults can serve either as conduits that focus and enhance flow or as barriers that limit flow. The major fault at West Hasting clearly falls into the later category, as large volumes of buoyant fluids (oil) have been trapped against it. This is a typical response in large throw faults of the Gulf Coast, in which ductile shale is smeared along the fault zone, providing a seal. Faults with smaller throw, such as parts of the cross-faults, may not completely seal.

Understanding and predicting the behavior of preexisting faults in settings being considered for large scale CO_2 storage is critical for operational success. Undesired migration of CO_2 away from the intended interval may be facilitated by permeable faults (if present). Accurate determination of fault behavior typically involves a graphical (i.e. Mohr circle) or analytical approach, both of which are faster than complex numerical (finite-difference) models, but both retain some level of simplification. However, these more simplified approaches are considered adequate for understanding the level of risk that a large injection project has with regard to fault reactivation and increased hydraulic conductivity. It has been demonstrated that fracture sets in granitic formations show preferential fluid flow for the fracture orientations that are near the critical stress in the given stress field. The critical stress is achieved for a feature with a known orientation when the shear stresses resolved on that surface exceed the stresses normal to (perpendicular to) that surface. An increase in fluid pore pressure (as with CO_2 injection) can lead to reduced normal stresses and an increased likelihood for achieving critical stress conditions.

In order to adequately determine the risk of fault criticality, the magnitude and orientation of the fault within the ambient principal stress field must be known. BEG will endeavor to constrain these conditions for the field of interest during the design phase. However, the anticipated elevation of pressure (400 psi) for West Hastings field is not considered high enough to bring even a favorably oriented fault structure into criticality. Thus, the research MVA program will focus on monitoring of the fault to determine if any flow can be identified along the fault using existing well penetrations. Localized temperature and or pressure perturbations in the vicinity of the fault may be indicative of preferential fluid migration within the fault zone. The simulation of the effects of transmissive faults will need to be undertaken in order to evaluate the conditions that may lead to unintended migration.

We place emphasis on “proving the container” prior to injection to anthropogenic CO_2. Because a field slated for EOR has undergone a variety of previous and preparatory activities, a number of opportunities are presented to demonstrate that storage of CO_2-A will be permanent prior to the start of injection. Although the program will run only over the 2 years of demonstration funded by the project, it is our goal to increase confidence that the injected CO_2 will be permanently stored (1000 year time frame). This is another advantage to proving the container, in that not only the area right around the injection wells will be assessed, but also the ultimate updip trap.

Non sealing well completions

Wells that penetrate the seal are potential weak points, especially during injection. Wells that perform adequately during extraction, when they are pressure sinks, can become upwardly transmissive during injection when pressure is increased. Wells that are open can be inspected via a logging program, however wells that have been plugged and abandoned (P&A) are prohibitively expensive to reenter to inspect. The research MVA program will extend the commercial well integrity program, and test its effectiveness.

Activities that have been included in the MVA plan:

(1) Additional logging program (e.g. temperature, tracers, high end wireline tools)
(2) Above zone-pressure monitoring – ambient and introduced fluids
(3) Near-surface soil gas and groundwater monitoring.

In West Hastings, water disposal into parts of the Miocene prior to CO_2 injection has elevated pressure and perturbed geochemistry. In addition, prior to CO_2 injection, water injection may be done in the Frio. If data are collected with care, water flood can serve as a pre- CO_2 injection proof of containment. In the short term, this elevated pressure is a barrier to upward flow. It will be interesting to assess how long this pressure barrier will be sustained with respect to long term storage goals.

Methods for assessing well integrity planned are:

1) Thermal anomalies though casing (hot fluids expelled from depth, or cold areas in shallow zones where CO_2 flashes to gas), noise anomalies though casing
2) Pressure and geochemical anomalies that require perforations
3) Augmented soil gas/aquifer surveillance methods (methane, CO_2, noble gases/isotopes, tracers)

Up fault migration

In a productive reservoir, faults are adequate seals with respect to the 1000 year retention standard, as accumulation even at slow rates greatly exceeds any migration. Uncertainly is produced however by injection at pressures above initial pressure. Three methods of documenting storage adequacy with respect to faults are (1) calculated, (2) measured via microseismic, (3) measured via up-fault fluid migration.

Calculated fault opening stress is based on fault geometries and considers ambient stress plus induced stress. Initial calculation shows that injection pressure planned lies well below critical pressure on the fault. However, uncertainties remain because of assumptions about the strength of the fault materials. Direct measurements are therefore desirable to document that the characterization assumptions are correct. In brittle rocks, the stress distribution along a fault may be measured by collection of microseismic data, from well bore or in some cases surface installations. However, Frio rocks are weak, and we expect that might be able to open without seismicity. We propose to directly measure indicators of fluid migration. These measurements are mostly well based, because of sensitivity and availability of idle wells, and include thermal changes, pressure changes, and fluid composition changes including tracers. The later two methods require wells be perforated and completed across a fault zone.

Out of pattern migration

In EOR, pressure gradients from injectors to producers generally control most of the flow. Production history, starting with monthly injection/withdrawal ratios (IWR) is a relatively simple method of confirming the correctness of this assumption. For the research program, BEG will collect monitoring data to determine if CO_2 migrates outside the pattern to confirm the relevance of this simple method. A combination of geophysics (VSP array and gravity) will be used to map the location of the plume edge. This technique will be further validated for this site by preparing injectors ahead of schedule, and using them early in the flood as monitoring points. After assumption are validated, these wells will be used for injection into additional patterns.

V. Monitoring activities

Denbury will conduct current commercial practices and provide nonproprietary results to the research MVA project at no cost to the project. The results of commercial practices provide the standard for the research MVA program. Denbury will provide documentation of the commercial activities described in the Scope of Work throughout the two year MVA monitoring period.

Denbury's typical EOR operation takes 100% of the produced well stream back to the recycle facility where the oil, water and gas are separated and measured. The produced volumes are allocated to each producer based on a monthly test. A sufficient number of test sites are constructed throughout each field to test each producer at least once a month. CO_2 injection is measured by meters located at each injector.

Tubing and casing pressures are measured continuously on the production and injection wells using radio transmitters that communicate back to the SCADA system. The daily CO_2 injection volumes to each injector is also measured using this system, along with wellhead and upstream pressures to the choke. The wellhead and downstream pressures to the choke will also be measured on the producing wells, thus allowing for continuous monitoring of well performance. If downstream pressure builds to high levels, relief valves will be activated to allow for bleed off of line pressure.

Tracer surveys and/or temperature logs will be run be run periodically in injectors to determine where the CO_2 is being injected. Temperature logs, spinner surveys and capacitance logs will be run in producers periodically to define from which zone(s) the production is originating from. This data will be used to update the model during the two year research monitoring period. Profile surveys in the injectors and producers are expected to be conducted a minimum of twice per year. If injection and production rates do not change significantly, it can be assumed that the profiles are not changing and the frequency of these surveys can be reduced.

Once reservoir pressure has been raised to the desired operating pressure, injection and production will be balanced so that an injection to voidage ratio of approximately 1:1 is maintained. As described in the "Performance of wells" section above, these calculations will be performed on a monthly basis to show whether the pattern is over or

under injecting. Remedial operations such as acidizing, re-perforating and/or other repairs will be performed on wells, if required, to maintain balanced patterns.

Research based monitoring augments the commercial monitoring through an interlocked system of collection of characterization data, modeling and risk assessment. As data is obtained, revisions will be made to our monitoring techniques and reservoir model. By the end of the two year research MVA program, the performance of the container is expected to be proven, greatly increasing confidence in storage permanence.

Scope of Work

Phase 2A, Task 1- Administrative task and subcontracting
Prior to initiation of Phase 2 activities, a number of subtasks will be completed. These are not assigned costs but past experience suggests that they may consume time.

Phase 2A, Task 2- Reservoir Modeling-Initial characterization and modeling
Denbury will provide data (as in-kind cost share) refined for input into the reservoir model to be constructed by BEG. This data will be input into task 2 reservoir modeling and used to document that the flood conforms to expected plume area and pressure elevation. Letter report will include data files as improved characterization data are collected. BEG will undertake reservoir modeling using the initial available data to predict range of plume sizes and the magnitude and distribution of pressure elevation. Table 6 shows the data that will be sought and the source. Reservoir modeling for research MVA differs from commercial monitoring done by Denbury as it (1) approaches from a migration of risk perspective, to identify uncertainties in the characterization that might lead to risk of CO_2 migrating from the intended injection area, such as unmapped heterogeneities in the reservoir, and (2) although oil is represented in the model as an important part of the system, predicted oil production will not be reported as such results are outside the scope of the study.

Table 6. Data for modeling and likely data source

Data	Source
Field history including historical production drive mechanism, water flood, historical pressures, etc	Denbury and literature search
Reservoir geometry / static model	BEG from task 1
Initial conditions (pressures, saturations, o/w contact…)	Denbury
Boundary conditions	BEG from task 1
Production tests / field tests results	Denbury
Permeability / porosity measurements	Denbury*
Relative permeability end points	Denbury*

Relative permeability and capillary pressure curves	Denbury* and literature
Oil and gas composition	Denbury*
PVT (viscosity, density) data for oil	Denbury*
Brine composition or at least TDS	Denbury, sampling program
Well locations	Denbury
Perforated intervals for injection and production wells	Denbury
Current injection and production schedule and rates	Denbury
Historical production/injection rates if available	Files, to be allocated
Temperature data	Denbury
Proximity of other oil/gas fields	Denbury + literature search

**Commercial proprietary non-funded data utilized to refine fluid flow and pressure modeling may be withheld from public information.*

. BEG, in consultation with Denbury, will prepare a formal report describing model assumptions and outputs, as well as uncertainties that should be considered in a monitoring program. Commercial proprietary data used for input in the model may be withheld by Denbury from the report.

Phase 2A, Task 3- Characterization and geomechanical description of fault(s)
BEG will undertake compilation of additional characterization data and further model the effect of a range of possible stress changes on faults, with focus on the main sealing fault at the east edge of the field. To the extent legally available, Denbury will provide the data and review the results as in-kind cost share. BEG will prepare a letter report, which will predict conditions at which critical stress on fault will occur and recommend improvements to the fault monitoring plan.

Phase 2A, Task 4- Soil Gas-Feasibility test of surveillance of P&A wells
BEG will undertake an initial assessment of soil gas conditions near representative P&A wells, in consultation with Denbury, to consider complexities that should be considered for soil gas assessment to reduce uncertainties about well integrity in P&A wells. BEG will also include learning from other soil gas tests now underway, for example work at Cranfield, by Denbury at Oyster Bayou, and international projects. This activity will occur after this part of the project has received a CX or under a NEPA waiver. BEG will prepare a letter report recommending future monitoring strategies.

Phase 2A, Task 5- Groundwater monitoring-Feasibility test of surveillance of P&A wells
BEG will sample available wells and review Texas Water Development Board historic records to obtain information about the range of water chemistries and how to best test for rock-CO_2-water interaction in the aquifer should unintended CO_2 migration occur. It will also include learning from other projects underway at BEG and elsewhere to identify criteria that may signal migration. Denbury will review with regard to placement of

monitoring wells for next stage of study. Field work will occur after CX or NEPA waiver is obtained. BEG will prepare a letter report recommending future monitoring strategies.

Phase 2A, Task 6-AZMI-Establish current pressure profile via Repeat Formation Test (RFT) on new drill wells

The pressure environment at West Hastings has been highly perturbed by salt water disposal, oil and brine production, and fresh water production. This test plan will be used to characterize the pressure field and select above zone monitoring interval (AZMI). Denbury will design the drilling program to collect good quality pressure data and will discuss the plan and results with BEG. Wells will then be completed by Denbury as AZMI wells in task 16. BEG expects the target for completion is the Miocene, provided that pressure is stable. The Miocene is currently significantly above original reservoir pressure since it has been used for the disposal of the water produced from the Frio reservoirs. Workovers were costed out, because remediating the lack of cement behind casing was more expensive than new drills. This activity will occur after CX or NEPA waiver is received. Denbury will prepare a report with as-build construction and RFT results.

Phase 2A, Task 7- Logging-Feasibility test of surveillance of idle wells and fault

Sandia will subcontract and guide development of a new tool for active temperature stimulation of the reservoir to identify fluid changes and fluid flow. Zones with permeability recover faster from a thermal pulse, and it is hoped that this tool will provide permeability information relevant to migration on faults and fluid changes in AZMI though casing. Denbury will provide initial assess points for testing this tool in up to three wells that are in operation prior to the B and C flood. Novel tool development is seen as an important part of this project. Sandia will prepare a letter report with as-built tool design and operation, test results and recommendation for further use.

Phase 2A, Task 8- Decision Point, Risk Assessment & Updated MVA plan and cost distribution

BEG, in consultation with Denbury, will update the risk assessment and research MVA plan and cost distribution based on the results of previous data collection efforts, and will make adjustments to the research MVA program to supplement commercial operations. BEG will prepare a formal report containing phase 2B recommendations.

Phase 2B, Task 9- Commercial Flood Monitoring - Well Review and Remediation

Denbury will define the mechanical status of every wellbore within the possible plume area of the injected CO_2. Wells with mechanical problems, that won't allow isolation of the CO_2 within the targeted reservoir being flooded, will be re-plugged or remediated prior to the start of injection. This work will be done as part of the commercial field development project, at no cost to the research MVA project. Denbury will prepare a letter report of well status showing compliance with RRC regulations.

Phase 2B, Task 10- Logging-Baseline Surveillance of idle wells and fault

Sandia will conduct a survey beyond that conducted by Denbury in task 9 using an array of tools to critically evaluate condition of wells, especially with regard to potential

for natural or anthropogenic fluid migration behind casing. This data will provide a baseline to show any changes that occur as the field is flooded. Sandia, in conjunction with Denbury will select, a sample of 20 representative wells that can be accessed. Many wells penetrate the major fault and can be used to assess if any change in fluids or fluid movement from injection is occurring in this zone. Sandia will prepare a letter report with methods and results.

Phase 2B, Task 11- Soil Gas-Site & Borehole preparation for surveillance of P&A wells

BEG, in consultation with Denbury, will select 20 P&A wells to assess using the methods recommended in Phase 2A, Task 4 and develop characterization data such as samples and access tubes, shallow wells or other infrastructure needed. BEG will prepare a letter report with as built construction and field notes.

Phase 2B, Task 12- Soil Gas-Baseline surveillance of P&A wells

BEG will conduct, in consultation with Denbury, data collection on soil gas sites that were developed in Task 11. Results will be critically assessed to provide information on the value of this approach to documenting well integrity. BEG will prepare a letter report of methods and data table.

Phase 2B, Task 13- Ground Water Monitoring -Well preparation

Denbury and BEG will select four wells that will be completed in the USDW interval and monitored for CO_2 migration following the methods developed in Phase 2A, Task 5. Denbury plans to recomplete existing wells. Thirteen wells with suitable cemented-in surface casing below 1650 ft have been identified by the Denbury Field team. BEG will prepare a letter report showing as-built construction and field notes

Phase 2B, Task 14- Ground Water Monitoring -Baseline surveillance

BEG will purchase a pump, sample and than analyze the groundwater wells installed in Task 13. Four sets of samples will be collected to establish a baseline before CO_2 injection starts. BEG will prepare a letter report including methods, field notes and data table.

Phase 2B, Task 15- Reservoir Modeling-Upgraded

BEG will incorporate data from Tasks 2A to predict range of plume sizes and magnitude and areas of pressure elevation and provide to Denbury for review. This result will be used to modify and adjust the risk assessment and monitoring strategy as needed. BEG will prepare a letter report showing changes in model parameters, revised predictions on area of CO_2 plume and distribution and magnitude of pressure change

Phase 2B, Task 16- AZMI-Well Completions

Denbury will complete the AZMI wells from Phase 2A, Task 6 in the above zone with screens that will protect the poorly consolidated Miocene from sanding over the perforations, and install any constructed-in temperature monitoring equipment. Denbury will prepare a letter report containing field notes and as-built construction

Phase 2B, Task 17- AZMI-Instrument Monitoring Wells
Sandia will install and maintain pressure gauges on monitoring wells completed in Task 16 in AZMI and fault zones. Completions are designed to be simple, without tubing and packer, and pressure gage hung in the water column. Pressure data will be available via cell phone or data logger. Sandia will prepare a letter report containing field notes.

Phase 2B, Task 18- AZMI- Hydrologic testing and Baseline geochemical sampling
Sandia, in consultation with Denbury, will conduct pressure interference test to show hydrologic communication and the area over which the AZMI provides evidence of containment. BEG will collect and analyze pre injection fluids and gases for geochemical samples. Sandia and BEG will prepare a letter report providing methods and field notes.

Phase 2B, Task 19- VSP-Baseline
Denbury, in coordination BEG, will plan and conduct a baseline VSP survey as an augmented measure of flood conformance. Each proposed 4D-VSP will illuminate an area approximately 1 sqmi. We should plan for 5 3DVSP's in fault block B/C to image CO_2 fillup through the reservoir and above/below the reservoir and along faults. With high resolution 3D-VSP seismic data we hope to resolve sand units as thin as 10ft. When these 3D-VSP's are repeated we will map where the reservoir changes based on density and pressure changes in the seismic response. Costs for surveys include the surveys, well operations, permitting for seismic sourcing on the surface, and processing. The seismic will require a baseline plus 4 repeats in Phase 2C and done in coordination with the gravity logging. Denbury will prepare a letter report providing the details of the field deployment.

Phase 2B, Task 20- Gravity-Baseline
Denbury may conduct gravity survey as an augmented measure of conformance. John Ferguson at UT Dallas was successful in monitoring water migration during the Delhi Field water flood and is studying a model for Hastings. The density variance between CO_2 and reservoir fluids in Hastings should be more significant than the density variance of the injected water and oil in the reservoir during the Delhi water flood, so gravity monitoring of the Hastings CO_2 flood is expected to be successful in defining the location of the CO_2 plume. Gravity logging will quantify CO_2 saturations in the boreholes where porosity is well constrained. Denbury may monitor above/below the reservoir and through the reservoir. The baseline is planned to be followed by 4 repeats in Phase 2C. Denbury will prepare a letter report documenting field notes and data tables.

Phase 2B, Task 21- Measure Out-Of-Pattern Migration (Completion of downdip wells)
As the first year of the flood is being developed, two wells outside that phase will be completed by Denbury and used to monitor the possible migration of the CO_2 and elevation of pressure outside the completed patterns. In the case of Hastings blocks B&C, the phases of development will be from the top of structure downdip. These wells will become active wells in future phases of development. Denbury will prepare a letter report including well completion diagrams and daily records of well-head pressure.

Phase 2B, Task 22- Decision Point, Risk Assessment & Updated MVA plan and cost distribution

BEG, in consultation with Denbury, will update the risk assessment and MVA plan and cost distribution in consideration of the results of previous data collection efforts, and will make adjustments to the research MVA program to supplement Denbury's commercial operations. BEG will prepare a formal report containing Phase 2C recommendations.

Phase 2C, Task 23- Commercial Flood Monitoring-Injection and Production Volumes

Denbury will report to the research MVA project the results of commercial flood monitoring quantifying all injected and produced fluids (including recycle),wellhead pressure, and intermittent injection profiles. This commercial monitoring program will account for purchase and recycle volumes giving the volume of CO_2 in the reservoir and the amount methane produced and recycled with the CO_2.

This work will be done as part of the commercial project but is the most essential monitoring data. BEG will prepare a monthly report providing details on the distribution of the stored CO_2.

Phase 2C, Task 24- Commercial Flood Monitoring-Best Practice Mitigation

Denbury will provide to the research MVA project information about mitigation for poor well performance to document how conformance is attained commercially. For example if a well will not accept the planned injection rate at field pressure, Denbury may acidize, reperforate, or inject at a higher rate in other parts of pattern. This work will be done as part of the commercial field development project.

Phase 2C, Task 25- Commercial Flood Monitoring-Pressure Maintenance

Denbury will perform normal well surveillance including monitoring casing pressures in both producers and injectors. Denbury will use remediation procedures to repair wells with compromised integrity. Denbury will provide the results of this work done as part of the commercial project.

Phase 2C, Task, 26- Commercial Flood Monitoring-IWR Calculation

Denbury will calculate material balance from data in Task 23 for each pattern on a monthly basis to define changes in reservoir performance. Significant changes in IWR identify potential problem wells within the pattern (i.e. mechanical problems with injectors or inactive wells that are causing the loss of CO_2 out of the pattern, or a mechanical problem with the producer(s) within that pattern). The problem wells will be identified and repaired (re-plugged or remediated). This work will be done as part of the commercial field development project.

Phase 2C, Task 27- Logging-Time lapse surveillance of idle wells and fault

Sandia will conduct a logging and surveillance program on 20 idle wells for which baseline data was collected in Phase 2B, Task 10. This data will be compared to the

baseline to show any changes that occur as the field is flooded. Sandia will prepare a letter report with methods and results.

Phase 2C, Task 28- Soil Gas Time lapse surveillance of P&A wells
BEG will collect time lapse data over two years for soil gas sites in which baseline data was collected in Phase 2B, Task 12. Results will be critically assessed to provide information on the value of this approach to documenting well integrity. BEG will prepae a letter report containing data tables and field notes.

Phase 2C, Task 29- Groundwater Monitoring-Time lapse surveillance
BEG will sample and then analyze the groundwater wells for which baseline was collected in Phase 2B, Task 14. Samples will be collected to look for changes as CO_2 injection starts. BEG will prepare a letter report containing data tables and field notes.

Phase 2C, Task 30- VSP-Time lapse surveys
Denbury will conduct 4 repeat VSP surveys over the two-year period following the baseline run in Phase 2B Task 19. This data will be used to show that the flood is conforming to the expected patterns, including providing data about out-of zone migration. Denbury will prepare a formal report including methods and results of surveys on annual basis

Phase 2C, Task 31- Gravity Time lapse surveys
Denbury will conduct 4 repeat gravity surveys over the two-year period following the baseline run in Phase 2B Task 20. This data will be used to show that the flood is conforming to the expected patterns and to quantify the volume distribution. Denbury will prepare a formal report including methods and results of surveys on annual basis.

Phase 2C, Task 32- Real Time BHP-Well Preparation
Sandia will deploy bottom hole pressure gage(s) on a real time read out in one well in the injection interval(s). This type of data has proven valuable at Cranfield to assess the nature of the flood, and given the complexity at West Hastings is expected to be even more valuable. The detailed plan for the well will be designed in 23. Letter report will show as-built well schematics.

Phase 2C, Task 33- Real Time BHP-Sandia
Sandia will maintain and back up data collected in the deployment described in Phase 2C Task 35. Sandia will prepare a letter report containing a data tables and field notes.

Phase 2C, Task 34- Logging-Time lapse Surveillance
Denbury will augment measures of conformance to provide data for match to the model by logging about half the injectors and producers in the fault block B and C patterns every half year after the flood starts. Combination temperature and tracer surveys will be run on injection wells twice per year per well. Producers will have spinner, temperature, and capacitance tools run twice a year per well, assuming a 6 month delay in start up in producing the wells, while each of the injectors would have a series of four

logs run. This program will run on about 1/2 wells and testing of additional log types is possible. Denbury will prepare a letter report containing a data tables and field notes.

Phase 2C, Task 35- Natural geochemical tracers-Collected at wellhead
BEG will, with the assistance of Denbury, collect at wellhead fluid samples from producers that serve as augmented measures of conformance, for example evidence of dissolution and rock-water interaction. BEG will prepare a letter report containing data tables and field notes.

Phase 2C, Task 36- AZMI-Time lapse geochemical sampling & hydrologic testing
Sandia will conduct time-lapse hydrologic sampling of AZMI wells via pumping for BEG to sample to look for any geochemical evidence of out of zone migration of CO_2 as part of the above -zone and fault monitoring program. BEG will conduct analysis of samples and prepare a letter report containing data table and field notes.

Phase 2C, Task 37- Measure Out-Of-Pattern Migration
In this task Denbury will report observation of the wells prepared in Task 21, including first year of fault block B and C flood pressure change at well heads. This should provide one year of data before beginning of flood near these wells. Denbury will prepare a letter report of pressure data and provide it to BEG for including Phase 2C Task 38 history match of well head pressure.

Phase 2C, Task 38- Reservoir Modeling-Updated
BEG will aggregate data from Phase 2C activities to history match plume size and pressure elevation and test if flood conformance to model expectation was achieved. This will focus on CO_2 and pressure quantification, not oil production. Denbury will review the formal report prepared.

Phase 2C, Task 39- Overview and Evaluation report
BEG will prepare and Denbury will review a report of the results of this study. BEG and Denbury will determine what, if any, added value the research program added to the commercial program in terms of confidence in the long-term permanence of storage. BEG will recommend any actions that may be informative to future regulations or policies related to storage monitoring at EOR sites. This will be a formal report.

THE LAKE CHARLES CCS PROJECT
PHASE 1 TOPICAL REPORT

APPENDIX 9

Project Management Plan

PROJECT MANAGEMENT PLAN
AND STATEMENT OF PROJECT OBJECTIVES

The Lake Charles CCS Project

1. Executive Summary

This Project Management Plan provides Leucadia's organizational and management capabilities. It also establishes the baseline for scope, schedule, and budget for the Lake Charles CCS Project and describes the change control process.

Objectives

The overall objective of this large-scale industrial carbon capture and sequestration (CCS) project is to demonstrate advanced technologies that capture and sequester carbon dioxide (CO_2) emissions from industrial sources into underground formations. Specifically the Lake Charles CCS Project will accelerate commercialization of large-scale CO_2 storage from industrial sources by leveraging synergy between a proposed petcoke to methanol plant (the LCC Gasification Project) and the largest integrated anthropogenic CO_2 capture, transport, and monitored sequestration program in the U.S. Gulf Coast Region. The Lake Charles CCS Project will promote the expansion of EOR in the Gulf region and supply greater energy security by expanding domestic energy supplies. The compression, pipeline, injection, and monitoring infrastructure will continue to sequester CO_2 for many years after the completion of the term of the DOE agreement.

The objectives of this project are expected to be fulfilled by working through two distinct phases. The overall objective of Phase 1 was to develop a fully definitive project basis for a competitive Renewal Application process to proceed into *Phase 2 - Design, Construction and Operations*. Phase 1 included several studies that established:

1) The engineering design basis for the capture, compression and transportation of CO_2 from the LCC Gasification Project; and
2) The criteria and specifications for a monitoring, verification and accounting (MVA) plan at the West Hastings oil field.

The overall objective of Phase 2 is to take the results of the above mentioned studies and execute design, construction and operations of three capital projects:

1) The CO_2 capture and compression equipment;
2) The Lateral from the LCC Gasification Project to Denbury's Green Pipeline; and
3) A comprehensive MVA system at the West Hasting oil field.

Scope of the Project

The overall project includes integration of CO_2 capture, transportation/delivery and sequestration with comprehensive monitoring, verification and accounting (MVA). The several CO_2 streams at 23, 40, and 60 psia from the Rectisol® units will be compressed

into a combined stream to 2,165 psia for injection into the proposed Lateral. The Lateral will transport the CO_2 to the Green Pipeline and then on to the oil fields in Texas and Louisiana on the Gulf Coast where it will be used for enhanced oil recovery (EOR). The West Hestings CO_2 injection site will utilize the required equipment to demonstrate the safe and effective storage of CO_2 in the oil bearing geological formations with the additional benefit of enhancing oil recovery in existing oil fields.

Phase 1 of the project included preliminary engineering studies to optimize the combined cost and energy consumption for Rectisol® and CO_2 compression. It also included a preliminary engineering investigation into the MVA specifications for two oil fields.

Phase 2 of this project includes program and project management, detailed engineering, procurement, construction, and operation of the Rectisol® unit and CO_2 compression equipment, the Lateral, and the MVA facilities.

2. Risk Management

The purpose of the Risk Management Plan is to describe the methodology for identifying, tracking, mitigating, and ultimately retiring items we believe are potentially significant risks associated with the Lake Charles CCS Project. This plan will be maintained during the entire life of this project. The plan will be reviewed monthly and updated as needed. Whenever changes occur, the document's revision history log will be updated to reflect the date, the person updating, and information about the change.

The Senior Project Manager is responsible for monthly review of the Risk Plan. This will be done as part of the monthly project progress reporting to the Executive Committee. Any risks already identified will be reviewed and assessed. If any new risks are identified as significant to the project, the Senior Project Manager will take the lead to identify and recommend to the Executive Committee a course of action. The project team member most knowledgeable in the subject area will be designated as the lead analyst in quantifying the risk and determining potential mitigation strategies. The analyst will provide the team with an assessment of the risk severity and probability of occurring. As the analysis process proceeds, the team will gain valuable insight into how the identified risk may impact project costs, schedules, scope, or quality. The Senior Project Manager, analyst, and key stakeholders will meet to plan, document, and implement the best mitigation strategy.

The diagram below (figure 1) summarizes this Risk Management Process:

- Step 1 – Identify
- Step 2 – Analyze
- Step 3 – Plan
- Step 4 – Implement
- Step 5 – Track and Control
- Step 1 through 5 – Communicate

That is, the cost of responding to unanticipated problems is always much larger than the cost of risk responses planned well in advance.

The Risk Management program for this project will include the following documented risks, accountabilities, and training for appropriate team members (Table 1). The responsible Team Member has been identified for each risk by functional title in the Risk Matrix as the Accountable Person (AP). They will be responsible for monitoring activities related to this risk and ensuring the team is immediately alerted, should that be necessary. Per DOE Phase-2 guidance, we have focused on risks the project team believes pose "significant technical, resource, or management risks that have the potential to impede project progress":

Risk Description	***Potential Impact***	***Probability / Severity***	***Time-Frame***	***Mitigation Strategy And The Accountable Person (AP)***
Changing Regulatory Conditions: Current policy shifts at the federal level, relative to energy efficiencies related to construction and EPA environmental regulation.	Cost, Schedule	Medium/ Medium	Design and Construction Period and Long Term	Negotiate with regulatory agencies to apply current regulations for the entire life of the implementation of the project. AP = Bus Dev & Gov Affairs
Procurement Risk: Inability to obtain key components in a timely manner could delay the project.	Cost, Schedule	Low / Medium	Throughout all phases	Monitor supplier and industry lead times on critical components to ensure they are ordered and received in a timely manner. Project team will maintain a file of vendor bids and alternate suppliers in the event the Leucadia supplier's lead time becomes unacceptable. AP = Engineering & Construction companies
Quality of Construction Issues: Failure to properly execute the work.	Schedule, Cost	Low/ Medium	Construction Period	Mandate quality assurance and control programs for all Leucadia vendors. Implement robust inspection and quality program oversight. AP = Site Project Manager + Project Analyst
Insufficient Construction Production: Failure to plan or recognize risk of timely completion due to lack of sufficient production of work activities.	Schedule	Design and Construction Period	Design and Construction Period	Implement production charting and reporting system that recognize all potential impacts and include pre-established mitigation strategies. Include time contingencies for design issues and potential regulatory delays. AP = Site Project Manager + LEC
Worker Safety Issues Related to Pressurized CO_2: Workforce may not be fully trained for risk and conditions relative to working with pressurized CO2 systems and facilities.	Safety, Schedule	Medium/ High	Design and Construction Period and Long Term	Implement comprehensive CO2 training program and mandate participation by individuals associated with this area of the project.

				AP = Site Project Mgr
Adverse Publicity Risk: The project may receive adverse publicity due to a safety or environmental accident or a vendor / personnel issue.	Cost, Schedule	Low / Low	Design and Construction periods	Field supervisors will be instructed to report any safety or environmental accident or vendor / personnel issue to the LC Site Project Manager. The LC Site Project Manager will assess the situation and immediately report it to the Program Manager and Senior Project manager who will inform the Executive Committee. Any serious incidents will be immediately reported to NETL. AP = Site Project Mgr + Bus Dev & Public Relations
Delays may cause could result in insufficient time for MVA. : Like any large complex project, the potential exists for slippages that could impact the ability to conduct MVA activities. .	Schedule	Low Medium	MVA	Early identification of scheduling challenges and mitigation measures. If, however, delays arise, the project can use existing Denbury capabilities to validate transmission, injection, and MVA AP = Executive Committee
Pipeline ROW delays:	Schedule	Medium Low	Transportation	Denbury has rights of eminent domain which can be exercised in necessary
Failure in the reservoir seal or in PA wells: The integrity of the designated injection zone may prove insufficient to maintain the CO_2 due to either not detected construction flaws/damage or elevated pressures resulting in migration to areas not controlled by the flood	Cost Schedule and Scope	Low Medium	MVA	Review of wells prior to flood coupled with regular and frequent evaluations of the amount of CO_2 being injected versus production would identify any such issues early and allow for appropriate corrective actions. AP =Site Program Manager

Table 1

The Accountable Person designated in the Risk Management Plan will provide an update on his assigned risks each month unless the risk is to a level that requires immediate action. This written update will be provided to the Senior Project Manager for inclusion in the Monthly Status Report to the Executive Committee.

This Risk Management Plan is a living document. Additional risks may be added and currently identified risks may be closed-out as the project progresses.

3. Project Milestones

Tasks To Be Performed and Associated Deliverables

The expected time line for the Lake Charles CCS Project is illustrated below (Figure 2). In addition, we have developed a detailed Microsoft Project Schedule at the work breakdown structure (WBS) level 6. The timeline shows that pipeline route selection and obtaining the Rectisol technology license occurred in 2009. The MVA plan is laid out in early 2010 as is the optimization of the capture and CO_2 compressor. Later in that year, permitting and surveying for the pipeline is initiated, as are pipeline right-of-way, and pipeline design and engineering. Design and engineering for the capture and compressor is initiated at the beginning of 2011. Pipe purchase is performed in 2012 with pipeline construction initiated later that year. The beginning of 2013 the Rectisol installation is initiated, with initial installation of the compressors following later that year. The CCS project becomes operational early in 2014.

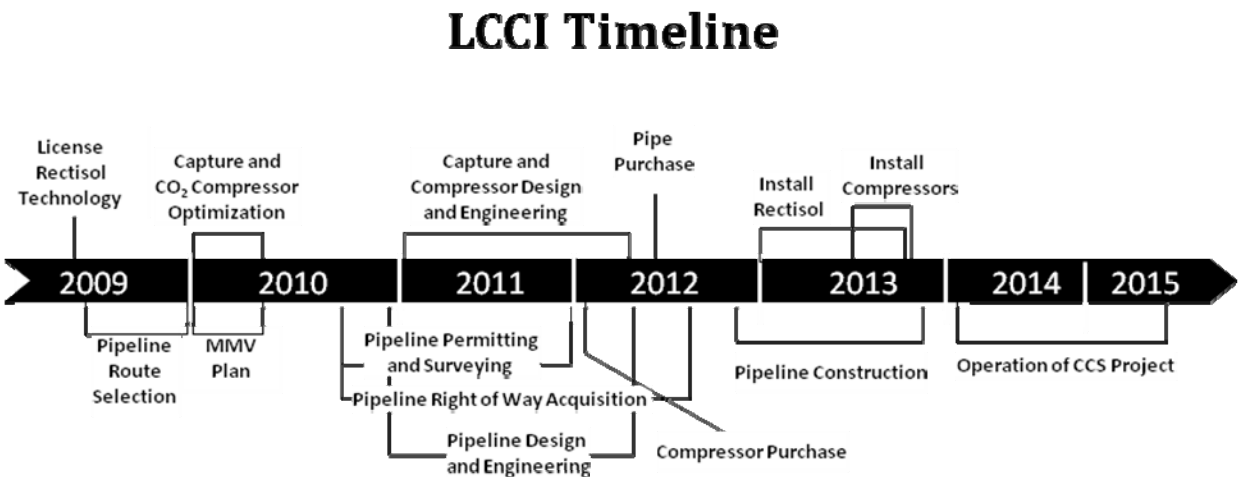


Figure 2

Significant Phase 2 Milestones:

The following figure provides a level 4 schedule.

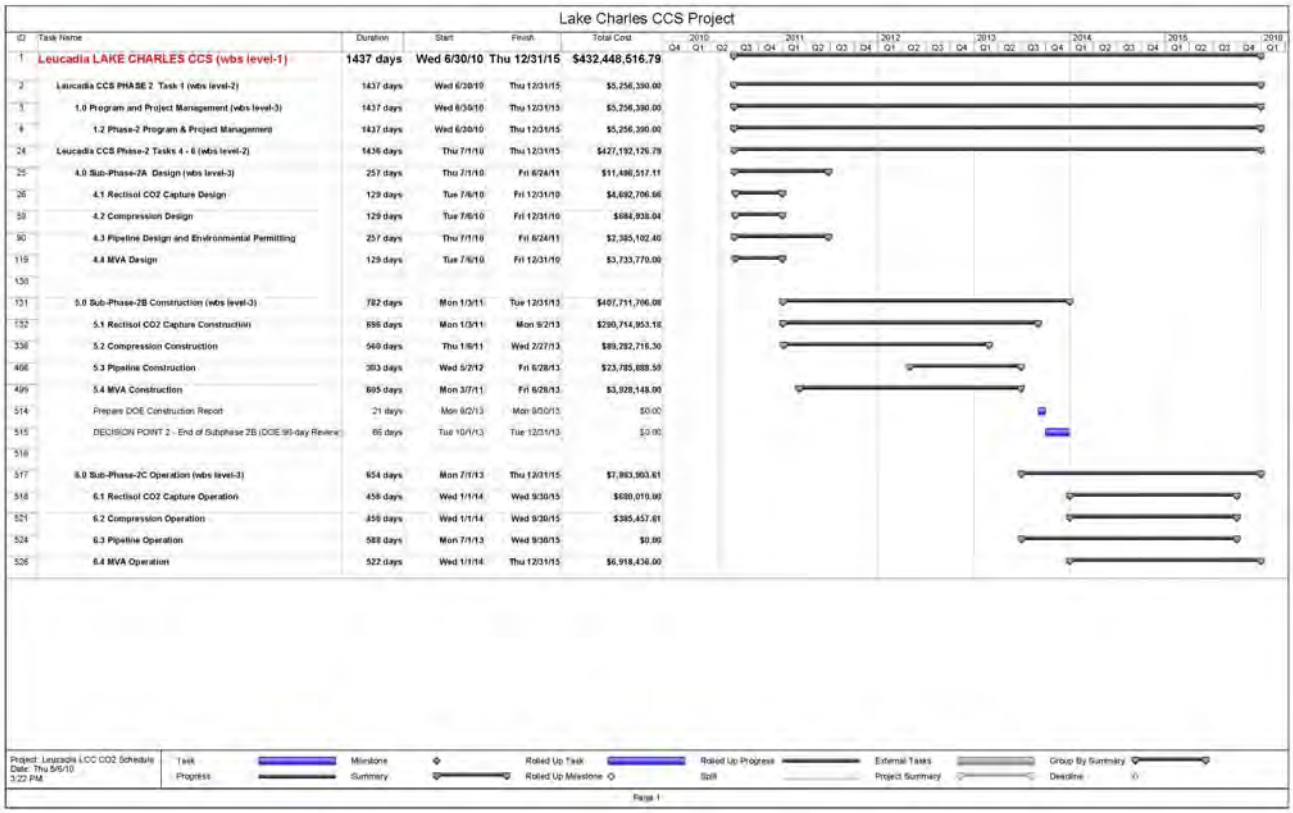


Figure 3

As identified in the Statement of Project Objectives (SOPO) and the resource loaded schedules, below are some of the significant technical and management milestones for Phase 2. These tasks show the methodology to be used in accomplishing our goals and they will be monitored closely. As new information becomes available, the project team will make any needed adjustments to ensure the specific needs of the project are achieved.

Significant Project Milestone Title	Planned Completion	Method used to verify completion
Rectisol CO2 Capture Design 01/03/2011		Design documents signed by licensed engineer and accepted by Leucadia
Compression Design	01/03/2011	Design documents signed by licensed engineer and accepted by Leucadia

Pipeline Design and Environmental Permitting	01/03/2011	Design documents signed by licensed engineer and accepted by Leucadia
MVA Design	01/03/2011	Design documents signed by licensed engineer and accepted by Leucadia
Rectisol CO2 Capture	09/02/2013	Engineering report of test run
Compression Energized	02/27/2013	Compressors run and lines brought up to full pressure
Pipeline Construction	06/30/2013	Pipeline brought up to full pressure
MVA Construction	06/30/2013	Engineering report of test run
Rectisol CO2 Capture	01/01/2014	Engineering report of test run accepted by Leucadia
Compression Operation	01/01/2014	Engineering report of test run accepted by Leucadia
Pipeline Operation	01/01/2014	Engineering report of test run accepted by Leucadia
MVA Operation	01/01/2014	Engineering report of test run accepted by Leucadia

Table 2

4. Funding and Costing Profile

Total Funding by Source

Total Funding	Government Cost Share Percentage	Government Funding	Leucadia Cost Share Percentage	Leucadia Funding
$432,448,517	60%	$259,469,110	40%	$172,979,407

Table 3

The total funding required for the Lake Charles CCS project is $432.5 million. Leucadia proposes a 60% government cost share, with Leucadia providing the remaining 40%.

Total Funding by Task

Design (2A)	Construction (2B)	Operation (2C)	Total
$13,648,647	$410,026,869	$8,773,001	$432,448,517

Table 4

Most of the required funding is required in subtask 2B, Construction. The funding profile anticipates the potential for an Environmental Impact Statement under the National Environmental Policy Act, should NETL make such a determination in the future.

Total Funding by System

CO_2 Capture	CO_2 Compression	CO_2 Transport	MVA Program Management	EIS/EA Total	
$296,087,670	$90,353,112	$26,170,991	$14,580,354	$4,656,390	$600,000	$432,448,517

Table 5

The CO2 capture and compression units account for nearly 90% of the total funding requirement by component system.

Monthly Spend Plan

Month 2010		**2011**	**2012**	**2013**	**2014**	**2015**
January		$85,522	$102,785,312	$14,445,384	$589,194	$364,746
February		$285,123	$16,929,060	$11,125,261	$527,781	$339,189
March		$735,330	$2,095,613	$9,295,774	$513,506	$364,746
April		$2,119,092	$33,819,498	$3,561,374	$533,977	$364,746
May		$4,374,225	$17,188,571	$1,765,830	$533,977	$351,968
June		$732,549	$11,374,074	$4,159,387	$513,506	$364,746
July $3,891,132		$982,654	$16,371,872	$1,880,889	$385,217	$379,026
August $1,319,979		$2,879,701	$106,137,619	$64,310	$351,968	$353,339
September $1,782,210		$9,772,494	$8,926,261	$720,873	$364,746	$364,046
October $1,844,459		$1,338,567	$4,948,542	$64,310	$377,525	$35,160
November $1,941,272		$2,937,649	$8,950,160	$64,310	$339,189	$41,210
December $2,869,597		$916,707	$6,128,659	$64,309	$377,525	$41,965
Total $13,648	**8,647**	**$27,159,612**	**$335,655,242**	**$47,212,013**	**$5,408,112**	**$3,364,889**

Table 6

An important component of the Renewal Application in response to Solicitation Number: DE-FOA-0000015, is the identification of a financial management system to coordinate with the other critical component, the project management system. Of essential importance is that the financial management system be acceptable to the Defense Contract Audit Agency (DCAA). Equally important is that the chosen system be scalable for use by Leucadia Energy as the project transitions from inception to construction to full operation.

In general, the following selection criteria were used for Project Management technology evaluation:

- Help project managers easily manage status, resources, revenue, and expenses for the various components of this complex projects.
- Ability to operate online to allow project managers to do their job effectively outside of the office.
- Scalable to meet future needs of a growing business.

- Provide project specific and enterprise-level reporting, flexible decision-making support, and timely, relevant business insight with significantly high usability and flexibility.
- Consolidate project information into one repository, for example, work plans, progress, issues, changes, documents, cost information, budgets, actuals and forecasts, performance, and status reports.
- Plan the work, assign resources, forecast to completion, and communicates to stakeholders, while streamlining the collaborative execution of project work.
- Centralizes accounting including track time for billing purposes and/or job cost allocation as well as establish budgets, for both projects and business units
- Enables reporting that allows expenses to be tracked, easily creates top level financial reports. Additionally it complies with assorted regulations, such as IRS, DOE, OMB and GAO standards and, specifically, Federal Financial Reports SF- 424A, SF-425, and the Reporting and Registration Requirements under Section 1512 of the American Recovery and Reinvestment Act.

Specifically as part of the Lake Charles CCS project, the following requirements will also be met:

Funding and Costing Profile – Showing: (a) for Phase 2, the total amount of funding and the government funding going to each member and cost-share provided by members, including totals and cost-sharing percentages; (b) budget by task and subtask for Phase 2; (c) budget by component system and subsystem; and, (d) project spend plan, by month, for the expenditure of Government funds in Phase 2. The system will also contribute to the creation and monitoring of the plan to obtain the funding for the entire non-DOE share of the total project cost. This funding plan will identify all sources of project funds and, specifically, the non-DOE share of the first sub-phase (i.e., Phase 2a, Design) prior to the Phase 2 award, and the plan to obtain the funding for the non-DOE share of future project sub-phases (i.e., Phase 2b and 2c).

Budget Details – The system will be capable of maintaining budget details for Phase 2, by task and system, including the following budget elements:

(a) Labor (direct) by labor category in terms of number of hours and percent of effort;
(b) Labor rates and costs;
(c) Travel;
(d) Equipment;
(e) Materials and supplies;
(f) Contracts (sub-awards);
(g) Other direct costs;
(h) Indirect costs;

Spend Plan – The financial management system will maintain the spend plan incorporated into the Project Management Plan for Phase 2. The spend plan will include tables of the following information:

(a) By sub-phase and reporting quarter, the amount of government funding going to each team member and cost-share provided by members. The table shall also calculate totals and cost-sharing percentages.
(b) For Phase 2 monthly the projected expenditure of the government funds.

Project Milestones – They system will handle the significant technical and management milestones associated with the Phase 2 efforts of the project, including title, planned completion date and a description of the method/process/ measure used to verify completion. .

Resource-Loaded Schedule – The system is able to handle a schedule timeline of the project broken down by phase/sub-phase and which incorporates the work breakdown structure, and funding and costing profile. The system will have to provide quarterly electronic updates in a format compatible with Primavera.

Work Breakdown Structure – The system is able to manage and report on the technical scope, budget and schedule basis at Levels 5 and 6. Additionally, the system will include and maintain the project resource-loaded schedule consistent with this work breakdown structure.

Project Monitoring, Change Control and Process Improvement – The system will support the project's formal change control process.

5. Resource-Loaded Schedule

The Lake Charles CCS Project resource loaded schedule, found in Attachment 1 below, has been prepared in Microsoft Office Project 2007. Per NETL guidance, the project schedule will be managed based upon a minimum Level-5 product-oriented work breakdown structure (WBS). For CO_2 capture and CO_2 transport, the project schedule will be managed at the Level-6. For MVA, the project schedule will be managed at Level-5. Section 9 of this Project Management Plan (PMP) describes the project's WBS. The resource estimates included in this resource loaded schedule were used to develop the Funding and costing profile included in section 4 of this PMP.

The overall objective of Phase 1 was to develop a fully definitive project basis for a competitive Renewal Application process to proceed into Phase 2 - Design, Construction and Operations. During Phase 1, the Leucadia team completed several studies that established:

1) The engineering design basis for the capture, compression and transportation of CO_2 from the LCC Gasification Project; and
2) The criteria and specifications for a monitoring, verification and accounting (MVA) plan at the West Hastings oil fields.

This phase was initiated on November 2009 and is scheduled to be completed in June 2010.

Phase 2 is projected to be initiated in September 2010. The objective of Phase 2 is to take the results of the two above mentioned studies and execute design, construction and operations of three capital projects:

1) The CO_2 capture and compression equipment;
2) The Lateral from the LCC Gasification Project to Denbury's Green Pipeline; and
3) An MVA system.

Phase 2 is broken into three subphases; Design (2A), Construction (2B), and Operation (2C).

Subphase 2A is projected to be completed in January 2011. Leucadia will notify NETL of its intent to progress to Subphase 2B in October 2010. The overall cost of this Subphase is $12,221,820. The major activities conducted in this subphase include the design of the Rectisol® and compression equipment, the design and permitting of Lateral, and the design of the MVA. During this subphase, the major milestones associated with CO_2 capture include the signing by a licensed engineer and the acceptance by Leucadia of design documents for the Rectisol® unit (01/02/2012) and the compression facility (11/29/2011). The major milestones associated with CO_2 transport is also the signing by a licensed engineer and the acceptance by Leucadia of the design documents for the pipeline (02/02/2012) and for the MVA (04/04/2011). Section 3 of this PMP includes a complete set of milestones.

Subphase 2B is projected to start on January 2011 and be completed in January 2014. Leucadia will notify NETL of its intent to progress to Subphase 2B in October 2013. The overall cost of this Subphase is $412,155,769. The major activities of this subphase are construction of the Rectisol® and compression units, as well as the pipeline and MVA. During this subphase, the major milestones associated with CO_2 capture activities include the engineering report of the test run of the Rectisol® unit (07/13/2013) and the running of the compressors at full pressure (09/15/2013). The major milestone associated with CO_2 transport activities is bringing the pipeline up to full pressure (07/01/2013). The major milestone associated with the MVA is the engineering report of the test run (07/01/2013).

Subphase 2C is projected to start on January 2014 and be completed in September 2015. The overall cost of this Subphase is $8,070,927. The major activities of this subphase are the operation of the Rectisol® and compression equipment, pipeline, and MVA. The major milestones for this subphase are the acceptance by Leucadia of the engineering report of test run for the Rectisol® (01/01/2014), the compression equipment (01/01/2014), the pipeline (07/01/2013), and the MVA (01/01/2014).

6. Project Management Organization

The Integrated Project Team for Lake Charles CCS includes Leucadia, Denbury, Black and Veatch, University of Texas Bureau of Economic Geology, Sandia Technologies, Turner Construction, and ENGlobal. Leucadia, as the Recipient, will coordinate resources to ensure the timely and successful completion of all Phase 2 Tasks. The Leucadia Executive Committee will be the overall project governing body. Figure 4 below is an overview of the project management reporting structure:

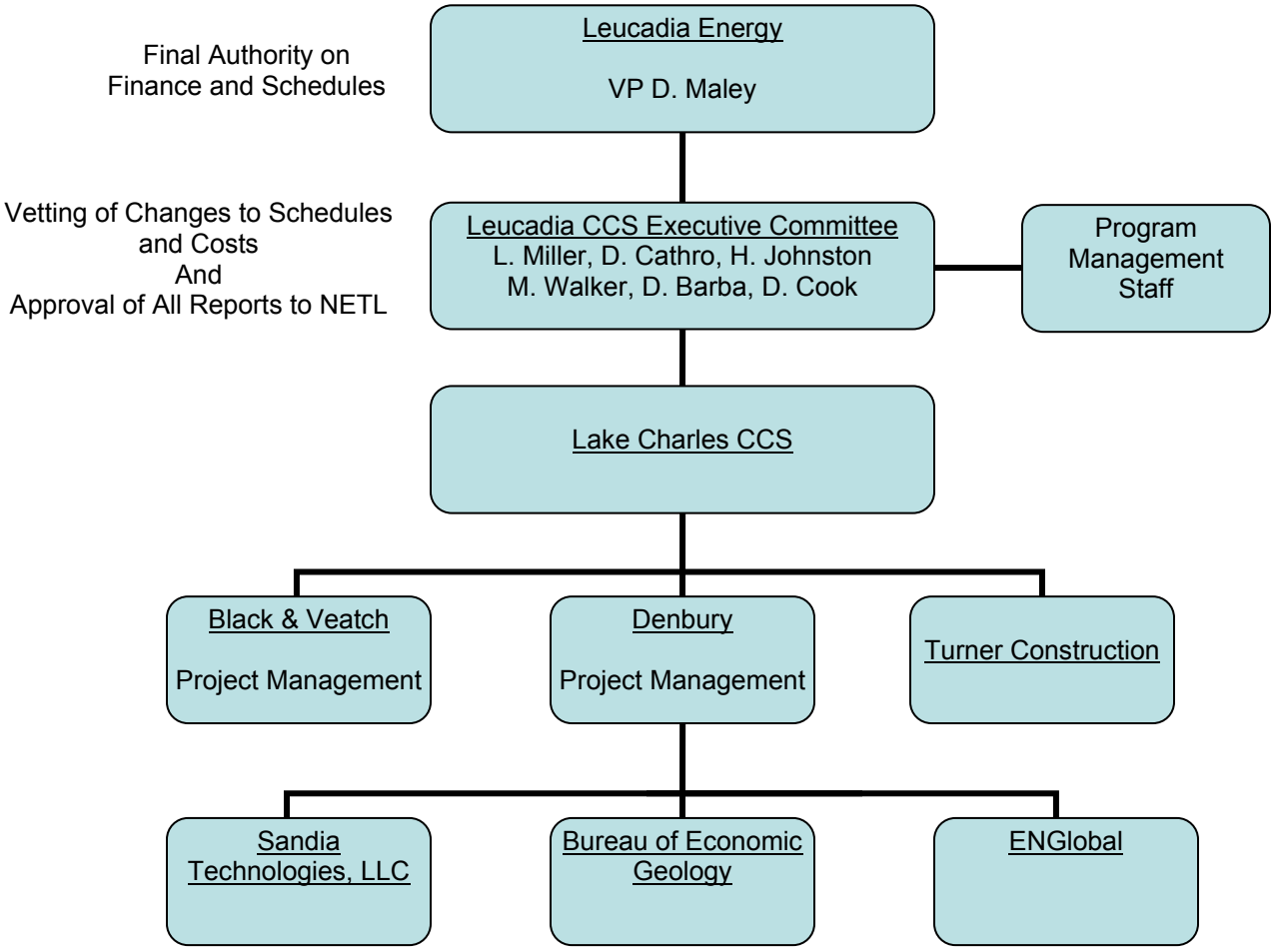


Figure 4

Leucadia plans to execute a consulting agreement with Black & Veatch ("B&V") upon selection for a Phase-2 Award to provide Program Management and Project Management services, and with Kroll to provide Financial Management Services. These services will include, but are not limited to:

- Coordinate project schedules between multiple entities
- Provide consolidated progress reporting for all project participants
- Coordinate project earned value reporting
- Help perform risk management assessments and identify mitigation strategies
- Provide financial systems support for project cost tracking
- Support Leucadia in complying with NETL and local, state, and federal reporting requirements
- Support the Leucadia Executive Committee

Leucadia will execute a contract with Denbury Onshore, LLC ("Denbury") to design, construct, and operate both the Lateral and the MVA for the Hastings field. Denbury has provided cost and schedule estimates via the Resource-Loaded Schedule for engineering and construction services related to the CO_2 pipeline and MVA activities. Denbury has extensive experience in planning and implementing pipelines.

Denbury plans to execute a contract with the University Texas Bureau of Economic Geology ("BEG") to undertake the tasks related to sequestration MVA. Specifically these tasks include the sequestration risk assessment and MVA plan, the site-specific options evaluation, and the final MVA plan and detailed budget. The University of Texas would in turn contract for specific assignments which require extensive supervision such as specialized MVA surveys and equipment installation to the Sandia Technologies. The specific assignments are spelled out in the MVA discussions and are included in the overall project schedule. Both BEG and Sandia Technologies were actively involved in similar efforts during Phase 1. Denbury plans to contract with ENGlobal to construct the Lateral. ENGlobal is an internationally recognized energy engineering and professional services company.

Leucadia plans to also execute a consulting agreement with B&V upon selection for a Phase-2 award for engineering services. B&V has designed, performed feasibility studies, and performed independent project assessments for numerous gasification and IGCC projects using various gasification technologies. B&V has provided cost and schedule estimates via the Resource-Loaded Schedule for engineering and construction services related to CO_2 capture and compression activities.

Leucadia will execute a contract with Turner Construction for the construction of the carbon capture facilities including both the Rectisol® unit and the compression facility. Turner is a world-class industrial contractor and an industry leader in construction and pipe fabrication, maintenance and turnarounds, and equipment.

The persons responsible for coordinating responses to NETL for this project (including consultants or retained counsel) from the Leucadia team are as follows:

- Business Development & Government Affairs: Hunter Johnston (hjohnston@steptoe.com)
- Financial Management: Jim Check (jcheck@kroll.com)
- Business Representative: Doug Cathro (dcathro@enerventech.com) and Bruce Smith (bruce.smith@denbury.com)
- Legal Representative: Environmental Counsel: Cynthia Taub (ctaub@steptoe.com) and Government Contracts Counsel: Andy Irwin (airwin@steptoe.com) (Steptoe & Johnson, LLC)
- Financial Representative: Linda Miller (lindaamiller@hotmail.com) and Alan Rhoades (alan.rhoades@denbury.com)

In addition to the above personnel, as provided in the application, Leucadia will also draw upon the expertise of Donald W. Maley, Jr., Cliff L. Kerr, Lawrence R. Leib, Scott K. Pierce, Robby Collums, and Jay F. Nagori to complete the tasks identified in section B above. Likewise Denbury will draw upon the expertise of Connell R. Rader, Barry Schneider, and Charles E. Gibson.

The program management function for the Leucadia CCS grant program is centered on the Leucadia CCS Executive Committee. This committee reports directly to the Leucadia Vice President. This committee will be responsible for complete oversight of the project, management of the integrated project team, submitting all required reports to NETL, and recommending action on major financial and scheduling decisions to Leucadia.

The committee is supported in carrying out these responsibilities by a Program Management team. The team will be led by a Program Manager with extensive experience working with DOE and NETL and familiar with the goals and objectives of the CCS projects. Under the Program Manager is a senior level of specialists focusing on financial, project management, and project technical. This level will be responsible for developing the reports, maintaining the schedules, managing the change control process, developing and implementing the financial management system, and providing other support as required by the Executive Committee. Figure 5 portrays the organization of the Leucadia Program Management function.

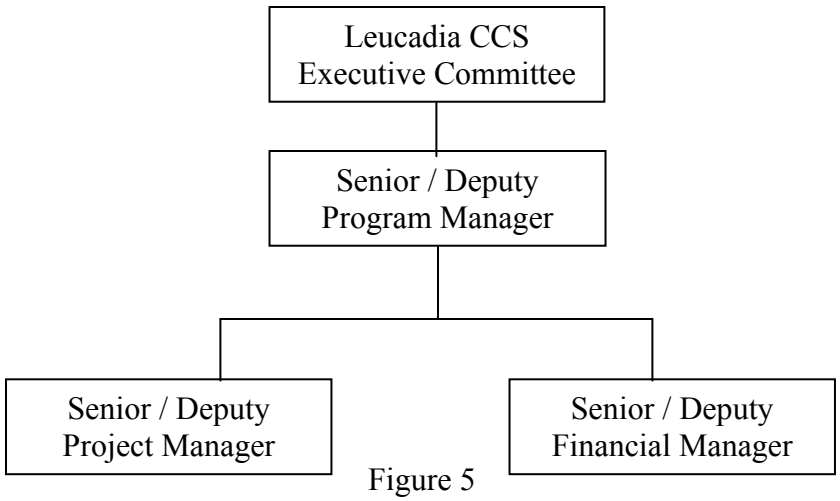


Figure 5

7. Roles and Responsibilities

The roles and responsibilities of the members of the integrated team are discussed below.

Government – NETL is responsible monitoring the progress of Leucadia's CCS project, providing technical direction, and recommending alternative approaches where appropriate. Leucadia will collaborate with NETL on all aspects of the project plan. NETL will conduct semiannual review meetings, act as a liaison with other programs and industry staff, and facilitate technology transfer efforts. In furthering their responsibilities on the project, NETL may evaluate any or all of the work being performed within the project. NETL is responsible for reviewing technical performance and approving the project to progress to subsequent subphases.

Leucadia - Leucadia has overall responsibility for working with NETL and managing the planning and implementation of the Lake Charles CCS Project and overseeing the conduct of all project participants. Leucadia is also responsible for working with NETL and all required reporting on the project, including ARRA required reporting.

Denbury – Denbury's responsibilities are focused on the CO_2 transport and sequestration. Within those areas, Denbury has responsibility the planning and implementation of the pipeline and MVA within the guidelines provided by Leucadia and NETL.

University of Texas, Bureau of Economic Geology – BEG is responsible for implementing portions of the MVA within Denbury's guidance. BEG's responsibilities include the sequestration risk assessment and MVA plan, the site-specific options evaluation, and the final MVA plan and detailed budget.

Sandia Technologies – Sandia is responsible for supporting BEG's MVA activities by conducting specialized MVA surveys and equipment installation.

Black & Veatch – B&V is responsible for providing to Leucadia the design and engineering of the facilities and equipment necessary for the carbon capture and compression processes, within the guidelines provided by Leucadia and NETL, and for provision of project management services.

ENGlobal – ENGlobal is responsible for the construction of the CO_2 pipeline following the design and guidance provided by Denbury.

8. Key Personnel

Table 7 provides the people who are considered essential to the project. Should the need arise to replace one or more of these individuals, Leucadia will notify NETL and receive NETL approval for the replacement. Leucadia will make this notification as soon as the change becomes known to minimize impact on the project.

Name	Title *(Leucadia unless specified)*
Don Maley	Vice President
Cliff Kerr	Construction Team Lead
Larry Lieb	Construction Team Lead
Jay Nagori	Project Engineering Manager
Scott Pierce	Operations Manager
Robby Collins	Operations Manager
Tracy Evans	Denbury – President and CEO
Connell Rader	Denbury - Manager Pipelines
Barry Sneider	Denbury - VP East Region Operations
Charles Gibson	Denbury VP West Region Operations

Table 7

9. Work Breakdown Structure

The Lake Charles CCS Project will be managed to the WBS level 5 or 6. CO_2 capture and transport are managed to level 6, while MVA is managed to level 5. The general description of the WBS structure is displayed in Figure 6. The details and definitions of the WBS are included in the Statement of Program Objectives.

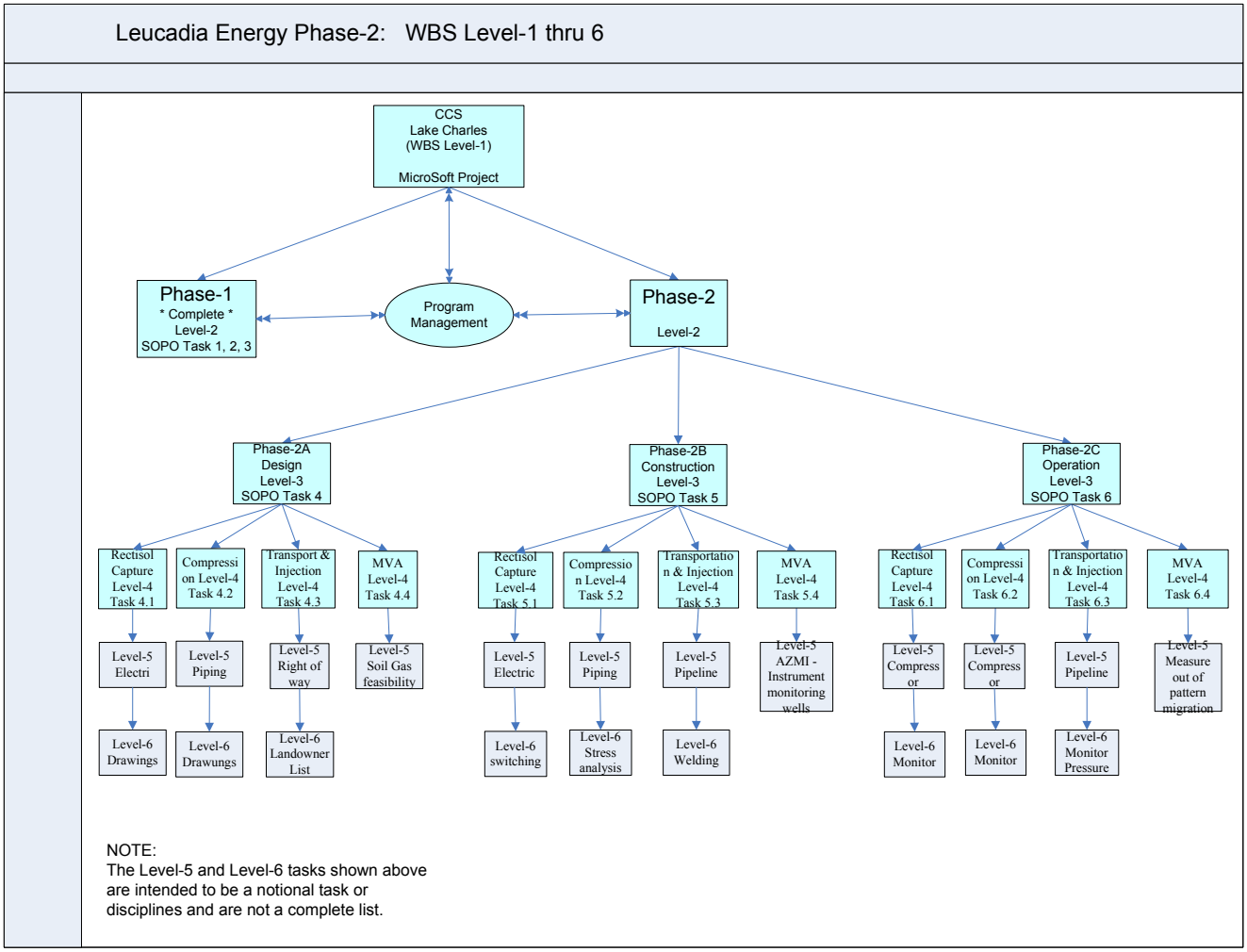


Figure 6

The specific levels in the work breakdown structure are as follows:

- WBS Level 1 – The Lake Charles CCS Project is the top level of the WBS.
- WBS Level 2 – The two phases of the Lake Charles Project, Phase 1 and Phase 2 constitute the second level of the WBS. Program management is identified as 1.1 in the Phase I plan. WBS 1.1 continues to be the program management for phase 2. In addition, there are separate program management elements within other layers of the WBS, demonstrating our view that proper program management requires involvement at all levels of the project.
- WBS Level 3 - Three subphases, Design (Phases 2A), Construction (Phase 2B), and Operation / Demonstration (Phase 2C), represent the third level of the WBS.
- WBS Level 4 - The three elements desired by the solicitation, CO_2 Capture, CO_2 Transport, and MVA constitute the fourth level of the WBS.
- WBS Level 5 – This level of WBS differs for the three Level 4 activities to better tailor the WBS to the management challenge. For CO_2 capture, this level is by discipline. For CO_2 transport, this level is by major activity (e.g., right of way,

environmental). For MVA, this level is the specific work packages at which the project will be managed (e.g., groundwater monitoring, reservoir modeling).

- WBS Level 6 – For CO_2 capture and CO_2 transport, this level constitutes the specific work packages at which the project will be managed.

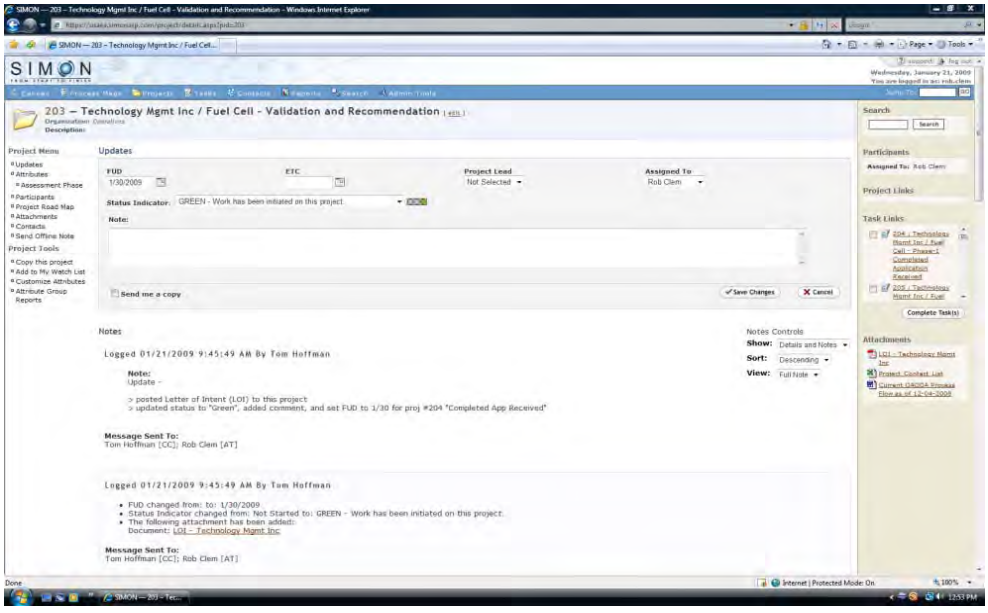
The complete list of level 5 and 6 packages can be found in the appropriate Statement of Program Objectives.

10. Statement of Project Objectives (SOPO)

The statement of project objectives for all aspects and phases of the project is contained in Attachment 2 to the PMP.

11. Communications

Project Communication Tool:
The Leucadia Project Team will utilizes a web-based, project management system, SIMON, to control unique and shared program activities, generate customized project reports, store supporting materials and serve as an online communication and collaboration platform for all project stakeholders. SIMON is a secure, web-based, collaborative project management tool used to govern and communicate with all primary internal and external stakeholders on a daily basis. Access by project team members can be customized so individuals have access to all the information they need do perform their function while keeping any proprietary information access restricted and secure.



This will ensure adherence to necessary project procedures and guidelines, in addition to providing the necessary transparency and long term governance for the project.

Of unique value is the ability of our team to provide secure and applicable communications and reporting between all program participants and sub-contractors. System configuration is customized so that we can fully control all aspects of the program in a coordinated fashion, thereby reducing management costs, providing ready access to all associated documents and the flexibility to modify system operations and meet requirements as project team and NETL needs are modified. The project management system Leucadia will be using is designed to maintain all data suitable for the purposes as project progress reports, risk management reporting, and NETL communications in electronic file format for ready access and audit.

Regarding an External Communication Plan the Leucadia Team will work closely with the NETL's Office of Public Affairs to help answer any inquires from the public. Our team has thoroughly reviewed the resources available at the NETL online Reference Shelf. These will also be important tools in helping inform the public on the benefits and facts about Carbon Sequestration Program. These publications, reports, facts sheet and the other materials will be referenced should Leucadia get general requests from the public. At the same time, we will work closely with NETL as we recognize it is critical to manage a project of this magnitude effectively especially in the ever-changing business, political, and economic environments. Leucadia is committed to working closely with the NETL's Office of Public Affairs as the project moves from inception to construction to full operation.

The Leucadia communications support team will provide crosscutting services throughout the CCS project. This will include support for development and execution of NETL reporting and general communications as well as any outreach strategy with all of our stakeholders. The Leucadia Team will commit to keep its stakeholders, including NTEL, DOE and to some extent public officials, well informed on the project's progress. We anticipate keeping the NETL informed not only through required reporting documentation, but also through regular progress reports, status meetings, financial updates and project status reports. As required we will anticipate regularly scheduled conference calls, periodic face-to- face meetings and electronic reports.

Below are the project conference calls, team meetings, and reporting that are anticipated:

<u>Weekly Project Status Conference Calls:</u>

- Weekly construction site meetings
- Weekly team member status
- Weekly progress and issues assessment

<u>Monthly Reporting:</u>

- Executive Committee Meeting
- Leucadia Monthly Financial Reporting
- Monthly internal Project Team Progress and Issues Reporting

<u>Quarterly Reporting:</u>

- NETL Progress Report

- Federal Financial Reports
- ARRA Reporting

As Requested or Needed:

- Support ad-hoc informational requests from NETL and project team members
- Site inspections from 3rd party inspectors as needed
- Site inspection by Executive Committee Members and NETL staff

Table 8 below is a list of reports that will be provided.

Report Purpose / Name	*Audience*	*Schedule*	*Description*
**Internal Reporting			
Lake Charles Schedule & Issues	Executive Team	Monthly	progress, issues, changes
Lake Charles Change Control & Risk Mgmt	Executive Team	Monthly	update as needed
Lake Charles Project Financial Reports	Executive Team	Monthly	accounting & financial reports
Lake Charles Communications & Public Relations	Executive Team	Monthly	
Status - Capture & Compression	Lake Charles Mgmt Team	Monthly	progress, issues, changes
Status - Transportation & Injection	Lake Charles Mgmt Team	Monthly	progress, issues, changes
Status - MVA	Lake Charles Mgmt Team	Monthly	progress, issues, changes
Status - Change Control	Lake Charles Mgmt Team	Monthly	update as needed
Status - Risk Mgmt Review	Lake Charles Mgmt Team	Monthly	update as needed
Project Financial Reports	Lake Charles Mgmt Team	Monthly	accounting & financial reports
Legal, Communications & Public Relations	Lake Charles Mgmt Team	Monthly	
A. Gov Management Reporting			
Progress Report	NETL	Quarterly	
Special Status Report	NETL	As required	
B. Gov Scientific/Technical Reporting			
Technical Reports	NETL	As required	need to define w/NETL
Technical Reports	NETL	Final	need to define w/NETL
C. Gov FINANCIAL REPORTING			
SF-425, Federal Financial Report	NETL	Qtrly & Final	
ARRA	DOE	Quarterly	
D. Gov CLOSEOUT REPORTING			
Patent Certification	NETL	Final	
Property Certificate	NETL	Final	
Other	NETL	Final	
E. Gov OTHER REPORTING			
Annual Indirect Cost Proposal	NETL	As required	
Annual Inventory Report of Federally Owned Property, if any	NETL	As required	
Other	NETL	As required	

Table 8

12. Project Monitoring, Change Control and Process Improvement:

This section describes the project management system for monitoring and controlling scope, schedule, and cost and a project communication protocol that will be utilized for the Phase 2 of the project.

Leucadia Team is committed to managing the project to ensure full compliance to all NETL policies and to the specific guidelines within the grant agreement. As part of this project, we have hired Kroll to assist the Leucadia Team and provide financial and technical subject matter experts to help ensure comprehensive project monitoring and change control management. They will also help implement change control and process improvement procedures. These procedures will be revised and updated on a regular basis should any changes be required within project management policies, processes, technical scope, budget and/or schedule.

The Leucadia CCS Executive Committee will report directly to a Leucadia Vice President. The Leucadia CCS Executive Committee will monitor and manage any change controls, specifically related to scope, budget and schedule, including any change that may affect the project management plan or the financial management plan. The controls include specific steps that will be taken to immediately mitigate issues or changes to the project.

Should issues, changes or procedure modifications be required, the solution to the risk situation will be documented and reported. These specific steps will taken to mitigate an issue: 1. Identify and Report; 2. Assess Issue; 3. Prepare Mitigation Plan; 4. Execute on Plan. Additionally, issues will be managed based on the financial and/or project impact of the associated change.

A project execution plan, project instructions manual, project construction plan, and various procedures manuals will be prepared and maintained by the contractor to guide administrative or procedural aspects of the work, including project execution planning, construction planning, procurement planning, team organization, document distribution, communications, and administration.

Copies of these documents or cited sections of the documents may be provided to the Owner as determined to be appropriate by the contractor for information and use after the notice to proceed is accepted by the contractor. The contractor will periodically provide the Owner with an updated and current copy of such documents.

At the onset of the project, the project management team help prepares the Authorization for Expenditure (AFE) which is presented for authorization to executive management or the Board of Directors, depending upon the magnitude of the AFE amount. The AFE is the project budget which outlines all project related costs, such as engineering costs, materials, subcontractors, equipment and other anticipated costs. This budget is maintained within production access of the project management system.

Project Manager, with the support of the Financial Manager, makes monthly estimates of costs based upon the project's activity. At a minimum, on a monthly basis, management reviews the incurred to date program costs, remaining estimates, scope, and remaining schedule to ensure any necessary adjustments to the project's scope, schedule, and budget are identified, communicated and incorporated into the program plan and budget. In addition, on a quarterly basis, project management prepares the development schedule

results report (DSRR) to present program budget and plan status to the Board of Directors.

A formal change control process will be put in place to accommodate required changes to cost, schedule, and scope from the project plan identified elsewhere in this Project Management Plan. The change control process will be handled at four levels:

1. Changes at the WBS Level-6 or lower that do not impact a WBS Level-5 project schedule, cost, functionality / utility, or quality (field changes) are to be reviewed by the Project Management team and approved by the WBS Level-5 Manager. All appropriate documentation will be updated to reflect the change and impacted Level-6 parties must be notified.
2. If the change in #1 above impacts multiple WBS Level-5 tasks, then the WBS Level-4 Manager and Senior Project Manager also need to approve the changes.
3. Changes that do impact the WBS Level-5 project schedule, cost, functionality / utility, or quality (field changes) and do not impact WBS Level-4, will be reviewed by the Project Manager and obtain a first level of authorizing from the WBS Level-5 Manager, WBS Level-4 Manager, and the Project Manager. The Project Manager will provide the Program Manager with a change notification to present to the Executive Committee. This does not require any Executive Committee action unless the Committee believes it is necessary. All appropriate documentation will be updated to reflect the change and impacted parties will be notified.
4. Changes that will impact the WBS Level-4 project schedule or cost will be reviewed by the Project Manager and authorized by the WBS Level-4 Manager and the Project Manager. The Project Manager will review with the Program Manager and they will provide the Executive Committee with a recommendation. If the change is approved by the Executive Committee, all appropriate documentation will be updated to reflect the change and impacted parties will be notified.

Figure 7 below is an approval matrix to help explain this:

Change Centered Approval Grid:

Change Description	WBS Level-5 Mgr	Project Analyst	PM WBS	Level-4 Mgr	SR-PM	Program Mgr	Executive Committee
Change to one Level 5 task w/o Level-5 Schd or cost impact	A R		A				
Change to multiple Level-5 tasks w/o any schd or cost impact	A R		A	A	A		
Change to Level-5 Task(s) *with* Level-5 schd or cost impact	A	R	A	A A A			I
Change to Level-4 Task *with* Level 4 schd or cost impact	n/a R		A A		A	A	A

Note: R=Review, A=Approval, I=informational

Figure 7

The Project Manager will keep a record or log of all changes that impact schedule, cost, or quality and the reasons behind these changes. Existing procedures will be reviewed to determine if a procedure modification would have prevented or anticipated the event sooner. This repository will serve as a history of events as well as a source for on-going process improvement.

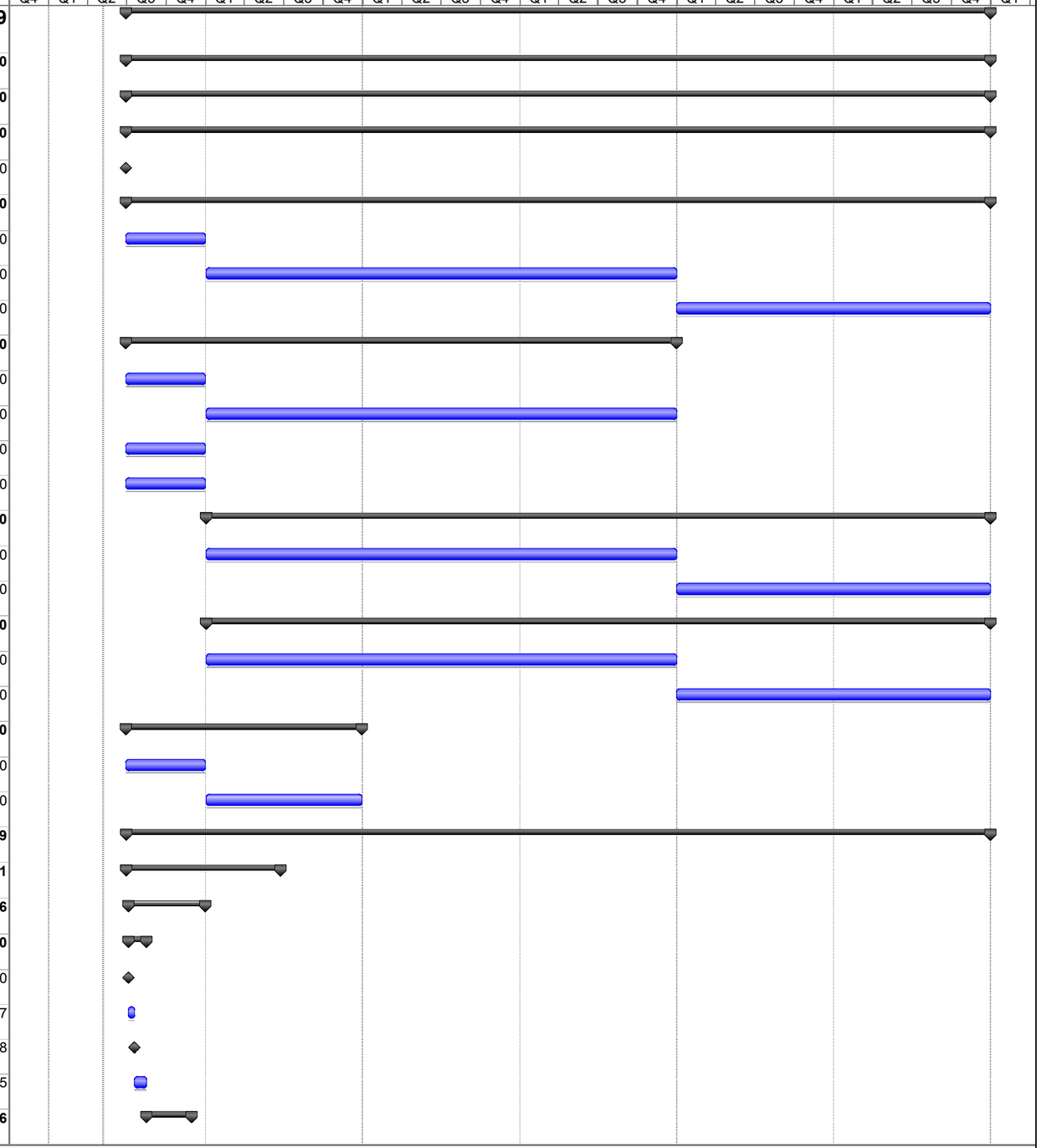
The following is a listing of the reports that will be provided to assure that all project and financial plans are properly executed:

Report Purpose / Name	***Audience***	***Schedule***	***Description***
**Internal Reporting			
Lake Charles Schedule & Issues	Executive Team	Monthly	progress, issues, changes
Lake Charles Change Control & Risk Mgmt	Executive Team	Monthly	update as needed
Lake Charles Project Financial Reports	Executive Team	Monthly	accounting & financial reports
Lake Charles Communications & Public Relations	Executive Team	Monthly	
Status - Capture & Compression	Lake Charles Mgmt Team	Monthly	progress, issues, changes
Status - Transportation & Injection	Lake Charles Mgmt Team	Monthly	progress, issues, changes
Status - MVA	Lake Charles Mgmt Team	Monthly	progress, issues, changes
Status - Change Control	Lake Charles Mgmt Team	Monthly	update as needed
Status - Risk Mgmt Review	Lake Charles Mgmt Team	Monthly	update as needed
Project Financial Reports	Lake Charles Mgmt Team	Monthly	accounting & financial reports
Legal, Communications & Public Relations	Lake Charles Mgmt Team	Monthly	
A. Gov Management Reporting			
Progress Report	NETL	Quarterly	
Special Status Report	NETL	As required	
B. Gov Scientific/Technical Reporting			
Technical Reports	NETL	As required	need to define w/NETL
Technical Reports	NETL	Final	need to define w/NETL
C. Gov FINANCIAL REPORTING			
SF-425, Federal Financial Report	NETL	Qtrly & Final	
ARRA	DOE	Quarterly	
D. Gov CLOSEOUT REPORTING			
Patent Certification	NETL	Final	
Property Certificate	NETL	Final	
Other	NETL	Final	
E. Gov OTHER REPORTING			
Annual Indirect Cost Proposal	NETL	As required	
Annual Inventory Report of Federally Owned Property, if any	NETL	As required	
Other	NETL	As required	

Report Purpose / Name	*Audience*	*Schedule*	*Description*
**Internal Reporting			
Lake Charles Schedule & Issues	Executive Team	Monthly	progress, issues, changes
Lake Charles Change Control & Risk Mgmt	Executive Team	Monthly	update as needed
Lake Charles Project Financial Reports	Executive Team	Monthly	accounting & financial reports
Lake Charles Communications & Public Relations	Executive Team	Monthly	
Status - Capture & Compression	Lake Charles Mgmt Team	Monthly	progress, issues, changes
Status - Transportation & Injection	Lake Charles Mgmt Team	Monthly	progress, issues, changes
Status - MVA	Lake Charles Mgmt Team	Monthly	progress, issues, changes
Status - Change Control	Lake Charles Mgmt Team	Monthly	update as needed
Status - Risk Mgmt Review	Lake Charles Mgmt Team	Monthly	update as needed
Project Financial Reports	Lake Charles Mgmt Team	Monthly	accounting & financial reports
Legal, Communications & Public Relations	Lake Charles Mgmt Team	Monthly	
A. Gov Management Reporting			
Progress Report	NETL	Quarterly	
Special Status Report	NETL	As required	
B. Gov Scientific/Technical Reporting			
Technical Reports	NETL	As required	need to define w/NETL
Technical Reports	NETL	Final	need to define w/NETL
C. Gov FINANCIAL REPORTING			
SF-425, Federal Financial Report	NETL	Qtrly & Final	
ARRA	DOE	Quarterly	
D. Gov CLOSEOUT REPORTING			
Patent Certification	NETL	Final	
Property Certificate	NETL	Final	
Other	NETL	Final	
E. Gov OTHER REPORTING			
Annual Indirect Cost Proposal	NETL	As required	
Annual Inventory Report of Federally Owned Property, if any	NETL	As required	
Other	NETL	As required	

Lake Charles CCS Project

ID	Task Name	Duration	Start	Finish	Total Cost
1	**Leucadia LAKE CHARLES CCS (wbs level-1)**	**1437 days**	**Wed 6/30/10**	**Thu 12/31/15**	**$432,448,516.79**
2	**Leucadia CCS PHASE 2 Task 1 (wbs level-2)**	**1437 days**	**Wed 6/30/10**	**Thu 12/31/15**	**$5,256,390.00**
3	**1.0 Program and Project Management (wbs level-3)**	**1437 days**	**Wed 6/30/10**	**Thu 12/31/15**	**$5,256,390.00**
4	**1.2 Phase-2 Program & Project Management**	**1437 days**	**Wed 6/30/10**	**Thu 12/31/15**	**$5,256,390.00**
5	1.2.1 NETL Award Announcement	0 days	Wed 6/30/10	Wed 6/30/10	$0.00
6	**1.2.2 Executive Committee**	**1437 days**	**Wed 6/30/10**	**Thu 12/31/15**	**$1,266,382.00**
7	1.2.2.1 Executive Committee - Phase 2A	133 days	Wed 6/30/10	Fri 12/31/10	$422,127.00
8	1.2.2.2 Executive Committee - Phase 2B	782 days	Mon 1/3/11	Tue 12/31/13	$527,659.00
9	1.2.2.3 Executive Committee - Phase 2C	522 days	Wed 1/1/14	Thu 12/31/15	$316,596.00
10	**1.2.3 LEC**	**915 days**	**Wed 6/30/10**	**Tue 12/31/13**	**$1,500,000.00**
11	1.2.3.1 LEC Phase 2A	133 days	Wed 6/30/10	Fri 12/31/10	$500,000.00
12	1.2.3.2 LEC Phase 2B	782 days	Mon 1/3/11	Tue 12/31/13	$1,000,000.00
13	1.2.4 Prog Mgmt - FMS & PMS systems Phase 2A	133 days	Wed 6/30/10	Fri 12/31/10	$315,001.50
14	1.2.5 Financial Mgmt Implementation Phase 2A	133 days	Wed 6/30/10	Fri 12/31/10	$315,001.50
15	**1.2.6 Program Management Project Reporting & Monitori**	**1304 days**	**Mon 1/3/11**	**Thu 12/31/15**	**$630,002.50**
16	1.2.6.1 PM Reporting Phase 2B	782 days	Mon 1/3/11	Tue 12/31/13	$393,751.50
17	1.2.6.2 PM Reporting Phase 2C	522 days	Wed 1/1/14	Thu 12/31/15	$236,251.00
18	**1.2.7 Financial Management Project Reporting & Monitor**	**1304 days**	**Mon 1/3/11**	**Thu 12/31/15**	**$630,002.50**
19	1.2.7.1 Financial Reporting Phase 2B	782 days	Mon 1/3/11	Tue 12/31/13	$393,751.50
20	1.2.7.2 Financial Reporting Phase 2C	522 days	Wed 1/1/14	Thu 12/31/15	$236,251.00
21	**1.2.8 NEPA**	**393 days**	**Wed 6/30/10**	**Fri 12/30/11**	**$600,000.00**
22	1.2.8.1 NEPA EIV Phase 2A	133 days	Wed 6/30/10	Fri 12/31/10	$600,000.00
23	1.2.8.2 NEPA EIS? Phase 2B	260 days	Mon 1/3/11	Fri 12/30/11	$0.00
24	**Leucadia CCS Phase-2 Tasks 4 - 6 (wbs level-2)**	**1436 days**	**Thu 7/1/10**	**Thu 12/31/15**	**$427,192,126.79**
25	**4.0 Sub-Phase-2A Design (wbs level-3)**	**257 days**	**Thu 7/1/10**	**Fri 6/24/11**	**$11,496,517.11**
26	**4.1 Rectisol CO2 Capture Design**	**129 days**	**Tue 7/6/10**	**Fri 12/31/10**	**$4,692,706.66**
27	**4.1.1 Rectisol CO2 Capture Design**	**30 days**	**Tue 7/6/10**	**Mon 8/16/10**	**$3,078,196.70**
28	4.1.1.1 CONTRACT AWARD	0 days	Tue 7/6/10	Tue 7/6/10	$0.00
29	4.1.1.3 RECEIVE CLIENT DOCUMENTS	10 days	Tue 7/6/10	Mon 7/19/10	$16,730.67
30	4.1.1.2 CONTRACT LICENSE AND AWARD	0 days	Mon 7/19/10	Mon 7/19/10	$3,028,004.68
31	4.1.1.4 RECEIVE LICENSOR DOCUMENTS	20 days	Tue 7/20/10	Mon 8/16/10	$33,461.35
32	**4.1.3 SYSTEM**	**75 days**	**Tue 8/17/10**	**Mon 11/29/10**	**$995,475.06**

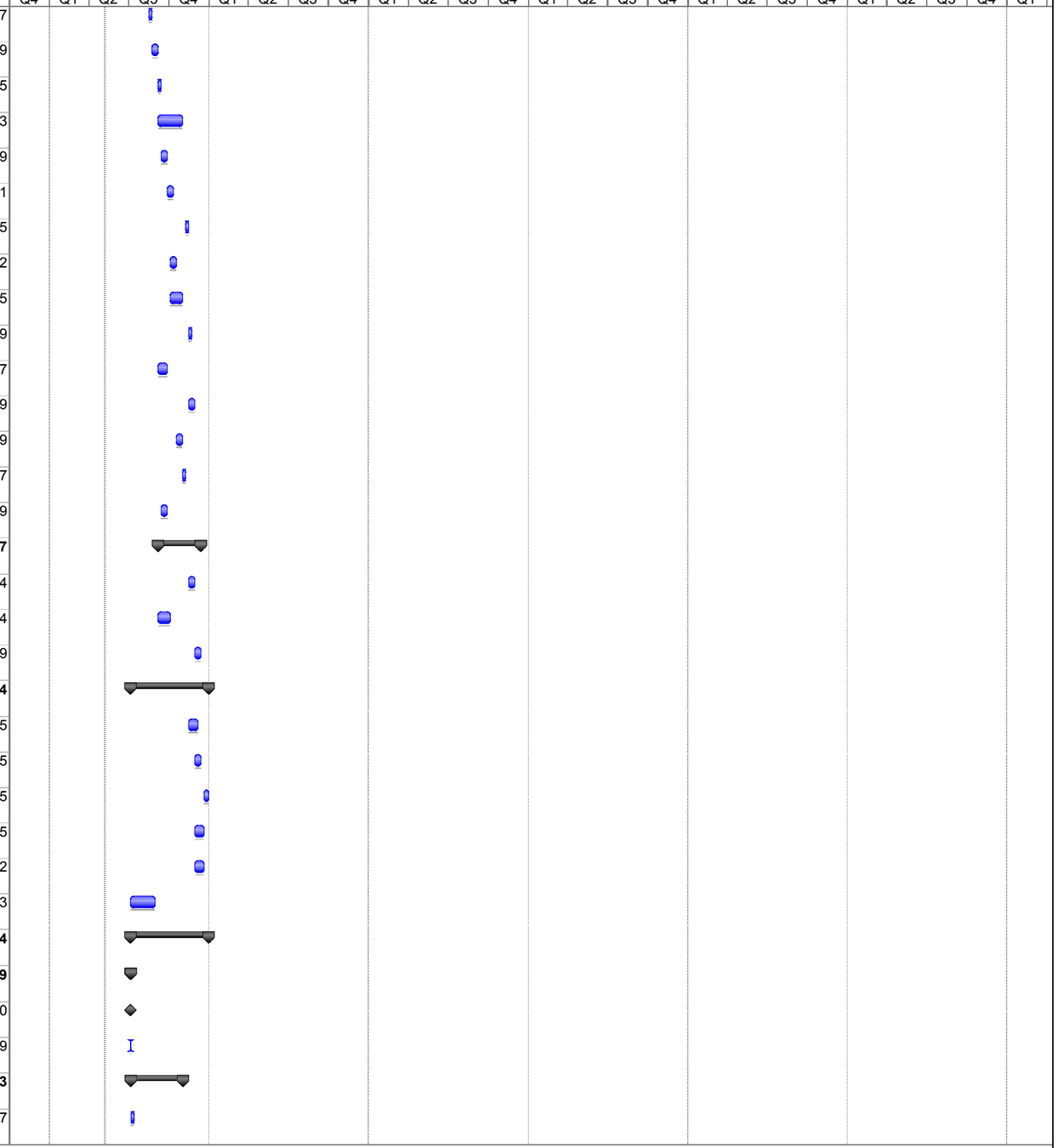


Project: Leucadia LCC CO2 Schedule
Date: Thu 5/6/10
3:25 PM

Task | Milestone | Rolled Up Task | Rolled Up Progress | External Tasks | Group By Summary
Progress | Summary | Rolled Up Milestone | Split | Project Summary | Deadline

Lake Charles CCS Project

ID	Task Name	Duration	Start	Finish	Total Cost
33	4.1.3.1 REVIEW DESIGN BASIS & DEVELOP BEDD	5 days	Tue 8/17/10	Mon 8/23/10	$83,653.37
34	4.1.3.2 ISSUE/REVIEW/BALANCE - PFD	10 days	Tue 8/24/10	Mon 9/6/10	$66,922.69
35	4.1.3.3 ISSUE MATERIAL SELECTION DIAGRAMS	5 days	Tue 9/7/10	Mon 9/13/10	$33,461.35
36	4.1.3.4 DEVELOP/REVIEW/ISSUE - P&ID	40 days	Tue 9/7/10	Mon 11/1/10	$167,306.73
37	4.1.3.6 PREPARE EQUIPMENT DATA SHEETS	10 days	Tue 9/14/10	Mon 9/27/10	$66,922.69
38	4.1.3.8 ISSUE EQUIPMENT LIST	10 days	Tue 9/28/10	Mon 10/11/10	$25,096.01
39	4.1.3.13 RELIEF SCENARIO (PRELIM. RELIEF VALVE	5 days	Tue 11/9/10	Mon 11/15/10	$33,461.35
40	4.1.3.9 ISSUE CONTROL LOGIC DESCRIPTION	10 days	Tue 10/5/10	Mon 10/18/10	$50,192.02
41	4.1.3.10 DESIGN HYDRAULICS	20 days	Tue 10/5/10	Mon 11/1/10	$33,461.35
42	4.1.3.14 P&ID TRANSFER TO (3D) MODEL	5 days	Tue 11/16/10	Mon 11/22/10	$66,922.69
43	4.1.3.5 PRELIMINARY LINE SIZING	15 days	Tue 9/7/10	Mon 9/27/10	$83,653.37
44	4.1.3.15 ISSUE LINE SCHEDULE	10 days	Tue 11/16/10	Mon 11/29/10	$66,922.69
45	4.1.3.11 ISSUE INSTRUMENT DATA SHEETS	10 days	Tue 10/19/10	Mon 11/1/10	$66,922.69
46	4.1.3.12 RELIEF VALVE DATA SHEETS	5 days	Tue 11/2/10	Mon 11/8/10	$83,653.37
47	4.1.3.7 ISSUE UTILITY SUMMARY	10 days	Tue 9/14/10	Mon 9/27/10	$66,922.69
48	**4.1.6 PIPING (DESIGN)**	**70 days**	**Tue 9/7/10**	**Mon 12/13/10**	**$267,690.77**
49	4.1.6.2 DESIGN/ISSUE/REVIEW - U.G. PIPING	10 days	Tue 11/16/10	Mon 11/29/10	$100,384.04
50	4.1.6.1 DEVELOP PIPING CLASSES & SPECIFICATIO	20 days	Tue 9/7/10	Mon 10/4/10	$100,384.04
51	4.1.6.3 PIPING PLAN INDEX	10 days	Tue 11/30/10	Mon 12/13/10	$66,922.69
52	**4.1.7 ELECTRICAL (DESIGN)**	**129 days**	**Tue 7/6/10**	**Fri 12/31/10**	**$351,344.14**
53	4.1.7.1 PREPARE/REVIEW/ISSUE ELECTRIC ONE-LI	15 days	Tue 11/16/10	Mon 12/6/10	$33,461.35
54	4.1.7.2 CONCEPTUAL UG ELECTRICAL DRWGS	10 days	Tue 11/30/10	Mon 12/13/10	$33,461.35
55	4.1.7.5 CONCEPTUAL CONDUIT & CABLE SCHEDULI	9 days	Tue 12/21/10	Fri 12/31/10	$33,461.35
56	4.1.7.3 CONCEPTUAL TRAY LAYOUT	15 days	Tue 11/30/10	Mon 12/20/10	$33,461.35
57	4.1.7.4 PREPARE/REVIEW/ISSUE AREA CLASSIFICA	15 days	Tue 11/30/10	Mon 12/20/10	$50,192.02
58	4.2.10 DEFINITIVE ESTIMATE	40 days	Tue 7/6/10	Mon 8/30/10	$167,306.73
59	**4.2 Compression Design**	**129 days**	**Tue 7/6/10**	**Fri 12/31/10**	**$684,938.04**
60	**4.2.1 DESIGN-CO2 COMPRESSION**	**1 day**	**Tue 7/6/10**	**Tue 7/6/10**	**$2,851.09**
61	4.2.1.1 CONTRACT AWARD	0 days	Tue 7/6/10	Tue 7/6/10	$0.00
62	4.2.1.2 RECEIVE CLIENT DOCUMENTS	1 day	Tue 7/6/10	Tue 7/6/10	$2,851.09
63	**4.2.3 SYSTEM**	**85 days**	**Wed 7/7/10**	**Tue 11/2/10**	**$417,855.43**
64	4.2.3.1 REVIEW DESIGN BASIS & DEVELOP BEDD	5 days	Wed 7/7/10	Tue 7/13/10	$11,994.57

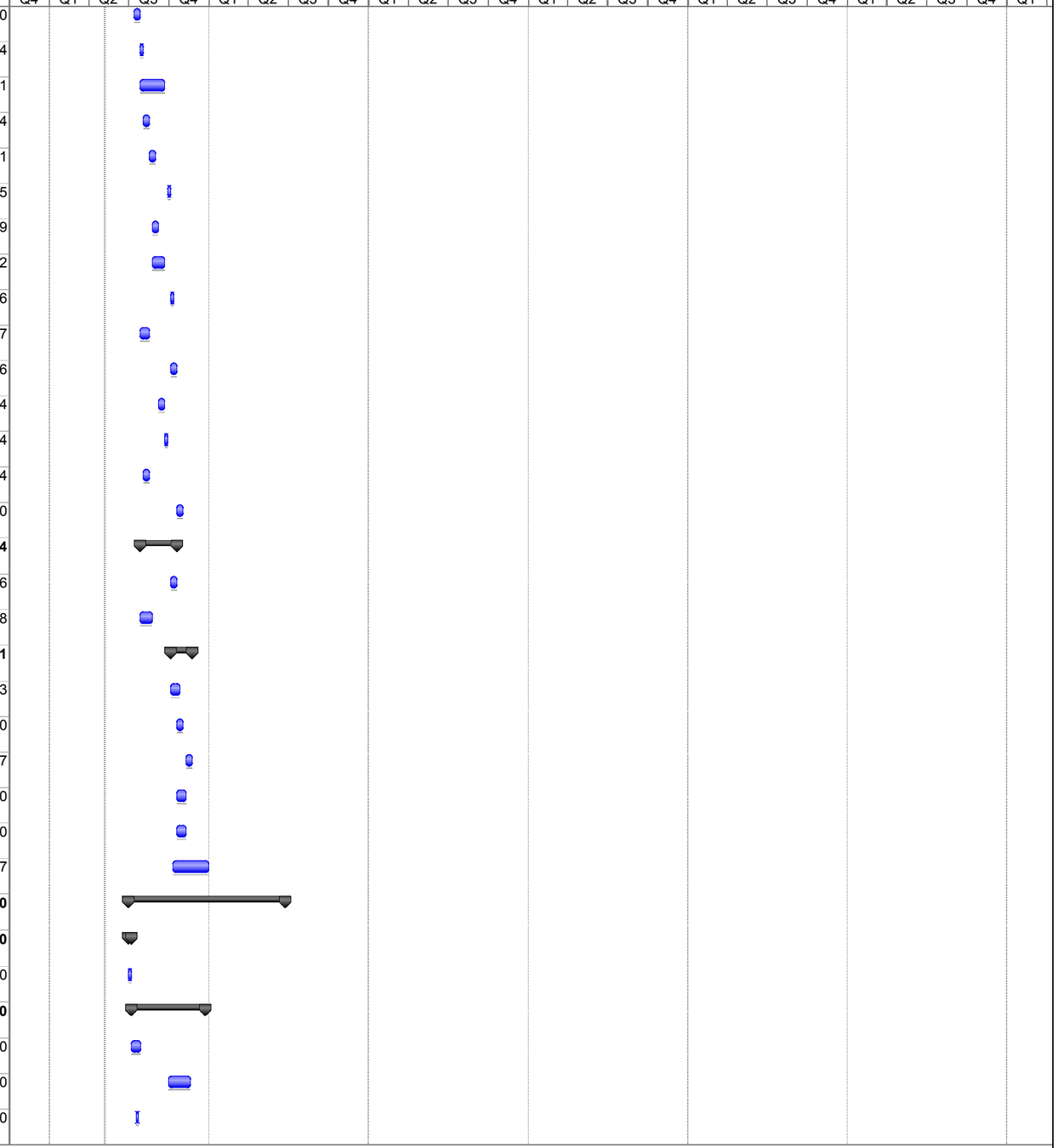


Project: Leucadia LCC CO2 Schedule
Date: Thu 5/6/10
3:25 PM

Task | Milestone | Rolled Up Task | Rolled Up Progress | External Tasks | Group By Summary
Progress | Summary | Rolled Up Milestone | Split | Project Summary | Deadline

Lake Charles CCS Project

ID	Task Name	Duration	Start	Finish	Total Cost
65	4.2.3.2 ISSUE/REVIEW/BALANCE - PFD	10 days	Wed 7/14/10	Tue 7/27/10	$24,016.30
66	4.2.3.3 ISSUE MATERIAL SELECTION DIAGRAMS	5 days	Wed 7/28/10	Tue 8/3/10	$12,021.74
67	4.2.3.4 DEVELOP/REVIEW/ISSUE - P&ID	40 days	Wed 7/28/10	Tue 9/21/10	$96,432.61
68	4.2.3.6 PREPARE EQUIPMENT DATA SHEETS	10 days	Wed 8/4/10	Tue 8/17/10	$24,071.74
69	4.2.3.8 ISSUE EQUIPMENT LIST	10 days	Wed 8/18/10	Tue 8/31/10	$24,107.61
70	4.2.3.13 RELIEF SCENARIO (PRELIM. RELIEF VALVE	5 days	Wed 9/29/10	Tue 10/5/10	$9,770.65
71	4.2.3.9 ISSUE CONTROL LOGIC DESCRIPTION	10 days	Wed 8/25/10	Tue 9/7/10	$24,126.09
72	4.2.3.10 DESIGN HYDRAULICS	20 days	Wed 8/25/10	Tue 9/21/10	$48,290.22
73	4.2.3.14 P&ID TRANSFER TO (3D) MODEL	5 days	Wed 10/6/10	Tue 10/12/10	$9,778.26
74	4.2.3.5 PRELIMINARY LINE SIZING	15 days	Wed 7/28/10	Tue 8/17/10	$36,094.57
75	4.2.3.15 ISSUE LINE SCHEDULE	10 days	Wed 10/6/10	Tue 10/19/10	$19,561.96
76	4.2.3.11 ISSUE INSTRUMENT DATA SHEETS	10 days	Wed 9/8/10	Tue 9/21/10	$24,163.04
77	4.2.3.12 RELIEF VALVE DATA SHEETS	5 days	Wed 9/22/10	Tue 9/28/10	$9,763.04
78	4.2.3.7 ISSUE UTILITY SUMMARY	10 days	Wed 8/4/10	Tue 8/17/10	$24,071.74
79	4.2.3.16 PIPING PLAN INDEX	10 days	Wed 10/20/10	Tue 11/2/10	$19,591.30
80	**4.2.6 PIPING (DESIGN)**	**60 days**	**Wed 7/28/10**	**Tue 10/19/10**	**$58,421.74**
81	4.2.6.2 DESIGN/ISSUE/REVIEW - U.G. PIPING	10 days	Wed 10/6/10	Tue 10/19/10	$19,561.96
82	4.2.6.1 DEVELOP PIPING CLASSES & SPECIFICATIO	20 days	Wed 7/28/10	Tue 8/24/10	$38,859.78
83	**4.2.7 ELECTRICAL (DESIGN)**	**35 days**	**Wed 10/6/10**	**Tue 11/23/10**	**$127,382.61**
84	4.2.7.1 PREPARE/REVIEW/ISSUE ELECTRIC ONE-LI	15 days	Wed 10/6/10	Tue 10/26/10	$29,355.43
85	4.2.7.2 CONCEPTUAL UG ELECTRICAL DRWGS	10 days	Wed 10/20/10	Tue 11/2/10	$19,591.30
86	4.2.7.5 CONCEPTUAL CONDUIT & CABLE SCHEDULI	10 days	Wed 11/10/10	Tue 11/23/10	$19,635.87
87	4.2.7.3 CONCEPTUAL TRAY LAYOUT	15 days	Wed 10/20/10	Tue 11/9/10	$29,400.00
88	4.2.7.4 PREPARE/REVIEW/ISSUE AREA CLASSIFICA	15 days	Wed 10/20/10	Tue 11/9/10	$29,400.00
89	4.2.10 DEFINITIVE ESTIMATE	60 days	Mon 10/11/10	Fri 12/31/10	$78,427.17
90	**4.3 Pipeline Design and Environmental Permitting**	**257 days**	**Thu 7/1/10**	**Fri 6/24/11**	**$2,385,102.40**
91	**4.3.1 Project Kickoff**	**5 days**	**Thu 7/1/10**	**Wed 7/7/10**	**$18,792.00**
92	4.3.1.1 Establish Project Criteria	5 days	Thu 7/1/10	Wed 7/7/10	$18,792.00
93	**4.3.2 Engineering and Design**	**121 days**	**Thu 7/8/10**	**Thu 12/23/10**	**$1,374,557.60**
94	4.3.2.1 Route Finalization	15 days	Thu 7/8/10	Wed 7/28/10	$140,941.80
95	4.3.2.2 Preliminary Civil and Easement Survey	36 days	Fri 10/1/10	Fri 11/19/10	$100,908.00
96	4.3.2.3 Hydraulic Calculations	5 days	Mon 7/19/10	Fri 7/23/10	$18,792.00

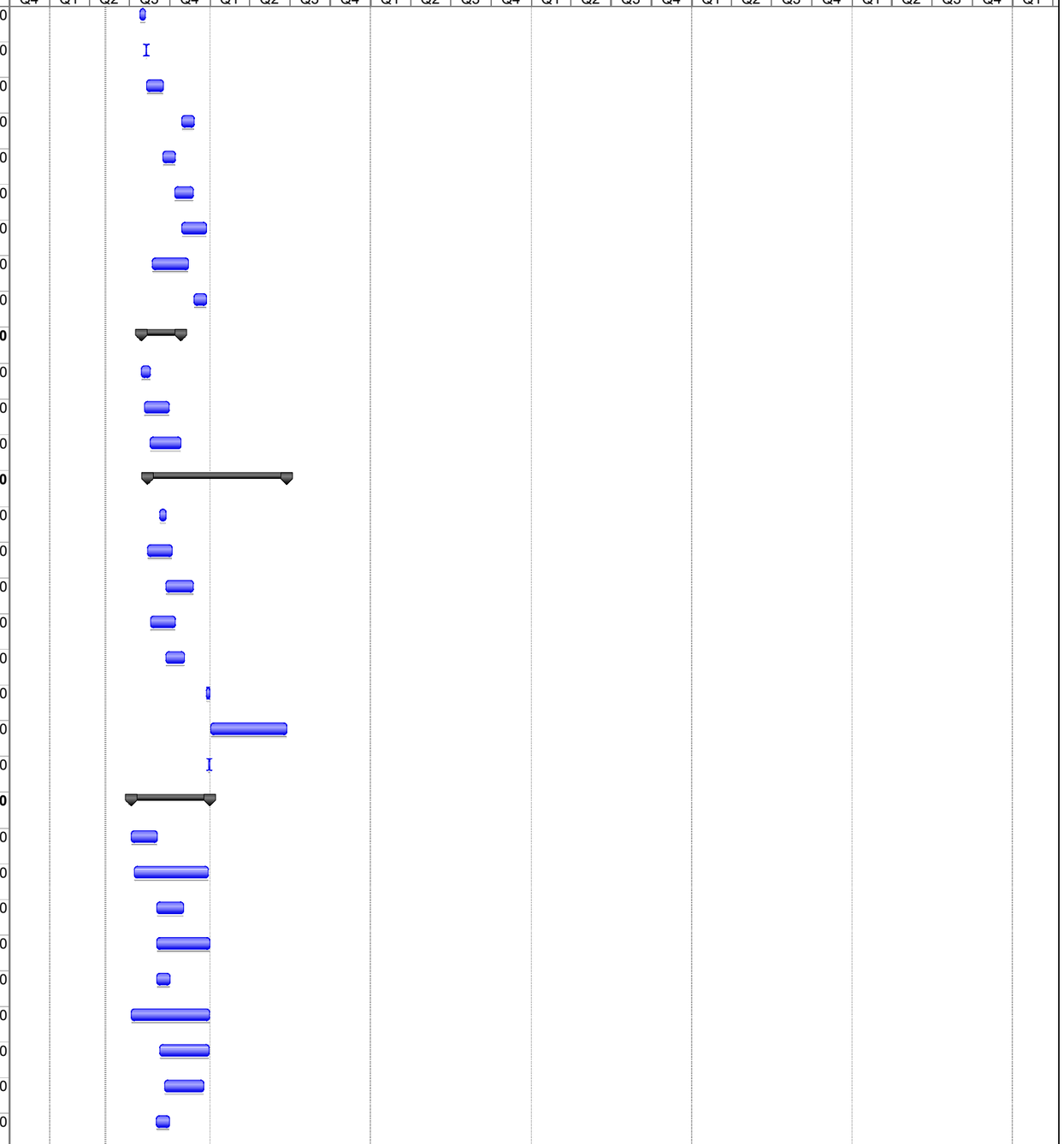


Project: Leucadia LCC CO2 Schedule
Date: Thu 5/6/10
3:25 PM

Task | Milestone | Rolled Up Task | Rolled Up Progress | External Tasks | Group By Summary
Progress | Summary | Rolled Up Milestone | Split | Project Summary | Deadline

Lake Charles CCS Project

ID	Task Name	Duration	Start	Finish	Total Cost
97	4.3.2.4 Prepare System PFD and P&IDs	10 days	Mon 7/26/10	Fri 8/6/10	$93,962.00
98	4.3.2.5 Determine Crossing Permit Requirements	1 day	Mon 8/9/10	Mon 8/9/10	$46,981.00
99	4.3.2.6 Development Material and Equipment Specifcati	28 days	Tue 8/10/10	Thu 9/16/10	$46,981.20
100	4.3.2.7 Prepare Alignment Drawings	20 days	Fri 10/29/10	Thu 11/25/10	$46,980.80
101	4.3.2.8 Prepare Landowner Plat Maps	20 days	Thu 9/16/10	Wed 10/13/10	$300,446.40
102	4.3.2.9 Prepare Permit Exhibits	30 days	Wed 10/13/10	Tue 11/23/10	$56,377.00
103	4.3.2.10 Prepare Pipeline Construction Details	40 days	Fri 10/29/10	Thu 12/23/10	$300,677.00
104	4.3.2.11 Design and Drawing Preparation for Facilities	60 days	Mon 8/23/10	Fri 11/12/10	$172,084.80
105	4.3.2.12 Cathodic Protection Design and Details	20 days	Fri 11/26/10	Thu 12/23/10	$49,425.60
106	**4.3.3 Right of Way/Land**	**64 days**	**Thu 7/29/10**	**Tue 10/26/10**	**$133,958.40**
107	4.3.3.1 Update Landowner Line List	14 days	Thu 7/29/10	Tue 8/17/10	$18,084.00
108	4.3.3.2 Obtain Access Permission for Preliminary Surve	40 days	Thu 8/5/10	Wed 9/29/10	$51,574.40
109	4.3.3.3 Perform Title Work and Market Study Appraisal	50 days	Wed 8/18/10	Tue 10/26/10	$64,300.00
110	**4.3.4 Environmental**	**227 days**	**Thu 8/12/10**	**Fri 6/24/11**	**$810,554.00**
111	4.3.4.1 Update Permit & NEPA Requirements	10 days	Thu 9/9/10	Wed 9/22/10	$4,874.40
112	4.3.4.2 Perform Environmental Field Surveys for Permitt	40 days	Thu 8/12/10	Wed 10/6/10	$29,373.00
113	4.3.4.3 Prepare and Submit Permit Applications	44 days	Thu 9/23/10	Tue 11/23/10	$11,372.00
114	4.3.4.4 Perform Cultural and Ecological Surveys, if requ	40 days	Thu 8/19/10	Wed 10/13/10	$43,139.80
115	4.3.4.5 Submit Cutural and Ecological Reports to COE,	30 days	Thu 9/23/10	Wed 11/3/10	$718,354.00
116	4.3.4.6 Prepare NEPA, FONSI, and COE Application	6 days	Fri 12/24/10	Fri 12/31/10	$3,440.80
117	4.3.4.7 Obtain NEPA, FONSI, and COE Permits	125 days	Mon 1/3/11	Fri 6/24/11	$0.00
118	4.3.5 Develop Construction Bid Packages	3 days	Wed 12/29/10	Fri 12/31/10	$47,240.40
119	**4.4 MVA Design**	**129 days**	**Tue 7/6/10**	**Fri 12/31/10**	**$3,733,770.00**
120	4.4.1 Administrative Tasks & Subcontracting	43 days	Tue 7/6/10	Thu 9/2/10	$0.00
121	4.4.2 Reservoir Modeling -Initial characterization and modelir	6 mons	Tue 7/13/10	Mon 12/27/10	$260,328.60
122	4.4.3 Characterization & Geochemical desc of faults	43 days	Thu 9/2/10	Mon 11/1/10	$25,694.60
123	4.4.4 Soil Gas -FeasibilityTest of Surveillance of P&A wells	87 days	Thu 9/2/10	Fri 12/31/10	$52,933.60
124	4.4.5 Ground Water Monitoring -Feasibility test of surveillanc	22 days	Thu 9/2/10	Fri 10/1/10	$23,554.60
125	4.4.6 AZMI (Above-zone monitoring interval) -Establish curre	128 days	Tue 7/6/10	Thu 12/30/10	$3,000,000.00
126	4.4.7 Logging - Feasibility test of surveillance of idle wells an	80 days	Thu 9/9/10	Wed 12/29/10	$300,000.00
127	4.4.8 Risk Assessment & Updated MVA plan and cost distrib	65 days	Mon 9/20/10	Fri 12/17/10	$71,258.60
128	Prepare DOE Design Report	22 days	Wed 9/1/10	Thu 9/30/10	$0.00

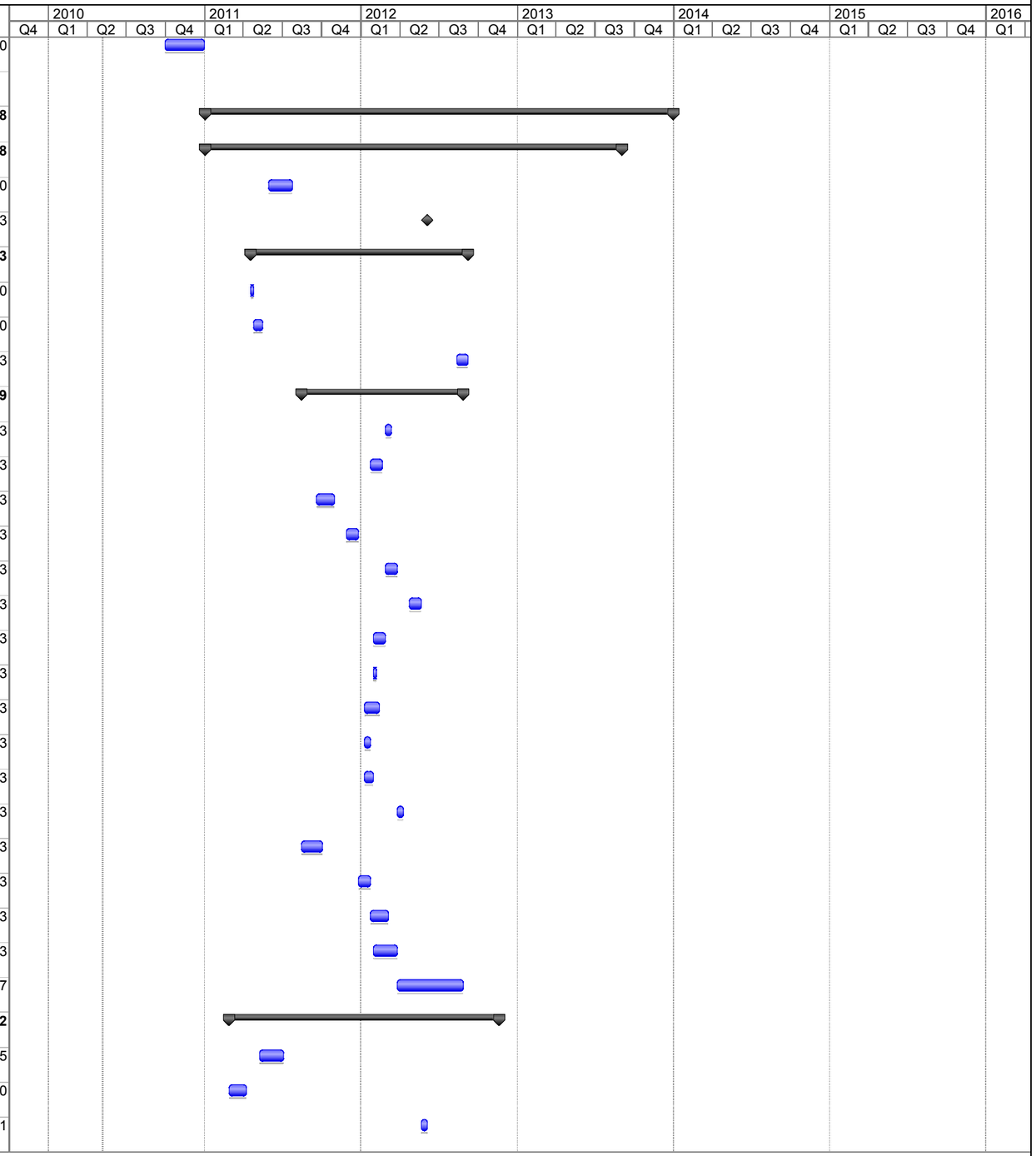


Project: Leucadia LCC CO2 Schedule
Date: Thu 5/6/10
3:25 PM

Task | Milestone | Rolled Up Task | Rolled Up Progress | External Tasks | Group By Summary
Progress | Summary | Rolled Up Milestone | Split | Project Summary | Deadline

Lake Charles CCS Project

ID	Task Name	Duration	Start	Finish	Total Cost
129	DECISION POINT 1 - End of Subphase 2A (DOE 90-day Re	66 days	Fri 10/1/10	Fri 12/31/10	$0.00
130					
131	**5.0 Sub-Phase-2B Construction (wbs level-3)**	**782 days**	**Mon 1/3/11**	**Tue 12/31/13**	**$407,711,706.08**
132	**5.1 Rectisol CO2 Capture Construction**	**696 days**	**Mon 1/3/11**	**Mon 9/2/13**	**$290,714,953.18**
133	5.1.1 CONSTRUCTABILITY REVIEW - EQUIPMENT LAYOU	40 days	Tue 5/31/11	Mon 7/25/11	$158,282.00
134	5.1.2 ENGINEERING 95% COMPLETE	0 days	Mon 6/4/12	Mon 6/4/12	$164,140.83
135	**5.1.3 SYSTEM**	**364 days**	**Tue 4/19/11**	**Fri 9/7/12**	**$1,477,267.43**
136	5.1.3.1 P&ID INSTRUMENT EXTRACT	5 days	Tue 4/19/11	Mon 4/25/11	$656,563.30
137	5.1.3.2 P.H.A. (HAZOP)	15 days	Tue 4/26/11	Mon 5/16/11	$656,563.30
138	5.1.3.3 OPERATION MANUALS	20 days	Mon 8/13/12	Fri 9/7/12	$164,140.83
139	**5.1.5 CIVIL & STRUCTURAL**	**270 days**	**Tue 8/16/11**	**Mon 8/27/12**	**$15,660,386.39**
140	5.1.5.17 DESIGN/REVIEW/ISSUE - PIPERACK FOUNI	10 days	Tue 2/28/12	Mon 3/12/12	$164,140.83
141	5.1.5.7 CIVIL UG DRWGS (SEWER)	20 days	Tue 1/24/12	Mon 2/20/12	$164,140.83
142	5.1.5.14 INPUT/REVIEW/ISSUE UNDERGROUND PIPI	30 days	Tue 9/20/11	Mon 10/31/11	$164,140.83
143	5.1.5.2 ISSUE AND REVIEW BUILDING LAYOUT & RE	20 days	Tue 11/29/11	Mon 12/26/11	$164,140.83
144	5.1.5.11 ENG DESIGN/INPUT/REVIEW/ISSUE - PLATF	20 days	Tue 2/28/12	Mon 3/26/12	$164,140.83
145	5.1.5.12 ENG DESIGN/INPUT/REVIEW/IS - MISC PLTF	20 days	Tue 4/24/12	Mon 5/21/12	$164,140.83
146	5.1.5.8 ENG DESIGN/INPUT/REVIEW/ISSUE-PIPE/ELI	20 days	Tue 1/31/12	Mon 2/27/12	$164,140.83
147	5.1.5.9 SCOPE WRITE-UP FOR CIVIL/STRUCTURAL	5 days	Tue 1/31/12	Mon 2/6/12	$115,656.33
148	5.1.5.4 ENG DESIGN/REVIEW/ISSUE - PILING	25 days	Tue 1/10/12	Mon 2/13/12	$164,140.83
149	5.1.5.5 ENG DESIGN/INPUT/REVIEW - BUILDING	10 days	Tue 1/10/12	Mon 1/23/12	$164,140.83
150	5.1.5.6 ENG DESIGN/INPUT/REVIEW/ISSUE - TOWEF	15 days	Tue 1/10/12	Mon 1/30/12	$164,140.83
151	5.1.5.13 ENG DESIGN/INPUT/REVIEW/ISSUE - PIPE/E	10 days	Tue 3/27/12	Mon 4/9/12	$164,140.83
152	5.1.5.1 ENG DESIGN/INPUT/REVIEW/ISSUE - ELECT	35 days	Tue 8/16/11	Mon 10/3/11	$164,140.83
153	5.1.5.3 ENG DESIGN/INPUT/REVIEW/ISSUE - MJR EC	20 days	Tue 12/27/11	Mon 1/23/12	$164,140.83
154	5.1.5.15 PREP REQ/IFB/BID TAB/VNDR ENG - BUILDI	30 days	Tue 1/24/12	Mon 3/5/12	$164,140.83
155	5.1.5.10 PREP REQ/IFB/BID TAB/VNDR ENG - STR. S	40 days	Tue 1/31/12	Mon 3/26/12	$164,140.83
156	5.1.5.16 AWARD/FAB/SHIP - BUILDINGS	110 days	Tue 3/27/12	Mon 8/27/12	$13,082,617.67
157	**5.1.6 PIPING**	**451 days**	**Mon 2/28/11**	**Mon 11/19/12**	**$47,679,533.62**
158	5.1.6.1 PREP REQ/IFB/BID TAB/VNDR ENG - TAGGEI	40 days	Tue 5/10/11	Mon 7/4/11	$328,281.65
159	5.1.6.2 VESSEL PLATFORM & NOZZLE ORIENTATIOI	30 days	Mon 2/28/11	Fri 4/8/11	$656,563.30
160	5.1.6.14 ISSUE ISOMETRICS	10 days	Tue 5/22/12	Mon 6/4/12	$1,313,126.61

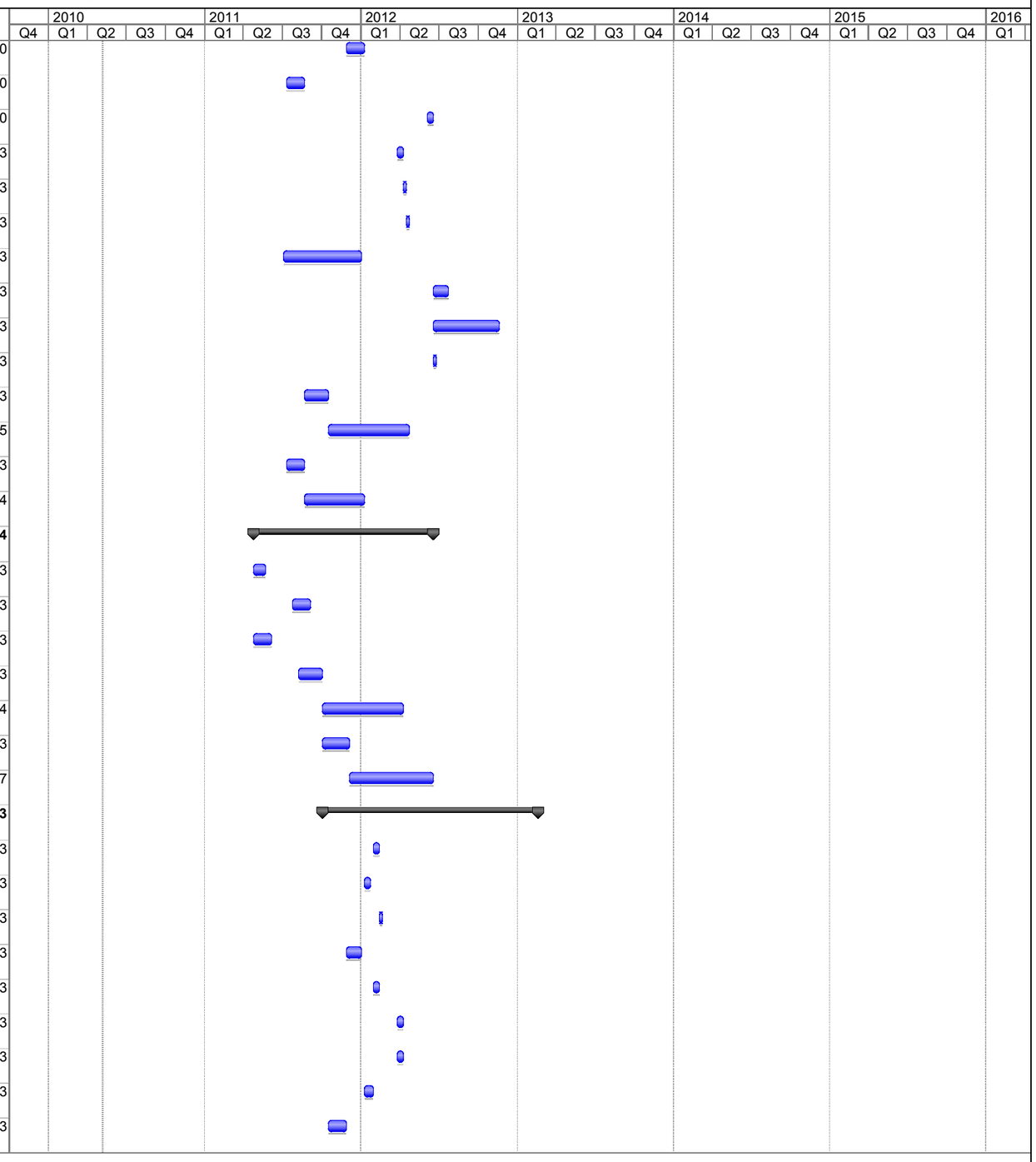


Project: Leucadia LCC CO2 Schedule
Date: Thu 5/6/10
3:25 PM

Task | Milestone | Rolled Up Task | Rolled Up Progress | External Tasks | Group By Summary
Progress | Summary | Rolled Up Milestone | Split | Project Summary | Deadline

Lake Charles CCS Project

ID	Task Name	Duration	Start	Finish	Total Cost
161	5.1.6.10 PIPE STRESS ANALYSIS	30 days	Tue 11/29/11	Mon 1/9/12	$656,563.30
162	5.1.6.4 TIE-IN DWGS	30 days	Tue 7/12/11	Mon 8/22/11	$656,563.30
163	5.1.6.15 MES RUN - MTO	10 days	Tue 6/5/12	Mon 6/18/12	$656,563.30
164	5.1.6.11 SCOPE WRITE-UPS - MECHANICAL	10 days	Tue 3/27/12	Mon 4/9/12	$164,140.83
165	5.1.6.12 SCOPE WRITE-UPS - INSULATION	5 days	Tue 4/10/12	Mon 4/16/12	$164,140.83
166	5.1.6.13 SCOPE WRITE-UPS - PAINTING	5 days	Tue 4/17/12	Mon 4/23/12	$164,140.83
167	5.1.6.3 AWARD/FAB/SHIP - TAGGED VALVES	130 days	Tue 7/5/11	Mon 1/2/12	$5,413,978.33
168	5.1.6.16 PREPARE REQ/IFB/BID/TAB - PIPE SPECIAL	25 days	Tue 6/19/12	Mon 7/23/12	$164,140.83
169	5.1.6.17 AWARD/FAB/SHIP - PIPE SPECIALS (TRAPS	110 days	Tue 6/19/12	Mon 11/19/12	$5,413,978.33
170	5.1.6.18 FINAL REQUISITION - BULK PIPE	5 days	Tue 6/19/12	Mon 6/25/12	$184,140.83
171	5.1.6.6 PREP REQ/IFB/BID TAB/VNDR ENG - SHOP F	40 days	Tue 8/23/11	Mon 10/17/11	$164,140.83
172	5.1.6.9 AWARD/FAB/SHIP - SHOP FAB PIPE	135 days	Tue 10/18/11	Mon 4/23/12	$26,807,266.35
173	5.1.6.5 PREP REQ/IFB/BID TAB/VNDR ENG - PVF ANI	30 days	Tue 7/12/11	Mon 8/22/11	$164,140.83
174	5.1.6.7 AWARD/FAB/SHIP - PVF AND MISC PIPE	100 days	Tue 8/23/11	Mon 1/9/12	$4,607,663.34
175	**5.1.8 INSTRUMENTATION**	**300 days**	**Tue 4/26/11**	**Mon 6/18/12**	**$8,158,322.04**
176	5.1.8.1 PREP/REVIEW/ISSUE - INSTRUMENT INDEX	20 days	Tue 4/26/11	Mon 5/23/11	$164,140.83
177	5.1.8.3 PREP/REVIEW/ISSUE - I/O LIST	30 days	Tue 7/26/11	Mon 9/5/11	$164,140.83
178	5.1.3.2 PREPARE & REVIEW - LOGIC DIAGRAMS	30 days	Tue 4/26/11	Mon 6/6/11	$164,140.83
179	5.1.8.4 PREP REQ/IFB/BID TAB/VNDR ENG-FLOW EL	40 days	Tue 8/9/11	Mon 10/3/11	$164,140.83
180	5.1.8.5 AWARD/FAB/SHIP - FLOW ELEMENTS	135 days	Tue 10/4/11	Mon 4/9/12	$3,860,524.94
181	5.1.8.6 PREP REQ/IFB/BID TAB - INSTRUMENTS	45 days	Tue 10/4/11	Mon 12/5/11	$164,140.83
182	5.1.8.7 AWARD/FAB/SHIP - INSTRUMENTS	140 days	Tue 12/6/11	Mon 6/18/12	$3,477,092.97
183	**5.1.7 ELECTRICAL**	**360 days**	**Tue 10/4/11**	**Mon 2/18/13**	**$20,506,880.33**
184	5.1.7.12 PRELIM. ELECT LAYOUT (PANELS / RECEP	10 days	Tue 1/31/12	Mon 2/13/12	$164,140.83
185	5.1.7.8 PRELIM/REVIEW/ISSUE U.G.ELECT DRAWIN(	10 days	Tue 1/10/12	Mon 1/23/12	$164,140.83
186	5.1.7.16 PREP/REVIEW/INSTR/ISSUE GROUNDING D	5 days	Tue 2/14/12	Mon 2/20/12	$164,140.83
187	5.1.7.4 PREP/REVIEW/ISSUE PANEL & CABINET DR/	25 days	Tue 11/29/11	Mon 1/2/12	$164,140.83
188	5.1.7.13 PREP/REVIEW/ISSUE POWER PLANS	10 days	Tue 1/31/12	Mon 2/13/12	$164,140.83
189	5.1.7.17 PREP/REVIEW/ISSUE I/E INSTRUMENT PLA	10 days	Tue 3/27/12	Mon 4/9/12	$164,140.83
190	5.1.7.18 PREP/REVIEW/ISSUE I / E INSTALLATION DI	10 days	Tue 3/27/12	Mon 4/9/12	$164,140.83
191	5.1.7.9 3D MODEL/PREP/REVIEW/ISSUE TRAY PLAN	15 days	Tue 1/10/12	Mon 1/30/12	$164,140.83
192	5.1.7.3 PREP/REVIEW/ISSUE LOOP DIAGRAMS	30 days	Tue 10/18/11	Mon 11/28/11	$164,140.83

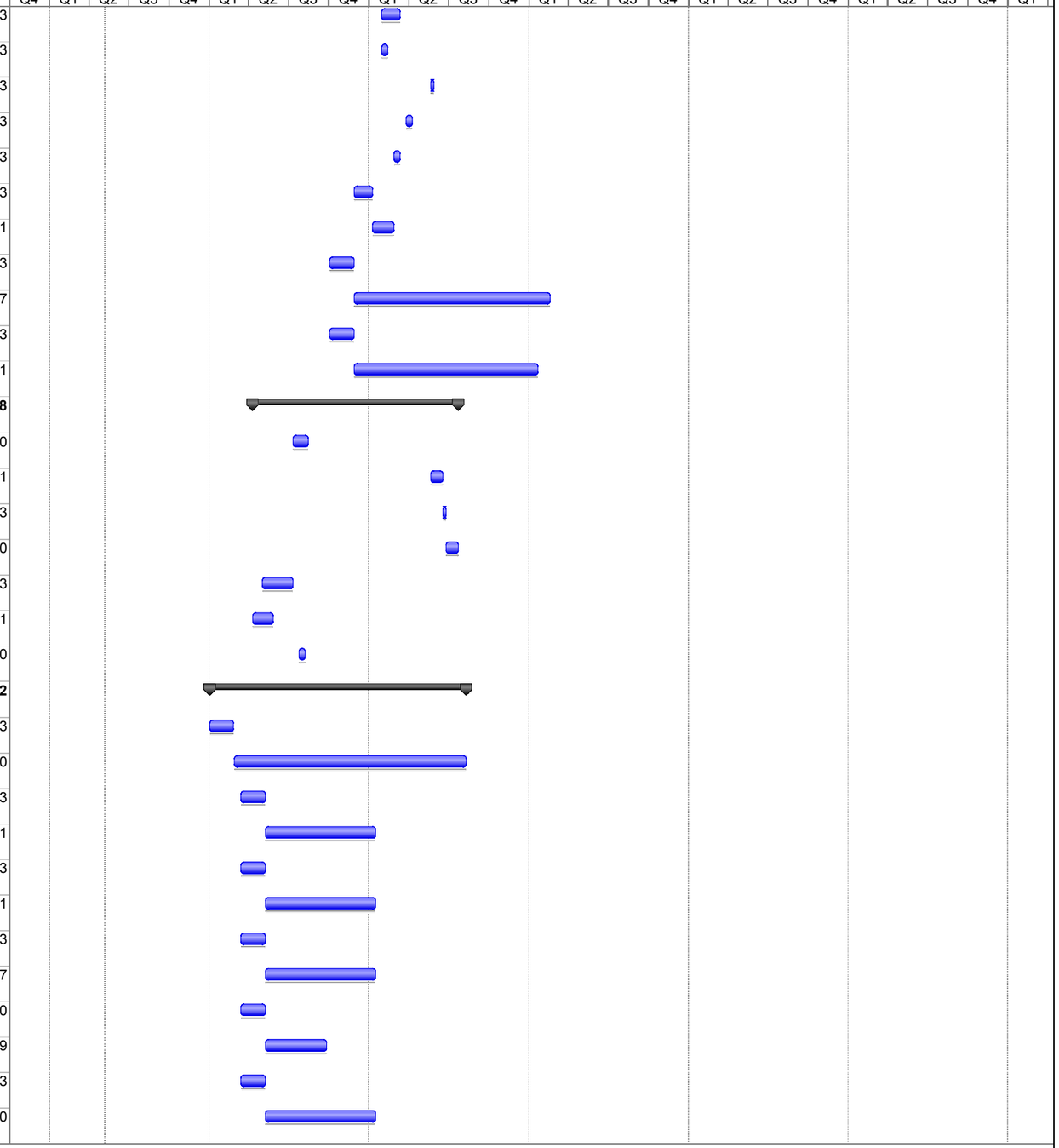


Project: Leucadia LCC CO2 Schedule
Date: Thu 5/6/10
3:25 PM

Task | Milestone | Rolled Up Task | Rolled Up Progress | External Tasks | Group By Summary
Progress | Summary | Rolled Up Milestone | Split | Project Summary | Deadline

Lake Charles CCS Project

ID	Task Name	Duration	Start	Finish	Total Cost
193	5.1.7.14 PREP/REVIEW/ISSUE MOTOR SCHEMATIC I	30 days	Tue 1/31/12	Mon 3/12/12	$164,140.83
194	5.1.7.15 PREP/REVIEW/ISSUE WIRING DIAGRAMS	10 days	Tue 1/31/12	Mon 2/13/12	$164,140.83
195	5.1.7.20 CONDUIT & CABLE SCHEDULE - (PWR/CNTI	5 days	Tue 5/22/12	Mon 5/28/12	$164,140.83
196	5.1.7.19 ELECTRICAL MATERIAL TAKE-OFF	10 days	Tue 3/27/12	Mon 4/9/12	$164,140.83
197	5.1.7.11 PREP/REVIEW/ISSUE INSTRUMENT WIRING	10 days	Tue 2/28/12	Mon 3/12/12	$164,140.83
198	5.1.7.5 PREP REQ/IFB/BID TAB/VNDR ENG - ELEC BI	30 days	Tue 11/29/11	Mon 1/9/12	$164,140.83
199	5.1.7.10 AWARD/FAB/SHIP - ELEC BULKS	35 days	Tue 1/10/12	Mon 2/27/12	$13,043,166.61
200	5.1.7.1 PREP REQ/IFB/BID TAB/VNDR ENG - TRANSF	40 days	Tue 10/4/11	Mon 11/28/11	$164,140.83
201	5.1.7.6 AWARD/FAB/SHIP - TRANSFORMERS	320 days	Tue 11/29/11	Mon 2/18/13	$1,579,658.67
202	5.1.7.2 PREP REQ/IFB/BID TAB/VNDR ENG - ELEC SV	40 days	Tue 10/4/11	Mon 11/28/11	$164,140.83
203	5.1.7.7AWARD/FAB/SHIP - ELEC SWITCHGEAR	300 days	Tue 11/29/11	Mon 1/21/13	$3,093,661.01
204	**5.1.9 MODELING**	**336 days**	**Mon 4/11/11**	**Mon 7/23/12**	**$4,924,224.78**
205	5.1.9.4 INITIAL EQUIPMENT MODELING IN (3D) MOD	25 days	Tue 7/12/11	Mon 8/15/11	$656,563.30
206	5.1.9.5 DEVELOP MODEL TO 3RD STAGE	20 days	Tue 5/22/12	Mon 6/18/12	$1,313,126.61
207	5.1.9.2 CLIENT MODEL REVIEW	5 days	Tue 6/19/12	Mon 6/25/12	$164,140.83
208	5.1.9.6 DEVELOP MODEL TO FINAL STAGE	20 days	Tue 6/26/12	Mon 7/23/12	$656,563.30
209	5.1.9.1 MODEL AUTOROUTER	50 days	Tue 5/3/11	Mon 7/11/11	$164,140.83
210	5.1.9.3 PIPE STRESS ANALYSIS	35 days	Mon 4/11/11	Fri 5/27/11	$1,313,126.61
211	5.1.9.7 PIPERACK STUDY (PIPING & ELECTRICAL)	10 days	Tue 7/26/11	Mon 8/8/11	$656,563.30
212	**5.1.4 EQUIPMENT**	**420 days**	**Mon 1/3/11**	**Fri 8/10/12**	**$119,040,292.42**
213	5.1.4.1 PREP REQ/IFB/BID TAB/VNDR ENG - COMPF	40 days	Mon 1/3/11	Fri 2/25/11	$164,140.83
214	5.1.4.2 AWARD/FAB/SHIP - COMPRESSORS & PLC	380 days	Mon 2/28/11	Fri 8/10/12	$22,775,691.40
215	5.1.4.5 PREP REQ/ISB/BID TAB/VNDR ENG - VESSEL	40 days	Tue 3/15/11	Mon 5/9/11	$164,140.83
216	5.1.4.6 AWARD/FAB/SHIP - VESSEL INTERNALS	180 days	Tue 5/10/11	Mon 1/16/12	$15,205,679.71
217	5.1.4.7 PREP REQ/IFB/BID TAB/VNDR ENG - PUMPS	40 days	Tue 3/15/11	Mon 5/9/11	$164,140.83
218	5.1.4.8 AWARD/FAB/SHIP - PUMPS	180 days	Tue 5/10/11	Mon 1/16/12	$15,205,679.71
219	5.1.4.9 PREP REQ/IFB/BID TAB/VNDR ENG - SHOP F	40 days	Tue 3/15/11	Mon 5/9/11	$164,140.83
220	5.1.4.10 AWARD/FAB/SHIP - SHOP FAB PRESSURE V	180 days	Tue 5/10/11	Mon 1/16/12	$45,485,726.47
221	5.1.4.12 PREP REQ/IFB/BID TAB/VNDR ENG - FIELD	40 days	Tue 3/15/11	Mon 5/9/11	$656,563.30
222	5.1.4.13 AWARD/FAB/SHIP - FIELD ERECTED TANKS	100 days	Tue 5/10/11	Mon 9/26/11	$8,226,574.99
223	5.1.4.14 PREP REQ/IFB/BID TAB/VNDR ENG - HEAT E	40 days	Tue 3/15/11	Mon 5/9/11	$164,140.83
224	5.1.4.15 AWARD/FAB/SHIP - HEAT EXCHANGERS	180 days	Tue 5/10/11	Mon 1/16/12	$10,663,672.70

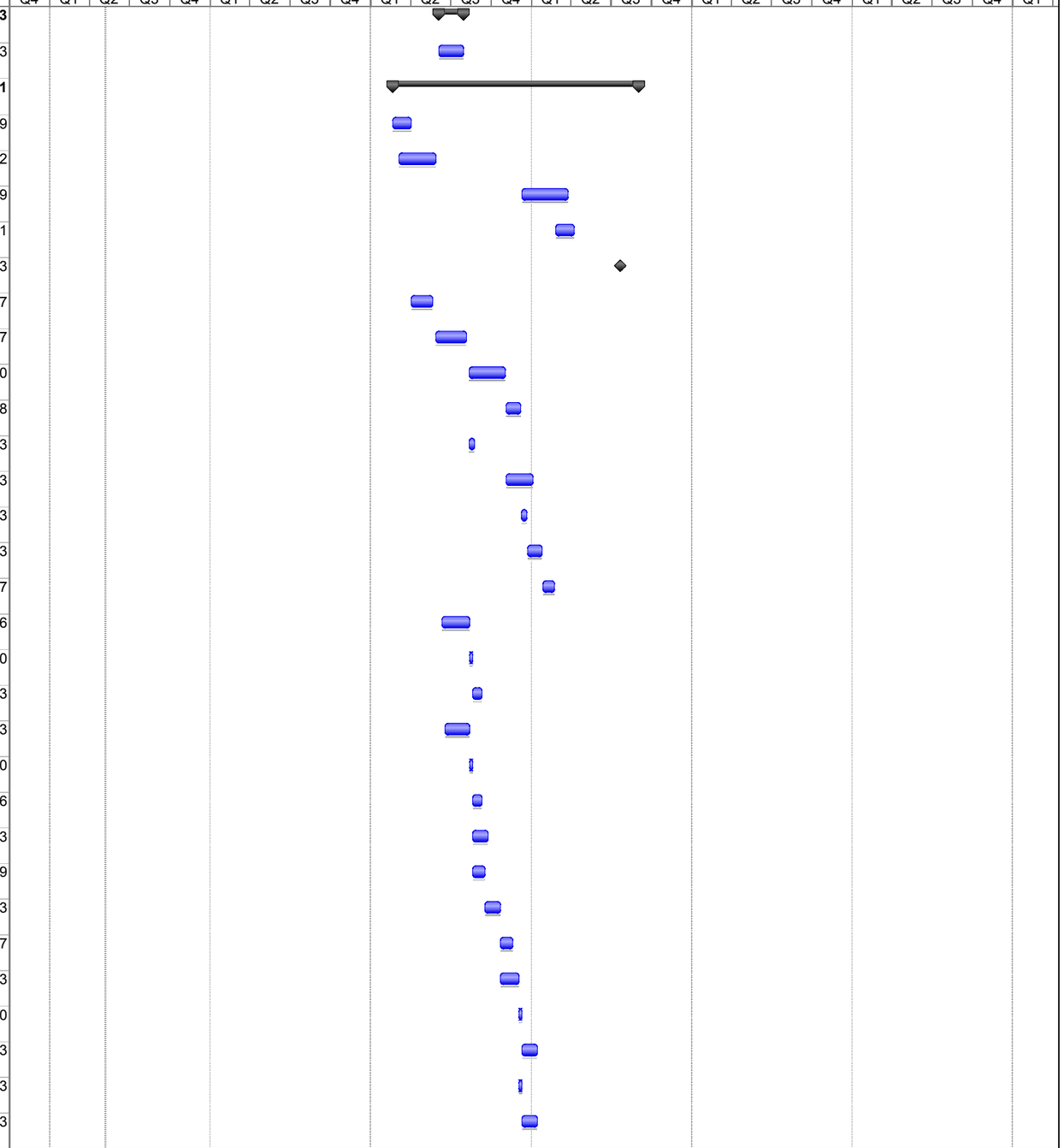


Project: Leucadia LCC CO2 Schedule
Date: Thu 5/6/10
3:25 PM

Task | Milestone | Rolled Up Task | Rolled Up Progress | External Tasks | Group By Summary
Progress | Summary | Rolled Up Milestone | Split | Project Summary | Deadline

Lake Charles CCS Project

ID	Task Name	Duration	Start	Finish	Total Cost
225	**5.1.11 SUBCONTRACT PACKAGES**	**40 days**	**Tue 6/5/12**	**Mon 7/30/12**	**$165,656.33**
226	5.1.11.2 INQUIRE/QUOTE/BID TAB/AWARD - GENER/	40 days	Tue 6/5/12	Mon 7/30/12	$165,656.33
227	**5.1.12 CONSTRUCTION**	**400 days**	**Tue 2/21/12**	**Mon 9/2/13**	**$72,779,967.01**
228	5.1.19.1 CONSTR - MOBILIZE & SITEWORK	30 days	Tue 2/21/12	Mon 4/2/12	$1,504,842.59
229	5.1.12.1 CONSTR - UNDERGROUND	60 days	Tue 3/6/12	Mon 5/28/12	$2,765,439.12
230	5.1.18.1 CONSTR - INSULATE & PAINT	75 days	Tue 12/11/12	Mon 3/25/13	$547,572.79
231	5.1.21.1 CONSTR - FINAL MECH / TEST TRAIN 1	30 days	Tue 2/26/13	Mon 4/8/13	$355,856.81
232	5.1.21.2 MECHANICAL COMPLETION TRAIN 1	0 days	Mon 7/22/13	Mon 7/22/13	$1,575,751.93
233	5.1.12.2 SITE FOUNDATION PILING	35 days	Tue 4/3/12	Mon 5/21/12	$2,846,854.47
234	5.1.13.1 EXC, F/R/P FOUNDATION COMPRESSORS	50 days	Tue 5/29/12	Mon 8/6/12	$2,846,854.47
235	5.1.14.5 SET COMPRESSORS TRAIN 1	60 days	Mon 8/13/12	Fri 11/2/12	$656,563.30
236	5.1.13.19 COMPRESSORS STEEL ERECTION TRAIN	25 days	Mon 11/5/12	Fri 12/7/12	$739,288.78
237	5.1.13.20 COMPRESSORS GROUNDING TRAIN 1	10 days	Mon 8/13/12	Fri 8/24/12	$164,140.83
238	5.1.15.11 COMPRESSORS PIPING TRAIN 1	45 days	Mon 11/5/12	Fri 1/4/13	$164,140.83
239	5.1.16.16 COMPRESSORS ELECTRICAL TRAIN 1	10 days	Mon 12/10/12	Fri 12/21/12	$164,140.83
240	5.1.17.6 COMPRESSORS INSTRUMENTATION TRAIN	25 days	Mon 12/24/12	Fri 1/25/13	$164,140.83
241	5.1.15.12 HYDRO TEST COMPRESSORS TRAIN 1	20 days	Mon 1/28/13	Fri 2/22/13	$32,828.17
242	5.1.13.21 EXC, F/R/P FDN VESSEL INTERNALS TRAI	45 days	Tue 6/12/12	Mon 8/13/12	$931,004.76
243	5.1.14.3 SET VESSEL INTERNALS TRAIN 1	5 days	Tue 8/14/12	Mon 8/20/12	$656,563.30
244	5.1.13.9 VESSEL INTERNALS FIELD DRESS TRAIN 1	15 days	Tue 8/21/12	Mon 9/10/12	$164,140.83
245	5.1.13.22 EXC, F/R/P FOUNDATION SHOP FAB PRES	40 days	Tue 6/19/12	Mon 8/13/12	$3,175,136.13
246	5.1.14.4 SET EQUIPMENT SHOP FAB PRESSURE VE	5 days	Tue 8/14/12	Mon 8/20/12	$656,563.30
247	5.1.13.10 SHOP FAB PRESSURE VESSELS STEEL EI	15 days	Tue 8/21/12	Mon 9/10/12	$931,004.76
248	5.1.15.1 SHOP FAB PRESSURE VESSELS PIPING TR	25 days	Tue 8/21/12	Mon 9/24/12	$164,140.83
249	5.1.16.9 SHOP FAB PRESSURE VESSELS ELECTRCI	20 days	Tue 8/21/12	Mon 9/17/12	$1,697,868.69
250	5.1.17.1 SHOP FAB PRESSURE VESSELS INSTRUME	25 days	Tue 9/18/12	Mon 10/22/12	$164,140.83
251	5.1.15.6 HYDRO TEST SHOP FAB PRESSURE VESSE	20 days	Tue 10/23/12	Mon 11/19/12	$32,828.17
252	5.1.13.23 EXC, F/R/P FND HEAT EXCHANGERS TRAI	30 days	Tue 10/23/12	Mon 12/3/12	$164,140.83
253	5.1.16.4 SET HEAT EXCHANGERS TRAIN 1	5 days	Tue 12/4/12	Mon 12/10/12	$656,563.30
254	5.1.13.15 HEAT EXCHANGERS STEEL & PLATFORMS	25 days	Tue 12/11/12	Mon 1/14/13	$164,140.83
255	5.1.13.11 HEAT EXCHANGERS GROUNDING TRAIN	5 days	Tue 12/4/12	Mon 12/10/12	$164,140.83
256	5.1.15.2 HEAT EXCHANGERS PIPING TRAIN 1	25 days	Tue 12/11/12	Mon 1/14/13	$164,140.83

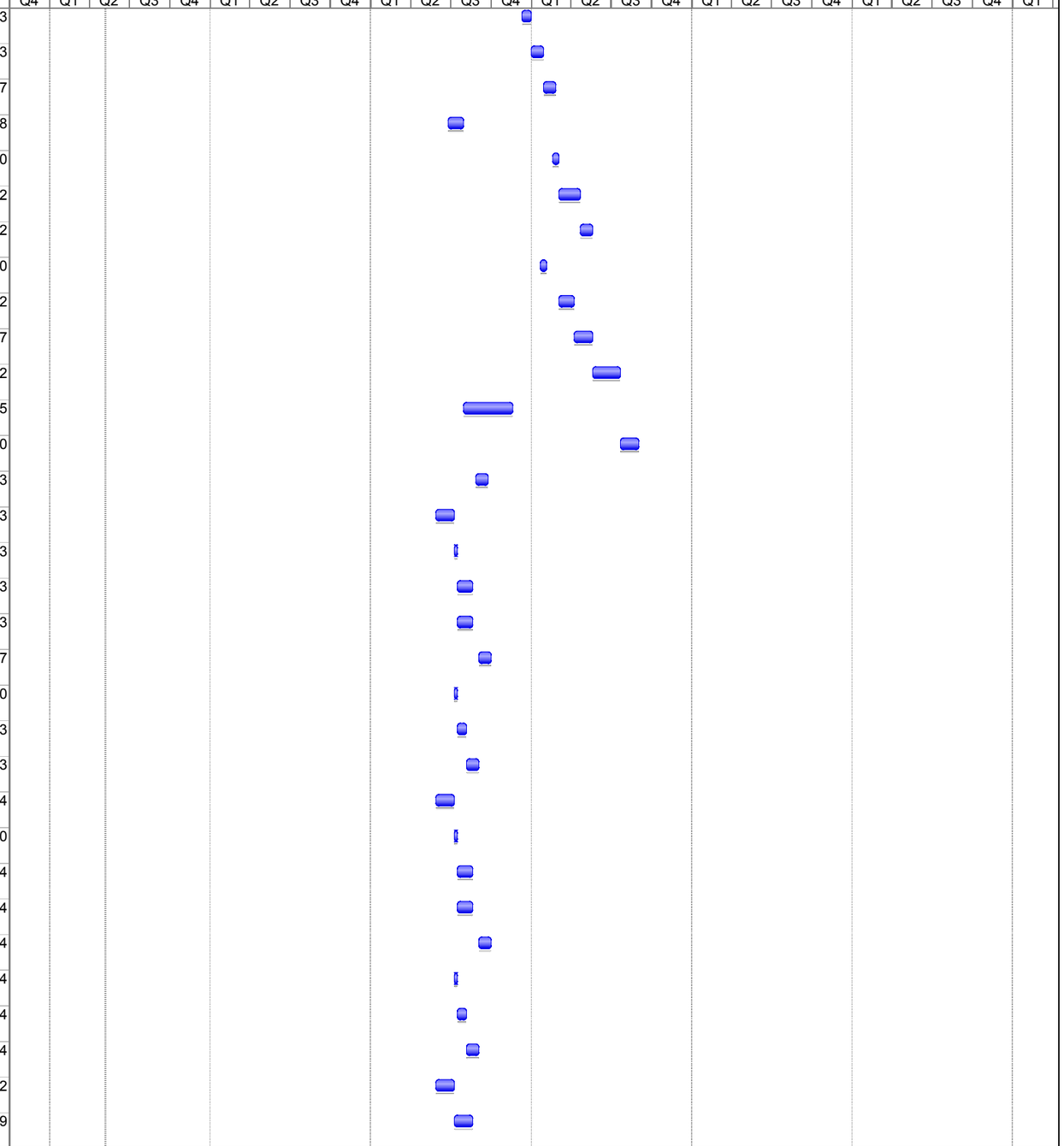


Project: Leucadia LCC CO2 Schedule
Date: Thu 5/6/10
3:25 PM

Task | Milestone | Rolled Up Task | Rolled Up Progress | External Tasks | Group By Summary
Progress | Summary | Rolled Up Milestone | Split | Project Summary | Deadline

Lake Charles CCS Project

ID	Task Name	Duration	Start	Finish	Total Cost
257	5.1.16.10 HEAT EXCHANGERS ELECTRICAL TRAIN 1	15 days	Tue 12/11/12	Mon 12/31/12	$164,140.83
258	5.1.17.2 HEAT EXCHANGERS INSTRUMENTATION T	20 days	Tue 1/1/13	Mon 1/28/13	$164,140.83
259	5.1.15.7 HYDRO TEST HEAT EXCHANGERS TRAIN 1	20 days	Tue 1/29/13	Mon 2/25/13	$32,828.17
260	5.1.13.4 EXC, F/R/P FOUNDATIONS FOR ELECTRICA	25 days	Tue 6/26/12	Mon 7/30/12	$1,905,081.68
261	5.1.14.1 SET TRANSFORMERS	10 days	Tue 2/19/13	Mon 3/4/13	$733,249.70
262	5.1.16.2 DRESS TRANSFORMERS	35 days	Tue 3/5/13	Mon 4/22/13	$240,827.22
263	5.1.16.14 INSTALL ISOPHASE BUSS	20 days	Tue 4/23/13	Mon 5/20/13	$240,827.22
264	5.1.14.2 SET SWITCHGEAR	10 days	Tue 1/22/13	Mon 2/4/13	$733,249.70
265	5.1.16.3 INSTALL CABLE TRAY	25 days	Tue 3/5/13	Mon 4/8/13	$240,827.22
266	5.1.16.8 ELECTRICAL CONDUIT TRAIN 1	30 days	Tue 4/9/13	Mon 5/20/13	$569,108.87
267	5.1.16.15 PULL AND TERMINATE TRAIN 1	45 days	Tue 5/21/13	Mon 7/22/13	$240,827.22
268	5.1.16.1 SWITCHYARD CONTRACTOR	80 days	Tue 7/31/12	Mon 11/19/12	$207,999.05
269	5.1.22.1 START UP TRAIN 1	30 days	Tue 7/23/13	Mon 9/2/13	$656,563.30
270	5.1.20.1 CONSTR - BUILDING	20 days	Tue 8/28/12	Mon 9/24/12	$164,140.83
271	5.1.13.6 EXC, F/R/P FND PUMPS TRAINS 1 & 2	30 days	Tue 5/29/12	Mon 7/9/12	$164,140.83
272	5.1.13.12 PUMPS GROUNDING TRAIN 1	5 days	Tue 7/10/12	Mon 7/16/12	$164,140.83
273	5.1.13.16 PUMPS STEEL & PLATFORMS TRAIN 1	25 days	Tue 7/17/12	Mon 8/20/12	$164,140.83
274	5.1.15.3 PUMPS PIPING TRAIN 1	25 days	Tue 7/17/12	Mon 8/20/12	$164,140.83
275	5.1.15.8 HYDRO TEST PUMPS TRAIN 1	20 days	Tue 9/4/12	Mon 10/1/12	$32,828.17
276	5.1.16.5 SET PUMPS TRAIN 1	5 days	Tue 7/10/12	Mon 7/16/12	$656,563.30
277	5.1.16.11 PUMPS ELECTRICAL TRAIN 1	15 days	Tue 7/17/12	Mon 8/6/12	$164,140.83
278	5.1.17.3 PUMPS INSTRUMENTATION TRAIN 1	20 days	Tue 8/7/12	Mon 9/3/12	$164,140.83
279	5.1.13.7 EXC, F/R/P FND FIELD ERECTED TANKS TR	30 days	Tue 5/29/12	Mon 7/9/12	$1,423,427.24
280	5.1.13.13 FIELD ERECTED TANKS GROUNDING TRA	5 days	Tue 7/10/12	Mon 7/16/12	$656,563.30
281	5.1.13.17 FIELD ERECTED TANKS STEEL & PLATFOI	25 days	Tue 7/17/12	Mon 8/20/12	$1,423,427.24
282	5.1.15.4 FIELD ERECTED TANKS PIPING TRAIN 1	25 days	Tue 7/17/12	Mon 8/20/12	$1,423,427.24
283	5.1.15.9 HYDRO TEST FIELD ERECTED TANKS TRAI	20 days	Tue 9/4/12	Mon 10/1/12	$1,423,427.24
284	5.1.16.6 SET FIELD ERECTED TANKS TRAIN 1	5 days	Tue 7/10/12	Mon 7/16/12	$1,423,427.24
285	5.1.16.12 FIELD ERECTED TANKS ELECTRICAL TRA	15 days	Tue 7/17/12	Mon 8/6/12	$1,423,427.24
286	5.1.17.4 FIELD ERECTED TANKS INSTRUMENTATIOI	20 days	Tue 8/7/12	Mon 9/3/12	$1,423,427.24
287	5.1.13.13 EXC, F/R/P - FOUNDATION PIPERACK	30 days	Tue 5/29/12	Mon 7/9/12	$2,518,572.82
288	5.1.13.14 STEEL ERECTION PIPERACK	30 days	Tue 7/10/12	Mon 8/20/12	$1,697,868.69

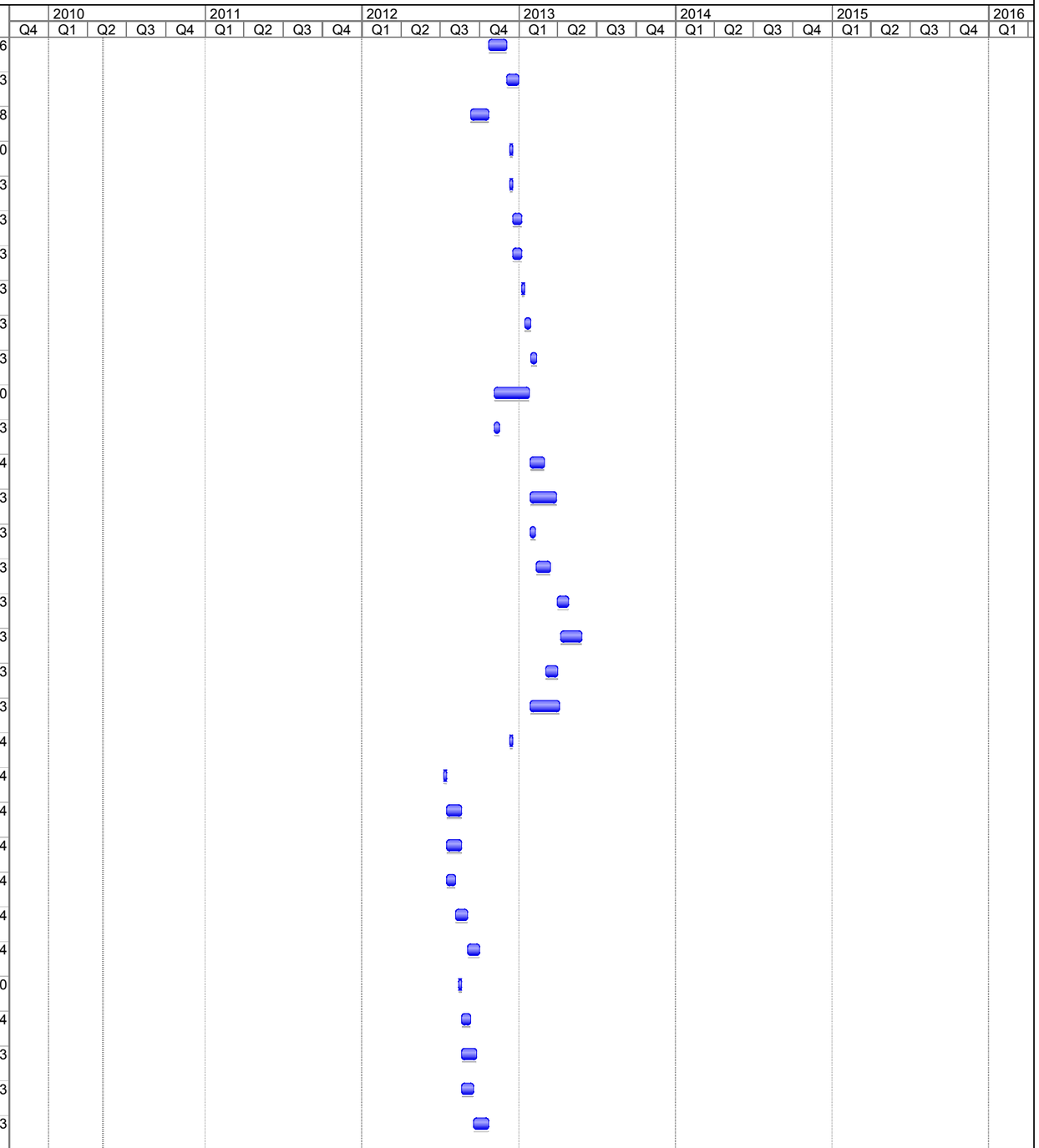


Project: Leucadia LCC CO2 Schedule
Date: Thu 5/6/10
3:25 PM

Task | Milestone | Rolled Up Task | Rolled Up Progress | External Tasks | Group By Summary
Progress | Summary | Rolled Up Milestone | Split | Project Summary | Deadline

Lake Charles CCS Project

ID	Task Name	Duration	Start	Finish	Total Cost
289	5.1.13.15 LB PIPE FOR PIPERACK	30 days	Tue 10/23/12	Mon 12/3/12	$984,844.96
290	5.1.13.16 INSTRUMENTATION PIPERACK	20 days	Tue 12/4/12	Mon 12/31/12	$164,140.83
291	5.1.13.17 SB PIPE FOR PIPERACK	30 days	Tue 9/11/12	Mon 10/22/12	$492,422.48
292	5.1.16.4	5 days	Tue 12/11/12	Mon 12/17/12	$656,563.30
293	5.1.13.11HEAT EXCHANGERS GROUNDING TRAIN 2	5 days	Tue 12/11/12	Mon 12/17/12	$164,140.83
294	5.1.13.15 HEAT EXCHANGERS STEEL & PLATFORMS	15 days	Tue 12/18/12	Mon 1/7/13	$164,140.83
295	5.1.15.2 HEAT EXCHANGERS PIPING TRAIN 2	15 days	Tue 12/18/12	Mon 1/7/13	$164,140.83
296	5.1.16.10 HEAT EXCHANGERS ELECTRICAL TRAIN 2	5 days	Tue 1/8/13	Mon 1/14/13	$164,140.83
297	5.1.17.2 HEAT EXCHANGERS INSTRUMENTATION T	10 days	Tue 1/15/13	Mon 1/28/13	$164,140.83
298	5.1.15.7 HYDRO TEST HEAT EXCHANGERS TRAIN 2	10 days	Tue 1/29/13	Mon 2/11/13	$164,140.83
299	5.1.14.5 SET COMPRESSORS TRAIN 2	60 days	Mon 11/5/12	Fri 1/25/13	$656,563.30
300	5.1.13.20 COMPRESSORS GROUNDING TRAIN 2	10 days	Mon 11/5/12	Fri 11/16/12	$164,140.83
301	5.1.13.19 COMPRESSORS STEEL ERECTION TRAIN	25 days	Mon 1/28/13	Fri 3/1/13	$1,423,427.24
302	5.1.15.11 COMPRESSORS PIPING TRAIN 2	45 days	Mon 1/28/13	Fri 3/29/13	$164,140.83
303	5.1.16.16 COMPRESSORS ELECTRICAL TRAIN 2	10 days	Mon 1/28/13	Fri 2/8/13	$164,140.83
304	5.1.17.6 COMPRESSORS INSTRUMENTATION TRAIN	25 days	Mon 2/11/13	Fri 3/15/13	$164,140.83
305	5.1.15.12 HYDRO TEST COMPRESSORS TRAIN 2	20 days	Mon 4/1/13	Fri 4/26/13	$164,140.83
306	5.1.20.1 PULL AND TERMINATE TRAIN 2	35 days	Tue 4/9/13	Mon 5/27/13	$164,140.83
307	5.1.20.2 ELECTRICAL CONDUIT TRAIN 2	20 days	Tue 3/5/13	Mon 4/1/13	$164,140.83
308	5.1.20.3 INSULATE & PAINT TRAIN 2	50 days	Mon 1/28/13	Fri 4/5/13	$164,140.83
309	5.1.13.13 FIELD ERECTED TANKS GROUNDING TRA	5 days	Tue 12/11/12	Mon 12/17/12	$1,423,427.24
310	5.1.16.6 SET FIELD ERECTED TANKS TRAIN 2	5 days	Tue 7/10/12	Mon 7/16/12	$1,423,427.24
311	5.1.13.17 FIELD ERECTED TANKS STEEL & PLATFOI	25 days	Tue 7/17/12	Mon 8/20/12	$1,423,427.24
312	5.1.15.4 FIELD ERECTED TANKS PIPING TRAIN 2	25 days	Tue 7/17/12	Mon 8/20/12	$1,423,427.24
313	5.1.16.12 FIELD ERECTED TANKS ELECTRICAL TRA	15 days	Tue 7/17/12	Mon 8/6/12	$1,423,427.24
314	5.1.17.4 FIELD ERECTED TANKS INSTRUMENTATIOI	20 days	Tue 8/7/12	Mon 9/3/12	$1,423,427.24
315	5.1.15.9 HYDRO TEST FIELD ERECTED TANKS TRAI	20 days	Tue 9/4/12	Mon 10/1/12	$1,423,427.24
316	5.1.14.4 SET EQUIPMENT SHOP FAB PRESSURE VE	5 days	Tue 8/14/12	Mon 8/20/12	$656,563.30
317	5.1.13.10 SHOP FAB PRESSURE VESSELS STEEL EI	15 days	Tue 8/21/12	Mon 9/10/12	$1,423,427.24
318	5.1.15.1 SHOP FAB PRESSURE VESSELS PIPING TR	25 days	Tue 8/21/12	Mon 9/24/12	$164,140.83
319	5.1.16.9 SHOP FAB PRESSURE VESSELS ELECTRCI	20 days	Tue 8/21/12	Mon 9/17/12	$164,140.83
320	5.1.17.1 SHOP FAB PRESSURE VESSELS INSTRUME	25 days	Tue 9/18/12	Mon 10/22/12	$164,140.83

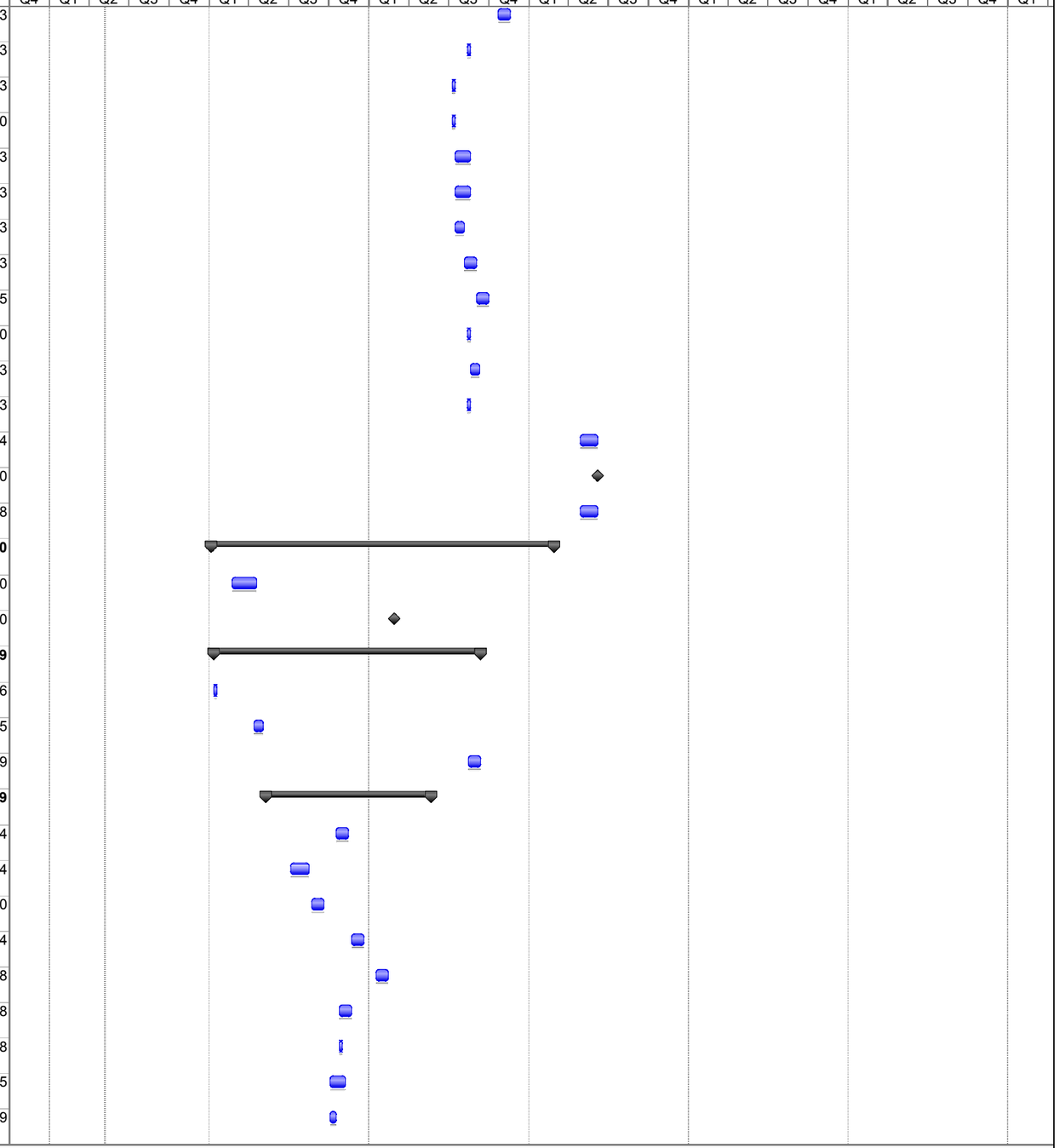


Project: Leucadia LCC CO2 Schedule
Date: Thu 5/6/10
3:25 PM

Task | Milestone | Rolled Up Task | Rolled Up Progress | External Tasks | Group By Summary
Progress | Summary | Rolled Up Milestone | Split | Project Summary | Deadline

Lake Charles CCS Project

ID	Task Name	Duration	Start	Finish	Total Cost
321	5.1.15.6 HYDRO TEST SHOP FAB PRESSURE VESSE	20 days	Tue 10/23/12	Mon 11/19/12	$164,140.83
322	5.1.13.23 SHOP FAB PRESSURE VESSELS GROUND	5 days	Tue 8/14/12	Mon 8/20/12	$164,140.83
323	5.1.13.12 PUMPS GROUNDING TRAIN 2	5 days	Tue 7/10/12	Mon 7/16/12	$164,140.83
324	5.1.16.5 SET PUMPS TRAIN 2	5 days	Tue 7/10/12	Mon 7/16/12	$656,563.30
325	5.1.13.16 PUMPS STEEL & PLATFORMS TRAIN 2	25 days	Tue 7/17/12	Mon 8/20/12	$164,140.83
326	5.1.15.3 PUMPS PIPING TRAIN 2	25 days	Tue 7/17/12	Mon 8/20/12	$164,140.83
327	5.1.16.11 PUMPS ELECTRICAL TRAIN 2	15 days	Tue 7/17/12	Mon 8/6/12	$164,140.83
328	5.1.17.3 PUMPS INSTRUMENTATION TRAIN 2	20 days	Tue 8/7/12	Mon 9/3/12	$164,140.83
329	5.1.15.8 HYDRO TEST PUMPS TRAIN 2	20 days	Tue 9/4/12	Mon 10/1/12	$328,281.65
330	5.1.14.3 SET VESSEL INTERNALS TRAIN 2	5 days	Tue 8/14/12	Mon 8/20/12	$656,563.30
331	5.1.13.9 VESSEL INTERNALS FIELD DRESS TRAIN 2	15 days	Tue 8/21/12	Mon 9/10/12	$164,140.83
332	5.1.13.25 SHOP FAB PRESSURE VESSELS GROUND	5 days	Tue 8/14/12	Mon 8/20/12	$164,140.83
333	5.1.21.1 CONSTR - FINAL MECH / TEST TRAIN 2	30 days	Mon 4/29/13	Fri 6/7/13	$1,423,427.24
334	5.1.21.2 MECHANICAL COMPLETION TRAIN 2	0 days	Fri 6/7/13	Fri 6/7/13	$656,563.30
335	5.1.22.2 START UP TRAIN 2	30 days	Mon 4/29/13	Fri 6/7/13	$1,148,985.78
336	**5.2 Compression Construction**	**560 days**	**Thu 1/6/11**	**Wed 2/27/13**	**$89,282,716.30**
337	5.2.1 CONSTRUCTABILITY REVIEW - EQUIPMENT LAYOU	40 days	Wed 2/23/11	Tue 4/19/11	$113,933.70
338	5.2.2 ENGINEERING 95% COMPLETE	0 days	Tue 2/28/12	Tue 2/28/12	$0.00
339	**5.2.3 SYSTEM**	**436 days**	**Wed 1/12/11**	**Wed 9/12/12**	**$175,592.39**
340	5.2.3.1 P&ID INSTRUMENT EXTRACT	5 days	Wed 1/12/11	Tue 1/18/11	$21,211.96
341	5.2.3.2 P.H.A. (HAZOP)	15 days	Thu 4/14/11	Wed 5/4/11	$64,254.35
342	5.2.3.3 OPERATION MANUALS	20 days	Thu 8/16/12	Wed 9/12/12	$90,126.09
343	**5.2.5 CIVIL & STRUCTURAL**	**270 days**	**Wed 5/11/11**	**Tue 5/22/12**	**$3,863,601.09**
344	5.2.5.8 CIVIL UG DRWGS (SEWER)	20 days	Wed 10/19/11	Tue 11/15/11	$87,471.74
345	5.2.5.4 INPUT/REVIEW/ISSUE UNDERGROUND PIPIN	30 days	Thu 7/7/11	Wed 8/17/11	$129,788.04
346	5.2.5.2 ISSUE AND REVIEW BUILDING LAYOUT & RE	20 days	Wed 8/24/11	Tue 9/20/11	$86,966.30
347	5.2.5.12 ENG DESIGN/INPUT/REVIEW/ISSUE - PLATF	20 days	Wed 11/23/11	Tue 12/20/11	$87,788.04
348	5.2.5.13 ENG DESIGN/INPUT/REVIEW/IS - MISC PLTF	20 days	Wed 1/18/12	Tue 2/14/12	$88,293.48
349	5.2.5.9 ENG DESIGN/INPUT/REVIEW/ISSUE-PIPE/ELI	20 days	Wed 10/26/11	Tue 11/22/11	$87,534.78
350	5.2.5.10 SCOPE WRITE-UP FOR CIVIL/STRUCTURAL	5 days	Wed 10/26/11	Tue 11/1/11	$21,859.78
351	5.2.5.5 ENG DESIGN/REVIEW/ISSUE - PILING	25 days	Wed 10/5/11	Tue 11/8/11	$109,220.65
352	5.2.5.6 ENG DESIGN/INPUT/REVIEW - BUILDING	10 days	Wed 10/5/11	Tue 10/18/11	$43,642.39

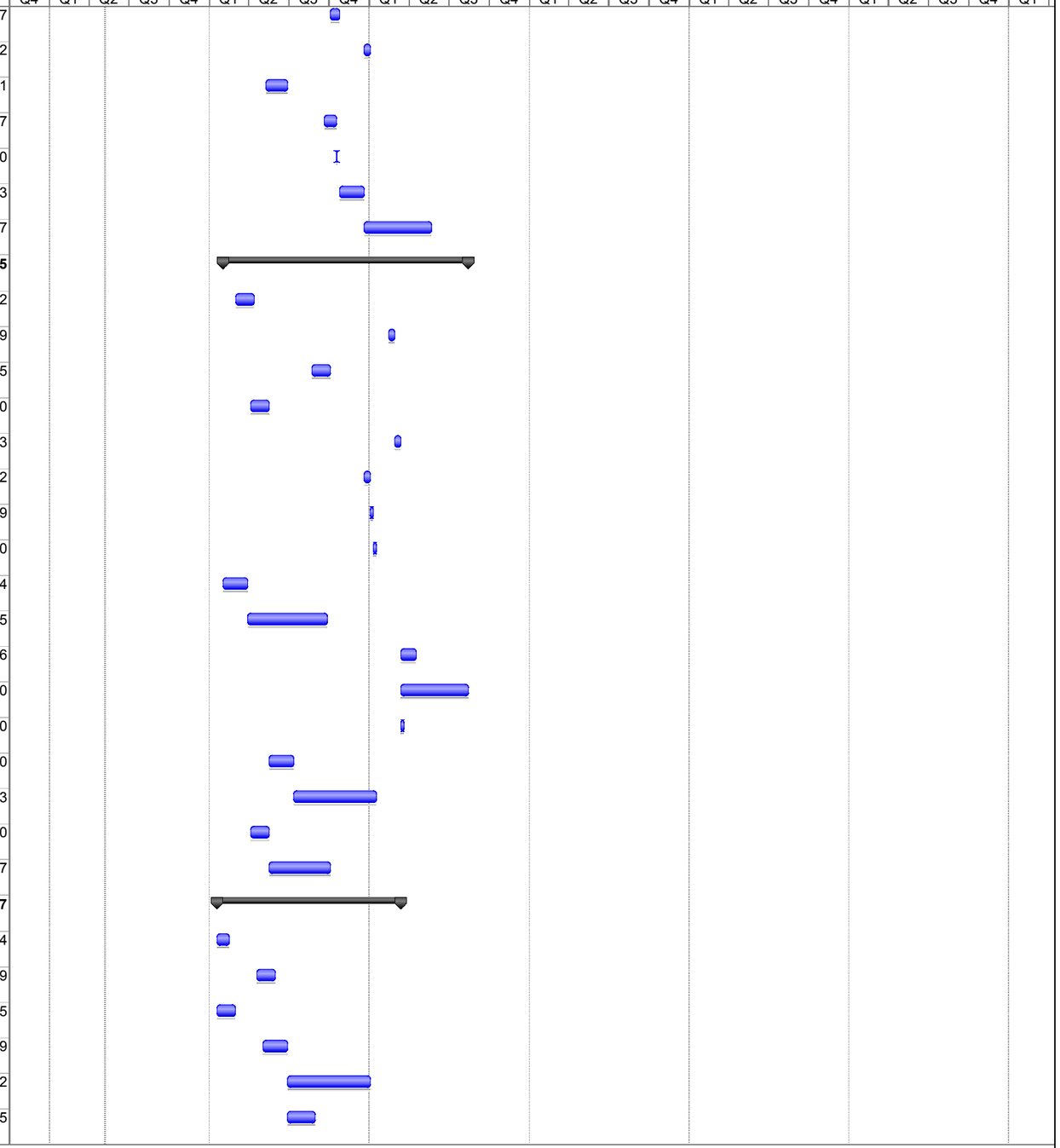


Project: Leucadia LCC CO2 Schedule
Date: Thu 5/6/10
3:25 PM

Task | Milestone | Rolled Up Task | Rolled Up Progress | External Tasks | Group By Summary
Progress | Summary | Rolled Up Milestone | Split | Project Summary | Deadline

Lake Charles CCS Project

ID	Task Name	Duration	Start	Finish	Total Cost
353	5.2.5.7 ENG DESIGN/INPUT/REVIEW/ISSUE - TOWEF	15 days	Wed 10/5/11	Tue 10/25/11	$65,485.87
354	5.2.5.14 ENG DESIGN/INPUT/REVIEW/ISSUE - PIPE/E	10 days	Wed 12/21/11	Tue 1/3/12	$43,990.22
355	5.2.5.1 ENG DESIGN/INPUT/REVIEW/ISSUE - ELECT	35 days	Wed 5/11/11	Tue 6/28/11	$150,698.91
356	5.2.5.3 ENG DESIGN/INPUT/REVIEW/ISSUE - MJR EC	20 days	Wed 9/21/11	Tue 10/18/11	$87,219.57
357	5.2.5.15 PREP REQ/IFB/BID TAB/VNDR ENG - BUILDI	1 day	Wed 10/19/11	Wed 10/19/11	$4,366.30
358	5.2.5.11 PREP REQ/IFB/BID TAB/VNDR ENG - STR. S	40 days	Wed 10/26/11	Tue 12/20/11	$175,322.83
359	5.2.5.16 AWARD/FAB/SHIP - BUILDINGS	110 days	Wed 12/21/11	Tue 5/22/12	$2,593,952.17
360	**5.2.6 PIPING**	**400 days**	**Wed 2/2/11**	**Tue 8/14/12**	**$6,340,054.35**
361	5.2.6.2 VESSEL PLATFORM & NOZZLE ORIENTATIOI	30 days	Thu 3/3/11	Wed 4/13/11	$128,081.52
362	5.2.6.14 ISSUE ISOMETRICS	10 days	Wed 2/15/12	Tue 2/28/12	$44,242.39
363	5.2.6.10 PIPE STRESS ANALYSIS	30 days	Wed 8/24/11	Tue 10/4/11	$130,545.65
364	5.2.6.4 TIE-IN DWGS	30 days	Wed 4/6/11	Tue 5/17/11	$128,650.00
365	5.2.6.15 MES RUN - MTO	10 days	Wed 2/29/12	Tue 3/13/12	$44,305.43
366	5.2.6.11 SCOPE WRITE-UPS - MECHANICAL	10 days	Wed 12/21/11	Tue 1/3/12	$43,990.22
367	5.2.6.12 SCOPE WRITE-UPS - INSULATION	5 days	Wed 1/4/12	Tue 1/10/12	$22,017.39
368	5.2.6.13 SCOPE WRITE-UPS - PAINTING	5 days	Wed 1/11/12	Tue 1/17/12	$22,033.70
369	5.2.6.1 PREP REQ/IFB/BID TAB/VNDR ENG - TAGGEI	40 days	Wed 2/2/11	Tue 3/29/11	$170,521.74
370	5.2.6.3 AWARD/FAB/SHIP - TAGGED VALVES	130 days	Wed 3/30/11	Tue 9/27/11	$1,058,245.65
371	5.2.6.16 PREPARE REQ/IFB/BID/TAB - PIPE SPECIAL	25 days	Wed 3/14/12	Tue 4/17/12	$111,036.96
372	5.2.6.17 AWARD/FAB/SHIP - PIPE SPECIALS (TRAPS	110 days	Wed 3/14/12	Tue 8/14/12	$269,900.00
373	5.2.6.18 FINAL REQUISITION - BULK PIPE	5 days	Wed 3/14/12	Tue 3/20/12	$22,175.00
374	5.2.6.6 PREP REQ/IFB/BID TAB/VNDR ENG - SHOP F	40 days	Wed 5/18/11	Tue 7/12/11	$172,416.30
375	5.2.6.9 AWARD/FAB/SHIP - SHOP FAB PIPE	135 days	Wed 7/13/11	Tue 1/17/12	$3,799,947.83
376	5.2.6.5 PREP REQ/IFB/BID TAB/VNDR ENG - PVF ANI	30 days	Wed 4/6/11	Tue 5/17/11	$128,650.00
377	5.2.6.7 AWARD/FAB/SHIP - PVF AND MISC PIPE	100 days	Wed 5/18/11	Tue 10/4/11	$43,294.57
378	**5.2.8 INSTRUMENTATION**	**300 days**	**Wed 1/19/11**	**Tue 3/13/12**	**$1,518,560.87**
379	5.2.8.1 PREP/REVIEW/ISSUE - INSTRUMENT INDEX	20 days	Wed 1/19/11	Tue 2/15/11	$56,671.74
380	5.2.8.3 PREP/REVIEW/ISSUE - I/O LIST	30 days	Wed 4/20/11	Tue 5/31/11	$85,892.39
381	5.2.8.2 PREPARE & REVIEW - LOGIC DIAGRAMS	30 days	Wed 1/19/11	Tue 3/1/11	$85,070.65
382	5.2.8.4 PREP REQ/IFB/BID TAB/VNDR ENG-FLOW EL	40 days	Wed 5/4/11	Tue 6/28/11	$114,776.09
383	5.2.8.5 AWARD/FAB/SHIP - FLOW ELEMENTS	135 days	Wed 6/29/11	Tue 1/3/12	$230,215.22
384	5.2.8.6 PREP REQ/IFB/BID TAB - INSTRUMENTS	45 days	Wed 6/29/11	Tue 8/30/11	$129,929.35

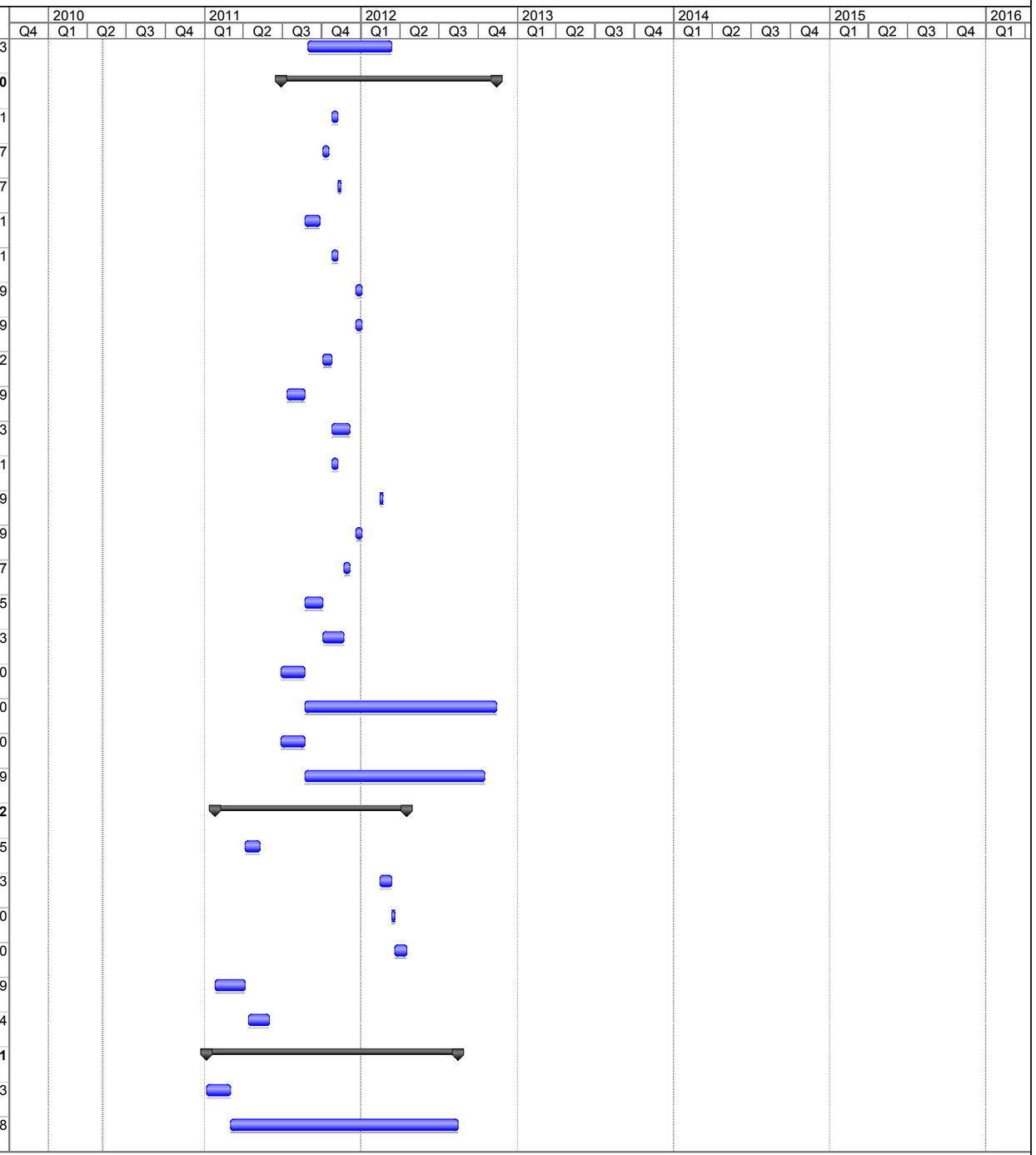


Project: Leucadia LCC CO2 Schedule
Date: Thu 5/6/10
3:25 PM

Task | Milestone | Rolled Up Task | Rolled Up Progress | External Tasks | Group By Summary
Progress | Summary | Rolled Up Milestone | Split | Project Summary | Deadline

Lake Charles CCS Project

ID	Task Name	Duration	Start	Finish	Total Cost
385	5.2.8.7 AWARD/FAB/SHIP - INSTRUMENTS	140 days	Wed 8/31/11	Tue 3/13/12	$816,005.43
386	**5.2.7 ELECTRICAL**	**360 days**	**Wed 6/29/11**	**Tue 11/13/12**	**$3,846,516.30**
387	5.2.7.12 PRELIM. ELECT LAYOUT (PANELS / RECEP	10 days	Wed 10/26/11	Tue 11/8/11	$29,157.61
388	5.2.7.8 PRELIM/REVIEW/ISSUE U.G.ELECT DRAWIN(	10 days	Wed 10/5/11	Tue 10/18/11	$29,094.57
389	5.2.7.16 PREP/REVIEW/INSTR/ISSUE GROUNDING D	5 days	Wed 11/9/11	Tue 11/15/11	$14,594.57
390	5.2.7.4 PREP/REVIEW/ISSUE PANEL & CABINET DR/	25 days	Wed 8/24/11	Tue 9/27/11	$72,498.91
391	5.2.7.13 PREP/REVIEW/ISSUE POWER PLANS	10 days	Wed 10/26/11	Tue 11/8/11	$29,157.61
392	5.2.7.17 PREP/REVIEW/ISSUE I/E INSTRUMENT PLA	10 days	Wed 12/21/11	Tue 1/3/12	$29,326.09
393	5.2.7.18 PREP/REVIEW/ISSUE I / E INSTALLATION DI	10 days	Wed 12/21/11	Tue 1/3/12	$29,326.09
394	5.2.7.9 3D MODEL/PREP/REVIEW/ISSUE TRAY PLAN	15 days	Wed 10/5/11	Tue 10/25/11	$43,656.52
395	5.2.7.3 PREP/REVIEW/ISSUE LOOP DIAGRAMS	30 days	Wed 7/13/11	Tue 8/23/11	$86,651.09
396	5.2.7.14 PREP/REVIEW/ISSUE MOTOR SCHEMATIC I	30 days	Wed 10/26/11	Tue 12/6/11	$87,597.83
397	5.2.7.15 PREP/REVIEW/ISSUE WIRING DIAGRAMS	10 days	Wed 10/26/11	Tue 11/8/11	$29,157.61
398	5.2.7.20 CONDUIT & CABLE SCHEDULE - (PWR/CNTI	5 days	Wed 2/15/12	Tue 2/21/12	$14,742.39
399	5.2.7.19 ELECTRICAL MATERIAL TAKE-OFF	10 days	Wed 12/21/11	Tue 1/3/12	$29,326.09
400	5.2.7.11 PREP/REVIEW/ISSUE INSTRUMENT WIRING	10 days	Wed 11/23/11	Tue 12/6/11	$29,135.87
401	5.2.7.5 PREP REQ/IFB/BID TAB/VNDR ENG - ELEC BI	30 days	Wed 8/24/11	Tue 10/4/11	$87,029.35
402	5.2.7.10 AWARD/FAB/SHIP - ELEC BULKS	35 days	Wed 10/5/11	Tue 11/22/11	$1,887,505.43
403	5.2.7.1 PREP REQ/IFB/BID TAB/VNDR ENG - TRANSF	40 days	Wed 6/29/11	Tue 8/23/11	$115,450.00
404	5.2.7.6 AWARD/FAB/SHIP - TRANSFORMERS	320 days	Wed 8/24/11	Tue 11/13/12	$694,666.30
405	5.2.7.2 PREP REQ/IFB/BID TAB/VNDR ENG - ELEC S\	40 days	Wed 6/29/11	Tue 8/23/11	$115,450.00
406	5.2.7.7 AWARD/FAB/SHIP - ELEC SWITCHGEAR	300 days	Wed 8/24/11	Tue 10/16/12	$392,992.39
407	**5.2.9 MODELING**	**320 days**	**Wed 1/26/11**	**Tue 4/17/12**	**$454,090.22**
408	5.2.9.4 INITIAL EQUIPMENT MODELING IN (3D) MOD	25 days	Wed 4/6/11	Tue 5/10/11	$71,445.65
409	5.2.9.5 DEVELOP MODEL TO 3RD STAGE	20 days	Wed 2/15/12	Tue 3/13/12	$59,030.43
410	5.2.9.2 CLIENT MODEL REVIEW	5 days	Wed 3/14/12	Tue 3/20/12	$22,175.00
411	5.2.9.6 DEVELOP MODEL TO FINAL STAGE	20 days	Wed 3/21/12	Tue 4/17/12	$59,241.30
412	5.2.9.1 MODEL AUTOROUTER	50 days	Wed 1/26/11	Tue 4/5/11	$142,101.09
413	5.2.9.3 PIPE STRESS ANALYSIS	35 days	Thu 4/14/11	Wed 6/1/11	$100,096.74
414	**5.2.4 EQUIPMENT**	**420 days**	**Thu 1/6/11**	**Wed 8/15/12**	**$47,967,557.61**
415	5.2.4.1 PREP REQ/IFB/BID TAB/VNDR ENG - CO2 GA	40 days	Thu 1/6/11	Wed 3/2/11	$169,889.13
416	5.2.4.4 AWARD/FAB/SHIP - CO2 GAS COMP & PLC	380 days	Thu 3/3/11	Wed 8/15/12	$47,797,668.48

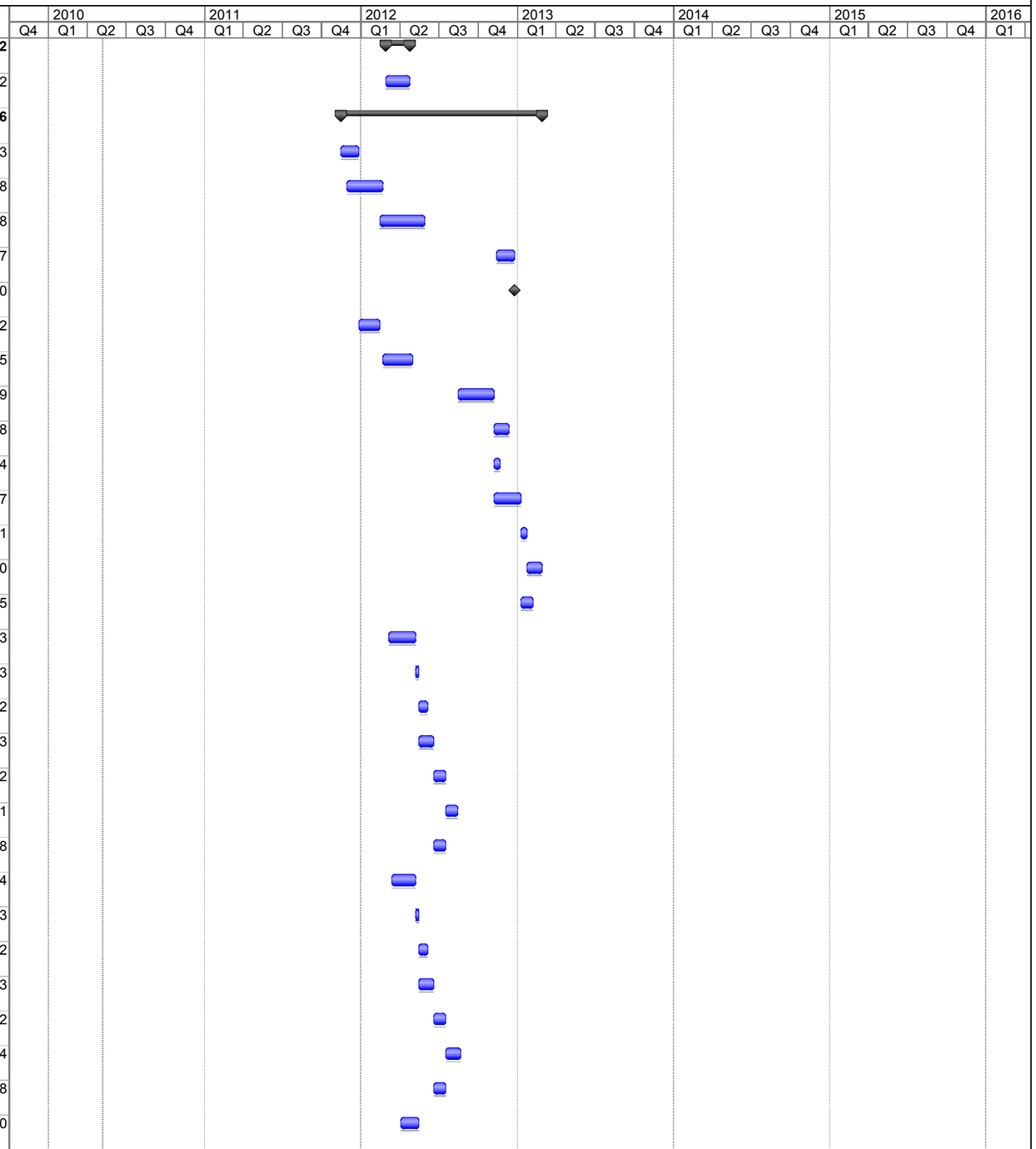


Project: Leucadia LCC CO2 Schedule
Date: Thu 5/6/10
3:25 PM

Task | Milestone | Rolled Up Task | Rolled Up Progress | External Tasks | Group By Summary
Progress | Summary | Rolled Up Milestone | Split | Project Summary | Deadline

Lake Charles CCS Project

ID	Task Name	Duration	Start	Finish	Total Cost
417	**5.2.11 SUBCONTRACT PACKAGES**	**40 days**	**Wed 2/29/12**	**Tue 4/24/12**	**$116,181.52**
418	5.2.11.3 INQUIRE/QUOTE/BID TAB/AWARD - GENER/	40 days	Wed 2/29/12	Tue 4/24/12	$116,181.52
419	**5.2.12 CONSTRUCTION**	**336 days**	**Wed 11/16/11**	**Wed 2/27/13**	**$24,886,628.26**
420	5.2.19.1 CONSTR - MOBILIZE & SITEWORK	30 days	Wed 11/16/11	Tue 12/27/11	$59,014.13
421	5.2.12.1 CONSTR - UNDERGROUND	60 days	Wed 11/30/11	Tue 2/21/12	$1,542,618.48
422	5.2.18.1 CONSTR - INSULATE & PAINT	75 days	Wed 2/15/12	Tue 5/29/12	$3,414,134.78
423	5.2.21.1 CONSTR - FINAL MECH / TEST	30 days	Wed 11/14/12	Tue 12/25/12	$421,869.57
424	MECHANICAL COMPLETION	0 days	Tue 12/25/12	Tue 12/25/12	$0.00
425	5.2.12.2 SITE FOUNDATION PILING	35 days	Wed 12/28/11	Tue 2/14/12	$788,040.22
426	5.2.13.1 EXC, F/R/P FOUNDATION CO2 GAS COMPR	50 days	Wed 2/22/12	Tue 5/1/12	$4,028,429.35
427	5.2.14.5 SET CO2 GAS COMPRESSOR	60 days	Thu 8/16/12	Wed 11/7/12	$1,305,142.39
428	5.2.13.12 CO2 GAS COMPRESSOR STEEL ERECTIOI	25 days	Thu 11/8/12	Wed 12/12/12	$18,409.78
429	5.2.13.13 CO2 GAS COMPRESSOR GROUNDING	10 days	Thu 11/8/12	Wed 11/21/12	$114,671.74
430	5.2.15.7 CO2 GAS COMPRESSOR PIPING	45 days	Thu 11/8/12	Wed 1/9/13	$2,209,527.17
431	5.2.16.11 CO2 GAS COMPRESSOR ELECTRICAL	10 days	Thu 1/10/13	Wed 1/23/13	$1,265,057.61
432	5.2.17.4 CO2 GAS COMPRESSOR INSTRUMENTATIC	25 days	Thu 1/24/13	Wed 2/27/13	$680,566.30
433	5.2.15.8 HYDRO TEST CO2 GAS COMPRESSOR PIPI	20 days	Thu 1/10/13	Wed 2/6/13	$113,820.65
434	5.2.13.2 EXC, F/R/P FDN COMPRESSOR DISCHARGE	45 days	Wed 3/7/12	Tue 5/8/12	$137,489.13
435	5.2.14.3 SET COMPRESSOR DISCHARGE COOLERS	5 days	Wed 5/9/12	Tue 5/15/12	$75,780.43
436	5.2.13.8 COMPRESSOR DISCHARGE COOLERS STE	15 days	Wed 5/16/12	Tue 6/5/12	$247,231.52
437	5.2.15.1 COMPRESSOR DISCHARGE COOLERS PIPI	25 days	Wed 5/16/12	Tue 6/19/12	$83,447.83
438	5.2.16.6 COMPRESSOR DISCHARGE COOLERS ELE	20 days	Wed 6/20/12	Tue 7/17/12	$59,990.22
439	5.2.17.1 COMPRESSOR DISCHARGE COOLERS INS	20 days	Wed 7/18/12	Tue 8/14/12	$41,757.61
440	5.2.15.4 HYDRO TEST COMPRESSOR DISCHARGE (	20 days	Wed 6/20/12	Tue 7/17/12	$55,809.78
441	5.2.13.3 EXC, F/R/P FOUNDATION SUCTION KO DRU	40 days	Wed 3/14/12	Tue 5/8/12	$137,538.04
442	5.2.14.4 SET EQUIPMENT SUCTION KO DRUMS	5 days	Wed 5/9/12	Tue 5/15/12	$75,780.43
443	5.2.13.9 SUCTION KO DRUMS STEEL ERECTION	15 days	Wed 5/16/12	Tue 6/5/12	$18,090.22
444	5.2.15.2 SUCTION KO DRUMS PIPING	25 days	Wed 5/16/12	Tue 6/19/12	$83,447.83
445	5.2.16.7 SUCTION KO DRUMS ELECTRCIAL	20 days	Wed 6/20/12	Tue 7/17/12	$59,990.22
446	5.2.17.2 SUCTION KO DRUMS INSTRUMENTATION	25 days	Wed 7/18/12	Tue 8/21/12	$41,771.74
447	5.2.15.5 HYDRO TEST SUCTION KO DRUM PIPING	20 days	Wed 6/20/12	Tue 7/17/12	$55,809.78
448	5.2.13.5 EXC, F/R/P FND CUSTODY TRANSFER MET	30 days	Wed 4/4/12	Tue 5/15/12	$137,733.70

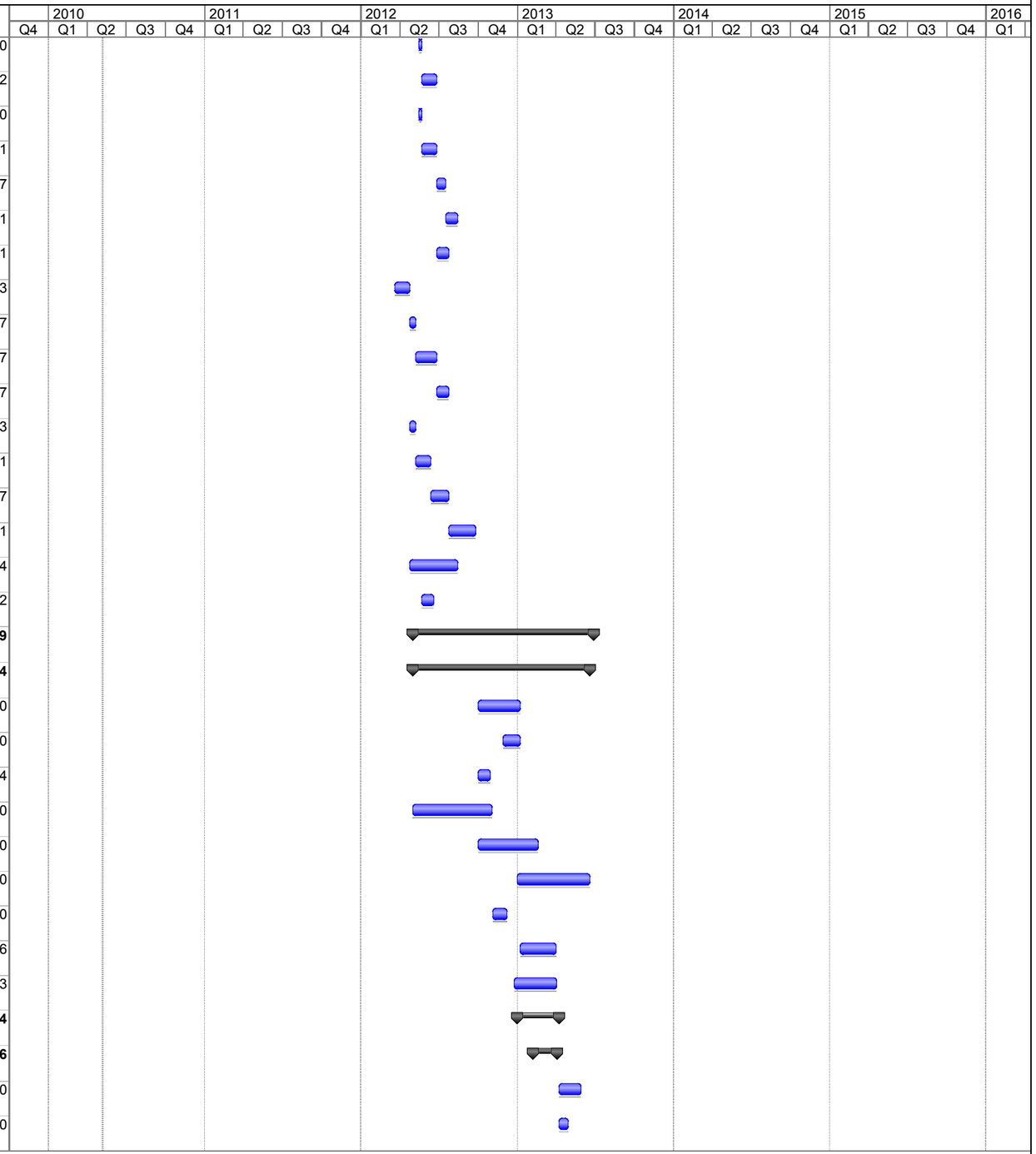


Project: Leucadia LCC CO2 Schedule
Date: Thu 5/6/10
3:25 PM

Task | Milestone | Rolled Up Task | Rolled Up Progress | External Tasks | Group By Summary
Progress | Summary | Rolled Up Milestone | Split | Project Summary | Deadline

Lake Charles CCS Project

ID	Task Name	Duration	Start	Finish	Total Cost
449	5.2.16.4 SET CUSTODY TRANSFER METERING SKID	5 days	Wed 5/16/12	Tue 5/22/12	$75,833.70
450	5.2.13.11 CUSTODY TRANSFER METERING SKID ST	25 days	Wed 5/23/12	Tue 6/26/12	$18,115.22
451	5.2.13.10 CUSTODY TRANSFER METERING SKID GF	5 days	Wed 5/16/12	Tue 5/22/12	$12,525.00
452	5.2.15.3 CUSTODY TRANSFER METERING SKID PIPI	25 days	Wed 5/23/12	Tue 6/26/12	$83,507.61
453	5.2.16.8 CUSTODY TRANSFER METERING SKID ELE	15 days	Wed 6/27/12	Tue 7/17/12	$60,010.87
454	5.2.17.3 CUSTODY TRANSFER METERING SKID INS	20 days	Wed 7/18/12	Tue 8/14/12	$41,757.61
455	5.2.15.6 HYDRO TEST CUSTODY TRANSFER METEF	20 days	Wed 6/27/12	Tue 7/24/12	$55,848.91
456	5.2.13.4 EXC, F/R/P FOUNDATIONS FOR ELECTRICA	25 days	Wed 3/21/12	Tue 4/24/12	$137,489.13
457	5.2.14.1 SET TRANSFORMERS	10 days	Wed 4/25/12	Tue 5/8/12	$96,319.57
458	5.2.16.2 DRESS TRANSFORMERS	35 days	Wed 5/9/12	Tue 6/26/12	$321,294.57
459	5.2.16.9 INSTALL ISOPHASE BUSS	20 days	Wed 6/27/12	Tue 7/24/12	$379,569.57
460	5.2.14.2 SET SWITCHGEAR	10 days	Wed 4/25/12	Tue 5/8/12	$29,272.83
461	5.2.16.3 INSTALL CABLE TRAY	25 days	Wed 5/9/12	Tue 6/12/12	$59,757.61
462	5.2.16.5 ELECTRICAL CONDUIT	30 days	Wed 6/13/12	Tue 7/24/12	$3,069,519.57
463	5.2.16.10 PULL AND TERMINATE	45 days	Wed 7/25/12	Tue 9/25/12	$60,307.61
464	5.2.16.1 SWITCHYARD CONTRACTOR	80 days	Wed 4/25/12	Tue 8/14/12	$341,838.04
465	5.2.20.1 CONSTR - BUILDING	20 days	Wed 5/23/12	Tue 6/19/12	$2,770,690.22
466	**5.3 Pipeline Construction**	**303 days**	**Wed 5/2/12**	**Fri 6/28/13**	**$23,785,888.59**
467	**5.3.1 Procurement**	**296 days**	**Wed 5/2/12**	**Wed 6/19/13**	**$2,641,031.44**
468	5.3.1.1 Procure Pipe and Long Lead Material/Equipmen	70 days	Tue 10/2/12	Mon 1/7/13	$51,828.60
469	5.3.1.2 Procure Miscellaneous Materials	28 days	Thu 11/29/12	Mon 1/7/13	$88,849.60
470	5.3.1.3 Procure Cathodic Protection Materials	20 days	Tue 10/2/12	Mon 10/29/12	$7,404.24
471	5.3.1.4 Right-of-Way and Site Acquistion	133 days	Wed 5/2/12	Fri 11/2/12	$2,189,425.00
472	5.3.1.5 Conduct Landowner Condemnation(s)	100 days	Tue 10/2/12	Mon 2/18/13	$243,269.00
473	5.3.1.6 Travel - Monitor Construction and Post Construc	122 days	Tue 1/1/13	Wed 6/19/13	$60,255.00
474	5.3.2 Bid & Award Construction	25 days	Mon 11/5/12	Fri 12/7/12	$20,246.20
475	5.3.3 Receive Material and Equipment	60 days	Tue 1/8/13	Mon 4/1/13	$6,066,460.16
476	5.3.4 Inspection	71 days	Tue 12/25/12	Tue 4/2/13	$464,703.53
477	**5.3.5 Pipeline Construction**	**70 days**	**Tue 1/1/13**	**Mon 4/8/13**	**$12,712,188.44**
486	**5.3.6 Facility Construction**	**40 days**	**Thu 2/7/13**	**Wed 4/3/13**	**$738,470.36**
493	5.3.7 Complete Pipeline As-Built Survey	37 days	Tue 4/9/13	Wed 5/29/13	$293,413.00
494	5.3.8 Pipeline and Equipment Commissioning	15 days	Tue 4/9/13	Mon 4/29/13	$553,723.40

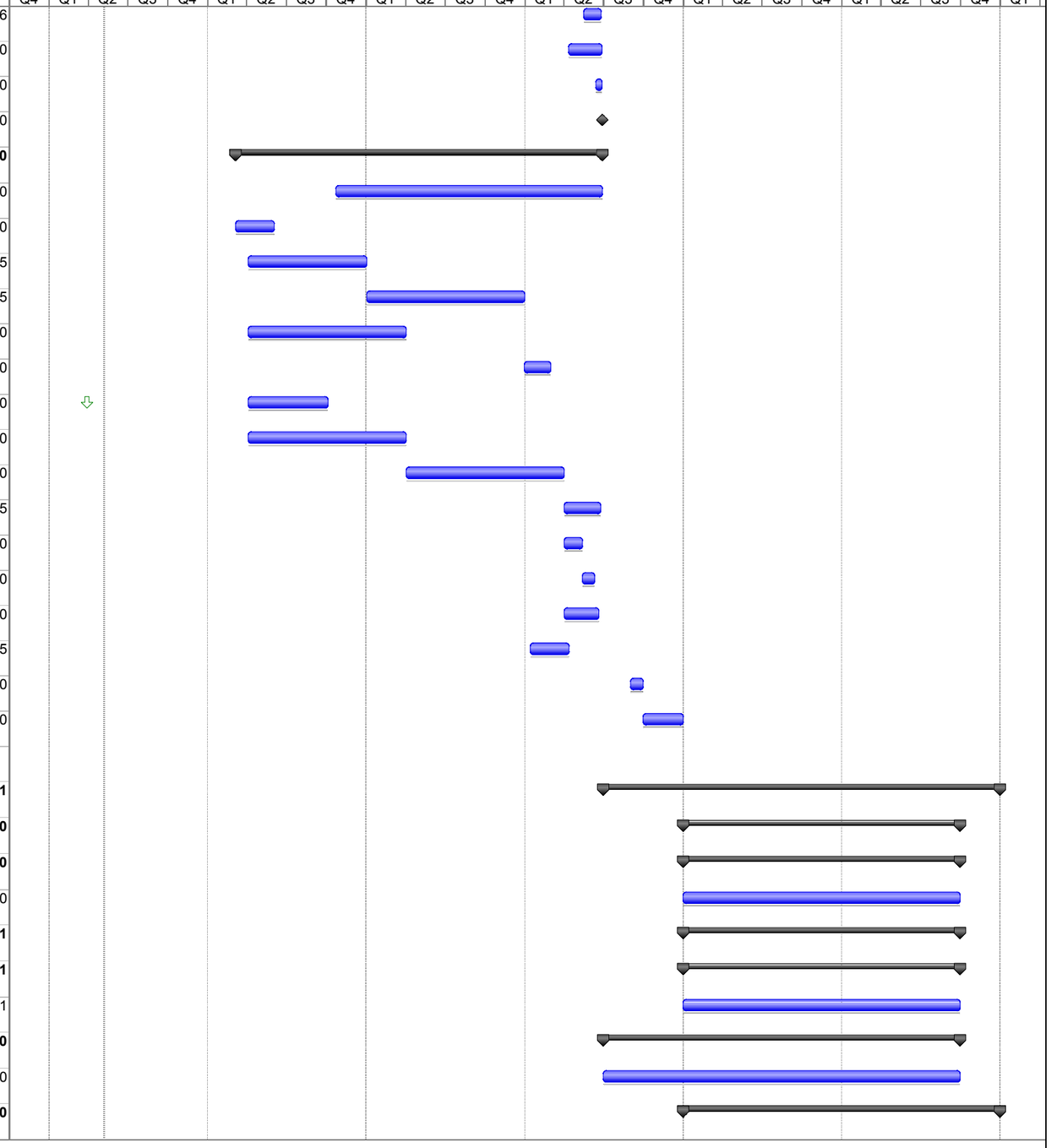


Project: Leucadia LCC CO2 Schedule
Date: Thu 5/6/10
3:25 PM

Task | Milestone | Rolled Up Task | Rolled Up Progress | External Tasks | Group By Summary
Progress | Summary | Rolled Up Milestone | Split | Project Summary | Deadline

Lake Charles CCS Project

ID	Task Name	Duration	Start	Finish	Total Cost
495	5.3.9 Complete Pipeline and Facility As-Built Drawings/Alignr	28 days	Fri 5/17/13	Tue 6/25/13	$37,584.96
496	5.3.10 ROW Damage Settlement, Road Repairs	55 days	Fri 4/12/13	Thu 6/27/13	$173,710.30
497	5.3.11 Complete Job Books and Final Pipeline Technical Rep	10 days	Fri 6/14/13	Thu 6/27/13	$84,356.80
498	5.3.12 END OF PIPELINE CONSTRUCTION - OPERATION	1 day	Fri 6/28/13	Fri 6/28/13	$0.00
499	**5.4 MVA Construction**	**605 days**	**Mon 3/7/11**	**Fri 6/28/13**	**$3,928,148.00**
500	5.4.1 Commercial Flood Monitoring Well Review & Remedia	440 days	Mon 10/24/11	Fri 6/28/13	$0.00
501	5.4.2 Logging -Baseline Surveillance of Idle wells	65 days	Mon 3/7/11	Fri 6/3/11	$840,000.00
502	5.4.3 Soil Gas -Site & Borehole preparation for surveillance c	195 days	Tue 4/5/11	Mon 1/2/12	$43,187.25
503	5.4.4 Soil Gas -Baseline Surveillance of P&A wells	260 days	Tue 1/3/12	Mon 12/31/12	$28,150.25
504	5.4.5 Ground Water Monitoring -Well preparation	260 days	Tue 4/5/11	Mon 4/2/12	$500,000.00
505	5.4.6 Ground Water Monitoring -Baseline Surveillance	45 days	Mon 12/31/12	Fri 3/1/13	$105,277.00
506	5.4.7 Reservoir Modeling - Upated	6.6 mons	Tue 4/5/11	Wed 10/5/11	$87,001.00
507	5.4.8 AZMI -Well Completions	260 days	Tue 4/5/11	Mon 4/2/12	$450,000.00
508	5.4.9 AZMI-Instrument Monitoring Wells	260 days	Tue 4/3/12	Mon 4/1/13	$48,000.00
509	5.4.10 AZMI-Baseline geochemical sampling and hydrologic	60 days	Tue 4/2/13	Mon 6/24/13	$40,000.25
510	5.4.11 VSP -Baseline	30 days	Tue 4/2/13	Mon 5/13/13	$564,080.00
511	5.4.12 Gravity-Baseline	20 days	Tue 5/14/13	Mon 6/10/13	$512,863.00
512	5.4.13 Measure Out-Of-Pattern Migration	58 days	Tue 4/2/13	Thu 6/20/13	$700,000.00
513	5.4.14 Risk Assessment & Updated MVA plan and cost distri	65 days	Mon 1/14/13	Fri 4/12/13	$9,589.25
514	Prepare DOE Construction Report	21 days	Mon 9/2/13	Mon 9/30/13	$0.00
515	DECISION POINT 2 - End of Subphase 2B (DOE 90-day Review)	66 days	Tue 10/1/13	Tue 12/31/13	$0.00
516					
517	**6.0 Sub-Phase-2C Operation (wbs level-3)**	**654 days**	**Mon 7/1/13**	**Thu 12/31/15**	**$7,983,903.61**
518	**6.1 Rectisol CO2 Capture Operation**	**456 days**	**Wed 1/1/14**	**Wed 9/30/15**	**$680,010.00**
519	**6.1.1 OPERATION-CO2 Rectisol**	**456 days**	**Wed 1/1/14**	**Wed 9/30/15**	**$680,010.00**
520	6.1.1.1 START UP	456 days	Wed 1/1/14	Wed 9/30/15	$680,010.00
521	**6.2 Compression Operation**	**456 days**	**Wed 1/1/14**	**Wed 9/30/15**	**$385,457.61**
522	**6.2.1 OPERATION-CO2 COMPRESSION**	**456 days**	**Wed 1/1/14**	**Wed 9/30/15**	**$385,457.61**
523	6.2.1.1 START UP	456 days	Wed 1/1/14	Wed 9/30/15	$385,457.61
524	**6.3 Pipeline Operation**	**588 days**	**Mon 7/1/13**	**Wed 9/30/15**	**$0.00**
525	6.3.1.1 Start-up	588 days	Mon 7/1/13	Wed 9/30/15	$0.00
526	**6.4 MVA Operation**	**522 days**	**Wed 1/1/14**	**Thu 12/31/15**	**$6,918,436.00**

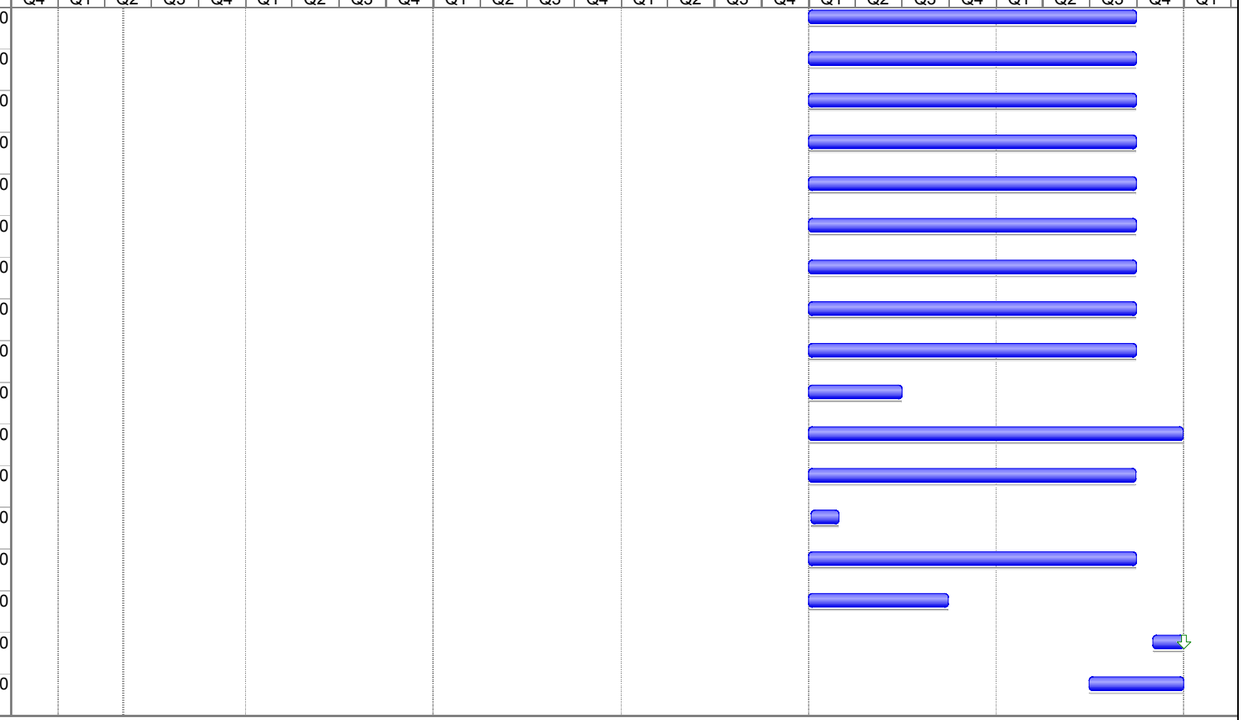


Project: Leucadia LCC CO2 Schedule
Date: Thu 5/6/10
3:25 PM

Task | Milestone | Rolled Up Task | Rolled Up Progress | External Tasks | Group By Summary
Progress | Summary | Rolled Up Milestone | Split | Project Summary | Deadline

Lake Charles CCS Project

ID	Task Name	Duration	Start	Finish	Total Cost
527	6.4.1 Commercial Flood Monitoring - Injection & Production \	456 days	Wed 1/1/14	Wed 9/30/15	$0.00
528	6.4.2 Commercial Flood Monitoring - Best Practice Mitigation	456 days	Wed 1/1/14	Wed 9/30/15	$0.00
529	6.4.3 Commercial Flood Monitoring - Pressure Maintenance	456 days	Wed 1/1/14	Wed 9/30/15	$0.00
530	6.4.4 Commercial Flood Monitoring -IWR Calculation	456 days	Wed 1/1/14	Wed 9/30/15	$0.00
531	6.4.5 Logging - Time lapse Surveillance of idle wells and faul	456 days	Wed 1/1/14	Wed 9/30/15	$300,000.00
532	6.4.6 Soil Gas - Time lapse Surveillance of P&A wells	456 days	Wed 1/1/14	Wed 9/30/15	$70,050.00
533	6.4.7 Ground Water Monitoring -Time lapse Surveillance	456 days	Wed 1/1/14	Wed 9/30/15	$97,614.00
534	6.4.8 VSP - Time lapse surveys	456 days	Wed 1/1/14	Wed 9/30/15	$2,256,320.00
535	6.4.9 Gravity - Augmented measures	456 days	Wed 1/1/14	Wed 9/30/15	$2,051,450.00
536	6.4.10 Real Time BHP -Well Preparation	130 days	Wed 1/1/14	Tue 7/1/14	$1,000,000.00
537	6.4.11 Real Time BHP -Sandia	521 days	Wed 1/1/14	Wed 12/30/15	$20,000.00
538	6.4.12 Logging - Time lapse Surveillance	455 days	Wed 1/1/14	Tue 9/29/15	$972,000.00
539	6.4.13 Natural Geochemical Tracers - Collected at wellhead	2 mons	Mon 1/6/14	Fri 2/28/14	$69,491.00
540	6.4.14 AZMI-Time lapse Geochemical sampling & hydrologic	456 days	Wed 1/1/14	Wed 9/30/15	$60,000.00
541	6.4.15 Measure Out-Of-Pattern Migration	194 days	Wed 1/1/14	Mon 9/29/14	$0.00
542	6.4.16 Reservoir Modeling -Updated	44 days	Mon 11/2/15	Thu 12/31/15	$12,895.00
543	6.4.17 Overview & Evaluation Report	132 days	Wed 7/1/15	Thu 12/31/15	$8,616.00



Project: Leucadia LCC CO2 Schedule
Date: Thu 5/6/10
3:25 PM

Task | Milestone | Rolled Up Task | Rolled Up Progress | External Tasks | Group By Summary
Progress | Summary | Rolled Up Milestone | Split | Project Summary | Deadline

Attachment 2

Statement of Project Objectives

1.2 Phase-2 Program & Project Management

1.2.1 NETL Award Announcement

NETL announces award, Leucadia Energy commences project implementation plan to launch project.

1.2.2 Executive Committee

Leucadia Energy CCS Executive Committee will monitor and manage all change controls, specifically related to scope, budget and schedule, including any change controls, specifically related to scope, budget and schedule including any changes that may affect the project management plan or the financial management plan. The Leucadia Energy CCS Executive Committee will report directly to the Leucadia Energy Vice President.

1.2.3 LEC

Leucadia Engineer Company will engage in the management of technical efforts by Monitoring project plans as appropriate to meet changing needs and requirements. In addition LEC will be responsible for defining, communicating and enforcing coding standards as well as monitoring the quality of deliverables and services. LEC will also over project construction reporting, as required including IRS, DOE, OMB and GAO standards and, specifically, Federal Financial Reports SF- 424A, SF-425, and the Reporting and Registration.

1.2.4 Program Mgmt - FMS & PMS systems + start-up

Program Management will include the Financial and Project management activities will commence and including all implementing all program protocols, including establishing reporting data points.

1.2.5 Financial Management Implementation

Commence Financial Management initiative including acquiring Deltek Vision, the financial management system to be used for the project along with MS SQL and MS Project Server

1.2.6 Program Management Project Reporting & monitoring

Reporting and Monitoring will include ensure all reporting be tracked and complies with assorted regulations, such as IRS, DOE, OMB and GAO standards and, specifically, Federal Financial Reports SF- 424A, SF-425, and the Reporting and Registration Requirements under Section 1512 of the American Recovery and Reinvestment Act.

1.2.7 Financial Management Project Reporting & monitoring

Reporting and Monitoring consolidated project financial information into one repository including work plans, progress, issues, changes, documents, cost information, budgets, actuals and forecasts, performance, and status reports. This reporting will include managing the data from a financial basis, assign resources, forecast to completion, and communicates financial data to stakeholders and ensure centralized accounting including track time for billing purposes and/or job cost allocation as well as establish budgets, for both projects and business units

1.2.8 Environmental Impact Statement (EIS)

An environmental impact statement (EIS) as required by the National Environmental Policy Act, will be conducted and used for decision making, describing the positive and negative environmental effects of proposed agency action - and will cites alternative actions. The EIS process in completed in the following ordered steps: Notice of Intent (NOI), draft EIS, final EIS, and record of decision (ROD).

4.1 RECTISOL DESIGN

4.1.01 DESIGN-RECTISOL

4.1.01.01 CONTRACT AWARD

This task is the contract award milestone.

4.1.01.03 RECEIVE CLIENT DOCUMENTS

Following contract award, the engineering firm will request data and information from the Client and commence engineering activities described below.

4.1.01.02 CONTRACT LICENSE AND AWARD

4.1.01.04 RECEIVE LICENSOR DOCUMENTS

4.1.03 SYSTEM

4.1.03.01 REVIEW DESIGN BASIS & DEVELOP BEDD

Upon receipt of the Client documents, engineering firm will develop and issue a Basic Engineering Design Document (BEDD) for review. The BEDD will be used to govern engineering design activities for the Lake Charles CCS Project.

4.1.03.02 ISSUE/REVIEW/BALANCE -– PFD

Based on information received/updated in the BEDD, the engineering firm will update the process flow diagrams (PFDs) and associated material balances. This information will be used as a basis for developing material selection diagrams (MSDs) and piping and instrumentation diagrams (P&IDs).

4.1.03.03 ISSUE MATERIAL SELECTION DIAGRAMS

The engineering firm will develop material selection diagrams (MSDs) for the CO2 compression equipment in accordance with applicable codes and standards. The MSDs will form the basis for developing P&IDs, equipment data sheets, and the definitive cost estimate.

4.1.03.04 DEVELOP/REVIEW/ISSUE - P&ID

The engineering firm will develop P&IDs for the CO2 compression system. The P&IDs will also be used for development of the 3-dimensional (3D) CO2 capture system model, piping and fabrication drawings, as well as electrical and instrumentation installation drawings.

4.1.03.06 PREPARE EQUIPMENT DATA SHEETS

The engineering firm will prepare equipment data sheets for the CO2 capture equipment. These equipment data sheets will be issued to original equipment manufacturers (OEMs) to obtain budgetary quotes to support a definitive cost estimate.

4.1.03.08 ISSUE EQUIPMENT LIST

An equipment list will be developed for the CO2 capture system. The equipment tag numbering for the equipment list will also be included in the P&IDs. Equipment will be listed in such a manner to support the work breakdown structure (WBS) of the definitive cost estimate.

4.1.03.13 RELIEF SCENARIO (PRELIM. RELIEF VALVE SIZES)

The engineering firm will perform an overpressure protection review to determine required relief locations, capacity, and design conditions.

4.1.03.09 ISSUE CONTROL LOGIC DESCRIPTION

The engineering firm will provide a description for the control logic of the CO2 capture system. This description will be supplemented with control logic diagrams.

4.1.03.10 DESIGN HYDRAULICS

The engineering firm will provide a description for the control logic of the CO2 capture system. This description will be supplemented with control logic diagrams.

4.1.03.14 P&ID TRANSFER TO (3D) MODEL

The engineering firm will develop a 3D model of the CO2 capture system based on the P&IDs developed. The 3D model will confirm appropriate equipment layout and pipe and cable tray routing.

4.1.03.05 PRELIMINARY LINE SIZING

The engineering firm will conduct calculations to determine preliminary line sizes for the CO2 capture system. The line sizes will be included in the P&IDs.

4.1.03.15 ISSUE LINE SCHEDULE

The engineering firm will prepare and issue a line schedule for the CO2 capture system.

4.1.03.11 ISSUE INSTRUMENT DATA SHEETS

The engineering firm will prepare instrument data sheets for the CO2 capture system. These instrument data sheets will be issued to OEMs to obtain budgetary quotes to support a definitive cost estimate.

4.1.03.12 RELIEF VALVE DATA SHEETS

The engineering firm will prepare relief valve data sheets for the CO2 capture system. These instrument data sheets will be issued to OEMs to obtain budgetary quotes to support a definitive cost estimate.

4.1.03.07 ISSUE UTILITY SUMMARY

A utility summary will be prepared for the CO2 capture system which will include electrical, water, and chemical requirements.

4.1.06 PIPING (DESIGN)

4.1.06.02 DESIGN/ISSUE/REVIEW - U.G. PIPING

The engineering firm will develop a conceptual design for the underground piping required to support the CO2 capture system.

4.1.06.01 DEVELOP PIPING CLASSES & SPECIFICATIONS

Piping classes and specifications will be determined by the engineering firm based on the material balances developed. These piping classes and specifications will be included in the P&IDs.

4.1.06.03 PIPING PLAN INDEX

4.1.07 ELECTRICAL (DESIGN)

4.1.07.01 PREPARE/REVIEW/ISSUE ELECTRIC ONE-LINES

The engineering firm will develop electrical one-line diagrams for the CO2 capture system.

4.1.07.02 CONCEPTUAL UG ELECTRICAL DRWGS

Conceptual underground electrical drawings will be developed by the engineering firm.

4.1.07.05 CONCEPTUAL CONDUIT & CABLE SCHEDULE

Conceptual conduit and cable schedules will be developed by the engineering firm.

4.1.07.03 CONCEPTUAL TRAY LAYOUT

The engineering firm will provide conceptual electrical tray layouts for the CO2 capture system. These tray layouts will also be included in the 3D model of the CO2 capture system.

4.1.07.04 PREPARE/REVIEW/ISSUE AREA CLASSIFICATION

The engineering firm will provide descriptions for, and develop a site layout with area classifications.

4.2.10 DEFINITIVE ESTIMATE

4.2.10.01 DEFINITIVE ESTIMATE

Based on the engineering design activities carried out, the engineering firm will prepare an AACEI Class 1, definitive capital cost estimate.

4.2 COMPRESSION DESIGN

4.2.01 DESIGN-CO2 COMPRESSION

4.2.01.01 CONTRACT AWARD

This task is the contract award milestone.

4.2.01.02 RECEIVE CLIENT DOCUMENTS

Following contract award, the engineering firm will request data and information from the Client and commence engineering activities described below.

4.2.03 SYSTEM

4.2.03.01 REVIEW DESIGN BASIS & DEVELOP BEDD

Upon receipt of the Client documents, engineering firm will develop and issue a Basic Engineering Design Document (BEDD) for review. The BEDD will be used to govern engineering design activities for the CCS Project.

4.2.03.02 ISSUE/REVIEW/BALANCE – PFD

Based on information received/updated in the BEDD, the engineering firm will update the process flow diagrams (PFDs) and associated material balances. This information will be used as a basis for developing material selection diagrams (MSDs) and piping and instrumentation diagrams (P&IDs).

4.2.03.03 ISSUE MATERIAL SELECTION DIAGRAMS

The engineering firm will develop material selection diagrams (MSDs) for the CO2 compression equipment in accordance with applicable codes and standards. The MSDs will form the basis for developing P&IDs, equipment data sheets, and the definitive cost estimate.

4.2.03.04 DEVELOP/REVIEW/ISSUE - P&ID

The engineering firm will develop P&IDs for the CO2 compression system. The P&IDs will also be used for development of the 3-dimensional (3D) CO2 compressions system model, piping and fabrication drawings, as well as electrical and instrumentation installation drawings.

4.2.03.06 PREPARE EQUIPMENT DATA SHEETS

The engineering firm will prepare equipment data sheets for the CO2 compression equipment. These equipment data sheets will be issued to original equipment manufacturers (OEMs) to obtain budgetary quotes to support a definitive cost estimate.

4.2.03.08 ISSUE EQUIPMENT LIST

An equipment list will be developed for the CO2 compression system. The equipment tag numbering for the equipment list will also be included in the P&IDs. Equipment will be listed in such a manner to support the work breakdown structure (WBS) of the definitive cost estimate.

4.2.03.13 RELIEF SCENARIO (PRELIM. RELIEF VALVE SIZES)

The engineering firm will perform an overpressure protection review to determine required relief locations, capacity, and design conditions.

4.2.03.09 ISSUE CONTROL LOGIC DESCRIPTION

The engineering firm will provide a description for the control logic of the CO2 compression system. This description will be supplemented with control logic diagrams.

4.2.03.10 DESIGN HYDRAULICS

Upon receipt of CO2 pipeline hydraulic calculations, the engineering firm will confirm hydraulic calculations for the CO2 compression system.

4.2.03.14 P&ID TRANSFER TO (3D) MODEL

The engineering firm will develop a 3D model of the CO2 compression system based on the P&IDs developed. The 3D model will confirm appropriate equipment layout and pipe and cable tray routing.

4.2.03.05 PRELIMINARY LINE SIZING

The engineering firm will conduct calculations to determine preliminary line sizes for the CO2 compression system. The line sizes will be included in the P&IDs.

4.2.03.15 ISSUE LINE SCHEDULE

The engineering firm will prepare a pipeline list for the CO2 compression system which will include preliminary line sizes, lengths, and material type. This list will be used to support a definitive cost estimate.

4.2.03.11 ISSUE INSTRUMENT DATA SHEETS

The engineering firm will prepare instrument data sheets for the CO2 compression system. These instrument data sheets will be issued to OEMs to obtain budgetary quotes to support a definitive cost estimate.

4.2.03.12 RELIEF VALVE DATA SHEETS

The engineering firm will prepare relief valve data sheets for the CO2 compression system. These instrument data sheets will be issued to OEMs to obtain budgetary quotes to support a definitive cost estimate.

4.2.03.07 ISSUE UTILITY SUMMARY

A utility summary will be prepared for the CO2 compression system which will include electrical, water, and chemical reagent requirements.

4.2.06 PIPING (DESIGN)

4.2.06.03 PIPING PLAN INDEX

A preliminary aboveground piping plan will be developed to determine a conceptual arrangement with line lengths and determine underground piping needs.

4.2.06.02 DESIGN/ISSUE/REVIEW - U.G. PIPING

The engineering firm will develop a conceptual design for the underground piping required to support the CO2 compression system.

4.2.06.01 DEVELOP PIPING CLASSES & SPECIFICATIONS

Piping classes and specifications will be determined by the engineering firm based on the material balances developed. These piping classes and specifications will be included in the P&IDs.

4.2.07 ELECTRICAL (DESIGN)

4.2.07.01 PREPARE/REVIEW/ISSUE ELECTRIC ONE-LINES

The engineering firm will develop electrical one-line diagrams for the CO2 compression system.

4.2.07.02 CONCEPTUAL UG ELECTRICAL DRWGS

Conceptual underground electrical drawings will be developed by the engineering firm.

4.2.07.05 CONCEPTUAL CONDUIT & CABLE SCHEDULE

A conceptual conduit and cable schedule will be developed by the engineering firm. The schedule will include preliminary sizes, types, and ratings to support a definitive cost estimate.

4.2.07.03 CONCEPTUAL TRAY LAYOUT

The engineering firm will provide conceptual electrical tray layouts for the CO2 compression system. These tray layouts will also be included in the 3D model of the CO2 compression system.

4.2.07.04 PREPARE/REVIEW/ISSUE AREA CLASSIFICATION

The engineering firm will provide descriptions for, and develop a site layout with area classifications.

4.2.10 DEFINITIVE ESTIMATE

4.2.10.01 DEFINITIVE ESTIMATE

Based on the engineering design activities carried out, the engineering firm will prepare an AACEI Class 1, definitive capital cost estimate.

4.3 SUBPHASE: Pipeline Design

4.3.1 Project Kickoff

4.3.1.1 Establish Project Criteria

The sub-recipient and its engineering firm will confirm the project requirements and evaluate any changes that may have occurred since project funding was obtained.

4.3.2 Engineering and Design

4.3.2.1 Route Finalization

The sub-recipient and its engineering firm will conduct a review of the proposed pipeline centerline to evaluate potential causes for route deviation. This will be performed prior to completion of the preliminary route survey by survey crews. A "final" preliminary route will then be issued to the ROW/Land and survey representatives for reference in their respective design tasks.

4.3.2.2 Preliminary Civil and Easement Survey

The sub-recipient and its engineering firm or subcontracted survey company will perform a preliminary route survey once landowner access has been obtained. This survey will be used as the backbone of the route for discussions with landowners and development of all route documentation, including route alignment sheets, wetland and stream crossing permits, road and highway crossing permits, levee and railroad crossing applications, etc. The survey will include GPS coordinates and preliminary pipeline stationing in addition to surveying of key benchmarks, property meets and bounds, and appurtenances.

4.3.2.3 Hydraulic Calculations

The sub-recipient and its engineering firm will use the preliminary survey data to refine the hydraulic calculations for the pipeline based off of distances and elevations. The hydraulic model will confirm the operating limits for delivery pressure and be made available to the recipient for use in compressor design conditions.

4.3.2.4 Prepare System PFD and P&IDS

The sub-recipient and its engineering firm will develop the system process flow diagram (PFD) and the more detailed process and instrumentation diagrams for the measurement and overpressure protection facilities. This information will also be used for development of piping and fabrication drawings, as well as electrical and instrumentation installation drawings.

4.3.2.5 Determine Crossing Permit Requirements

The sub-recipient and its engineering firm will use the preliminary route survey information to confirm the proposed crossing construction methods and specifications for environmental, road, highway, levee, and railroad permit preparation.

4.3.2.6 Develop Material and Equipment Specifications

The sub-recipient and its engineering firm will confirm design and operating conditions and perform calculations to make pipe material selections. The engineering firm will also develop material and equipment specifications that will be used to support the material and equipment bid documents. The specifications will include the Recovery and Reinvestment Act requirement of American-sourced steel for all project materials.

4.3.2.7 Prepare Alignment Drawings

The sub-recipient and its engineering firm will create pipeline route alignment information using survey data and information that has been collected in the project GIS database. The alignments include information such as roads, rivers, pipe and coating specifications, method of construction, temporary work space, easement width, cathodic protection station locations, pipeline elevation, etc.

4.3.2.8 Prepare Landowner Plat Maps

The sub-recipient, its engineering firm and/or its contract ROW/Land agents will prepare property plats for land parcels along the route. The plats will be used for landowner negotiation and ultimately filed with local court houses once negotiations are final and the easement has been purchased.

4.3.2.9 Prepare Permit Exhibits

The sub-recipient and its engineering firm will design and prepared ocumentation to support permit applications for the various pipeline crossings along the route. This documentation will be used to help define the scope of the environmental field surveys required in below, as well as support permit applications for road, highway, and rail road crossings.

4.3.2.10 Prepare Pipeline Construction Details

The sub-recipient and its engineering firm will design and prepare detailed drawings for engineered items, such as pipe overbends for ditches or distinct elevation changes, horizontal directional drills under canals, trenching and construction methods for wetlands, etc.

4.3.2.11 Design and Drawing Preparation for Facilities

The sub-recipient and its engineering firm will design and prepare detailed drawings for installation of measurement, overpressure protection and control, pipeline interconnect, and pipeline pigging facilities. The detailed drawings will address all civil, electrical, mechanical, and instrumentation required for the successful installation of the facilities.

4.3.2.12 Cathodic Protection Design and Details

The sub-recipient and its engineering firm will design and prepare detailed drawings for installation of the cathodic protection system, which helps to ensure the mechanical integrity of the pipeline against external corrosion.

4.3.3 Right-of-Way/Land

4.3.3.1 Update Landowner Line List

The sub-recipient ROW/Land group, engineering firm and its contract land agents will update the landowner line list for the pipeline route. This list will be used to initiate title search for current landowner and property title information, as well as to obtain survey permission once ownership of each property is confirmed.

4.3.3.2 Obtain Access Permission for Preliminary Survey

The sub-recipient ROW/Land group and its contract agents will obtain survey and access permission from landowners along the proposed pipeline route and for potential facility locations.

4.3.3.3 Perform Title Work and Market Study Appraisal

The sub-recipient ROW/Land group and its contract agents will perform property and landowner title searches online through county/parish tax authorities and in local court houses. The sub-recipient ROW/Land group will hire independent third party appraisers to value properties by area, tract size, best use and proximity to other improvements in oder to estimate property values for use in right of way negotiations and acquisition.

4.3.4 Environmental

4.3.4.1 Update Permit & NEPA Requirements

The sub-recipient and its engineering firm will conduct preliminary meetings with the DOE and permitting agencies to discuss the sub-recipient's project to determine the need for an Environmental Assessment (EA) or Environmental Impact Statement (EIS) and crossing permits. Information obtained at these meetings or subsequent calls with permitting agencies or authorities will be used to define specific areas to conduct environmental field surveys below. The sub-recipient and its engineering firm or environmental subcontractor will also review Storm water Pollution Prevention Plan (SWP3) and National Pollutant Discharge Elimination System (NPDES) requirements to confirm design requirements for stormwater retention, secondary containment, and site grading for water runoff management.

4.3.4.2 Perform Environmental Field Surveys for Permitting and NEPA Requirements

The sub-recipient and its engineering firm or environmental subcontractor will perform surveys of predetermined areas along the route to obtain dimensions of the sensitive area and determine the need for additional construction controls or mitigation efforts. This information will be used to complete the NEPA study and finalize the crossing permit applications, as well as the Storm water Pollution Prevention Plan (SWP3) and National Pollutant Discharge Elimination System (NPDES) permit(s).

4.3.4.3 Prepare and Submit Permit Applications

The sub-recipient and its environmental subcontractor will finalize the crossing and hydrotest water discharge permit applications for submittal to the corresponding agencies and permitting authorities. The sub-recipient and its environmental subcontractor will also prepare the NPDES permit applications, if required. Submittal of the permit will be completed by the sub-recipient just prior to system start-up. The sub-recipient, its

engineering firm, and its environmental subcontractor will monitor the agency reviews and approvals, reporting permitting progress noting any potential delays, and address requests for additional information. The engineering firm will update the project schedule, if required.

4.3.4.4 Perform Cultural and Ecological Surveys, if required

The sub-recipient may be required to investigate potential culturally or ecologically sensitive areas along the route. The sub-recipient will retain an environmental contractor to perform physical surveys to catalogue various items, such as flora, endangered fauna, and Native American and Civil War remnants. The environmental contractor will perform the survey and generate reports that will be submitted by the sub-recipient to the requesting agencies for review and approval.

4.3.4.5 Submit Cultural and Ecological Reports to COE, SHPO, DOE

The sub-recipient will submit any reports generated in Task 2a.4.4 above to the requesting agency.

4.3.4.6 Obtain NEPA Finding of No Significant Impact (and Corps of Engineers Approval

The sub-recipient and its environmental subcontractor will conduct any meetings and conference calls and/or address any data calls from the requesting agencies such that the required permits for construction are obtained and all NEPA requirements have been met.

4.3.5 Develop Construction Bid Packages

The sub-recipient and its engineering firm will develop construction bid packages for the pipeline and facility construction. The bid package(s) will consist of pipeline route alignment sheets, construction standards, material and equipment data, project schedule and in-service date, bid specifications and instructions, safety/training requirements, and financial bonding and contract requirements. The contract requirements will be written to observe and comply with the requirements of the Davis Bacon Act.

4.4 MVA Design

4.4.1 Administrative task and subcontracting

Prior to initiation of Phase 2 activities, a number of subtasks will be completed. These are not assigned costs but past experience suggests that they may consume time.

4.4.2 Reservoir Modeling-Initial characterization and modeling

Denbury will provide data refined for input into the reservoir model to be constructed by BEG. This data will be used to document that the flood conforms to expected plume area and pressure elevation. Table 7 shows the data that will be sought and the source. Reservoir modeling for research MVA differs from commercial monitoring done by Denbury as it (1) approaches from a migration of risk perspective, to identify are uncertainties in the characterization that might lead to risk of CO2 migrating from the intended injection area, such as unmapped heterogeneities in the reservoir, and (2) although oil is represented in the model as an important part of the system, predicted oil production will not be reported as such results are outside the scope of the study.

Table 7. Data for modeling and likely data source

Data Source	
Field history including historical production drive mechanism, water flood, historical pressures, etc	Denbury + literature search
Reservoir geometry / static model	BEG from task 1
Initial conditions (pressures, saturations, o/w contact…)	Denbury
Boundary conditions	BEG from task 1
Production tests / field tests results	Denbury*
Permeability / porosity measurements	Denbury*
Relative permeability end points	Denbury*
Relative permeability and capillary pressure curves	Denbury* and literature
Oil and gas composition	Denbury*
PVT (viscosity, density) data for oil	Denbury*
Brine composition or at least TDS	Denbury, sampling program
Well locations	Denbury
Perforated intervals for injection and production wells	Denbury
Current injection and production schedule and rates	Denbury
Historical production/injection rates if available	Files, to be allocated
Temperature data	Denbury
Proximity of other oil/gas fields	Denbury + literature search

**Commercial proprietary non-funded data utilized to refine fluid flow and pressure modeling may be withheld from public information.*

BEG, in consultation with Denbury, will prepare a formal report describing model assumptions and outputs, as well as uncertainties that should be considered in the monitoring program. Commercial proprietary data used for input in the model may be withheld by Denbury from the report.

4.4.3 Characterization and geomechanical description of fault(s)

BEG will undertake compilation of additional characterization data and further model the effect of a range of possible stress changes on faults, with focus on the main sealing fault at the east edge of the field. To the extent legally available, Denbury will provide the data and review the results as in-kind cost share. BEG will prepare a letter report, which will predict conditions at which critical stress on fault will occur and recommend improvements to the fault monitoring plan.

4.4.4 Soil Gas-Feasibility test of surveillance of P&A wells

BEG will undertake an initial assessment of soil gas conditions near representative Soso P&A wells, in consultation with Denbury, to consider complexities that should be considered for soil gas assessment to reduce uncertainties about well integrity in P&A wells. BEG will also include learning from other soil gas tests now underway. This activity will occur after this part of the project has received a CX or under a NEPA waiver. BEG will prepare a letter report recommending future monitoring strategies.

4.4.5 Groundwater monitoring-Feasibility test of surveillance of P&A wells

BEG will sample existing available domestic and other water wells and review historic water well records of aquifer properties to obtain information about the range of ground water chemistries and how to best test for rock-CO2-water interaction in the aquifer should unintended CO2 migration occur. It will also include learning from other projects underway at BEG and elsewhere to identify criteria that may signal migration. Denbury will review with regard to placement of monitoring wells for next stage of study. Field work will occur after CX or NEPA waiver is obtained. BEG will prepare a letter report recommending future monitoring strategies.

4.4.6 AZMI-Establish current pressure profile via Repeat Formation Test (RFT) on new drill wells

BEG assumes that the simple structure can be properly monitored using two wells. This test plan will used to characterize the pressure field and if the plan has value, select above zone monitoring interval (AZMI), and wells will then be completed as AZMI wells. Several choices will be assessed for best value. Field staff estimate $400,000 each to workover and prepare for AZMI completion, which might save considerable cost compared to new drills. However, cement condition may require costly and possibly unsuccessful remediation. In this budget we planned new drills, which have the advantage of allowing more than one interval to be pressure tested using repeat formation tester (RFT). If workover is selected, additional funds will be transferred to verify good cement and well conditions, and install tubing and packers to maintain casing integrity.

This activity will occur after CX or NEPA waiver is received. Denbury will prepare a report with as-build construction and RFT results.

4.4.7 Logging-Feasibility test of surveillance of idle wells

Sandia will subcontract and guide development of a new tool for active temperature stimulation of the reservoir to identify fluid changes and fluid flow. Zones with permeability recover faster from a thermal pulse, and it is hoped that this tool will provide permeability information relevant to migration on faults and fluid changes in AZMI through casing. Denbury will provide initial assess points for testing this tool in up to three wells that are in operation prior to the expansion area flood. Novel tool development is seen as an important part of this project. Sandia will prepare a letter report with as-built tool design and operation, test results and recommendation for further use.

4.4.8 Decision Point, Risk Assessment & Updated MVA plan and cost distribution

BEG in consultation with Denbury, will update the risk assessment and research MVA plan and cost distribution based on the results of previous data collection efforts, and will make adjustments to the research MVA program to supplement commercial operations. BEG will prepare a formal report containing Phase 2B recommendations.

TASK 5.1 CAPTURE CONSTRUCTION

5.1.01 CONSTRUCTABILITY REVIEW - EQUIPMENT LAYOUT

The engineering firm will conduct a constructability review to determine equipment layout for the CO2 capture system.

5.1.02 ENGINEERING 95% COMPLETE

This task is the 95% engineering complete milestone.

5.1.03 SYSTEM

5.1.03.01 P&ID INSTRUMENT EXTRACT

5.1.03.02 P.H.A. (HAZOP)

The engineering firm will conduct a hazard and operability (HAZOP) study for the CO2 capture system. Meetings will be held with the Client to discuss this study.

5.1.03.03 OPERATION MANUALS

To ensure safe operation of the CO2 system, the engineering firm will develop and issue operation manuals to the Client.

5.1.05 CIVIL & STRUCTURAL

5.1.05.07 CIVIL UG DRWGS (SEWER)

The engineering firm will develop drawings for underground civil structures. The underground civil drawings will be issued for Client review.

5.1.05.14 INPUT/REVIEW/ISSUE UNDERGROUND PIPING

The engineering firm will develop, review, and issue underground piping drawings for the CO2 capture system based on information received from Client, process technology licensor and other sources.

5.1.05.02 ISSUE AND REVIEW BUILDING LAYOUT & REQ (PRE-FAB)

The engineering firm will develop the CO2 capture building layout with associated pre-fabricated buildings. The layout will be issued for Client review.

5.1.05.11 ENG DESIGN/INPUT/REVIEW/ISSUE - PLATFORM STEEL

The engineering firm will develop the design for CO2 capture system platform steel. The platform steel design will be issued for Client review.

5.1.05.12 ENG DESIGN/INPUT/REVIEW/IS - MISC PLTFRM & SUPT STL

The engineering firm will develop the design for miscellaneous platform and support steel for the CO2 capture system. The miscellaneous platform and support steel will be issued for Client review.

5.1.05.08 ENG DESIGN/INPUT/REVIEW/ISSUE-PIPE/ELECT SUPT FDNS

The engineering firm will develop the foundation design for pipe and electrical supports. The pipe and electrical support foundation design will be issued for Client review.

5.1.05.09 SCOPE WRITE-UP FOR CIVIL/STRUCTURAL

The engineering firm will develop a write-up for the civil/structural scope of the CO2 capture system.

5.1.05.04 ENG DESIGN/REVIEW/ISSUE – PILING

The engineering firm will develop piling design to support the CO2 capture equipment. The piling design will be issued for Client review.

5.1.05.05 ENG DESIGN/INPUT/REVIEW – BUILDING

Engineering design for the CO2 capture building will be developed with input from the selected building vendor. Building design will be issued for Client review.

5.1.05.06 ENG DESIGN/INPUT/REVIEW/ISSUE - TOWER / VESSEL FDNS

The engineering firm will develop foundation design for towers and vessels. The tower and vessel foundation design will be issued for Client review.

5.1.05.13 ENG DESIGN/INPUT/REVIEW/ISSUE - PIPE/ELECT SPRTS

The engineering firm will develop the design for pipe and electrical supports for the CO2 capture system. The miscellaneous pipe and electrical support design will be issued for Client review.

5.1.05.01 ENG DESIGN/INPUT/REVIEW/ISSUE - ELECT EQUIP FDTNS

The engineering firm will develop the design for the all electrical equipment foundations for the CO2 capture system. The design will subsequently be sent to the Client for review.

5.1.05.03 ENG DESIGN/INPUT/REVIEW/ISSUE - MJR EQUIP FDNS

The engineering firm will develop the major equipment foundation design based on OEM bids received. The major equipment foundation design will be issued for Client review.

5.1.05.15 PREP REQ/IFB/BID TAB/VNDR ENG – BUILDINGS

The engineering firm will develop REQ and IFB documents for the CO2 capture building. These documents will be sent to OEMs for bidding. Upon receipt of OEM bids, the engineering firm will tabulate and evaluate the bids.

5.1.05.10 PREP REQ/IFB/BID TAB/VNDR ENG - STR. STEEL

The engineering firm will develop REQ and IFB documents for the structural steel required for the CO2 capture system. These documents will be sent to OEMs for bidding. Upon receipt of OEM bids, the engineering firm will tabulate and evaluate the bids.

5.1.05.16 AWARD/FAB/SHIP – BUILDINGS

Following bid evaluation, the CO2 compressor building will be awarded to the selected OEM for fabrication and shipment.

5.1.06 PIPING

5.1.06.01 PREP REQ/IFB/BID TAB/VNDR ENG - TAGGED VALVES

The engineering firm will develop REQ and IFB documents for tagged valves. These documents will be sent to OEMs for bidding. Upon receipt of OEM bids, the engineering firm will tabulate and evaluate the bids.

5.1.06.02 VESSEL PLATFORM & NOZZLE ORIENTATION

The engineering firm will determine vessel platform and nozzle orientation to support the CO2 capture system.

5.1.06.14 ISSUE ISOMETRICS

Following pipe stress calculations, the engineering firm will issue isometrics for Client review.

5.1.06.10 PIPE STRESS ANALYSIS

The engineering firm will conduct pipe stress analyses.

5.1.06.04 TIE-IN DWGS

The engineering firm will develop tie-in drawings for the CO2 capture equipment.

5.1.06.15 MES RUN – MTO

5.1.06.11 SCOPE WRITE-UPS – MECHANICAL

The engineering firm will develop a write-up for the mechanical scope of the CO2 capture system.

5.1.06.12 SCOPE WRITE-UPS – INSULATION

The engineering firm will develop a write-up for the insulation scope of the CO2 capture system.

5.1.06.13 SCOPE WRITE-UPS – PAINTING

The engineering firm will develop a write-up for the painting scope of the CO2 capture system.

5.1.06.03 AWARD/FAB/SHIP - TAGGED VALVES

Following bid evaluation for the tagged valves, the tagged valves will be awarded to the selected OEM for fabrication and shipment.

5.1.06.16 PREPARE REQ/IFB/BID/TAB - PIPE SPECIALS (TRAPS ETC.)

The engineering firm will develop REQ and IFB documents for pipe specials such as strainers and traps. These documents will be sent to OEMs for bidding. Upon receipt of OEM bids, the engineering firm will tabulate and evaluate the bids.

5.1.06.17 AWARD/FAB/SHIP - PIPE SPECIALS (TRAPS ETC.)

Following bid evaluation, the pipe specials will be awarded to the selected OEM(s) for fabrication and shipment.

5.1.06.18 FINAL REQUISITION - BULK PIPE

The engineering firm will issue the final requisition for bulk pipe.

5.1.06.06 PREP REQ/IFB/BID TAB/VNDR ENG - SHOP FAB PIPE

The engineering firm will develop REQ and IFB documents for shop fabricated pipe. These documents will be sent to OEMs for bidding. Upon receipt of OEM bids, the engineering firm will tabulate and evaluate the bids.

5.1.06.09 AWARD/FAB/SHIP - SHOP FAB PIPE

Following bid evaluation for the shop fabricated pipe, bids will be awarded to the selected OEM for fabrication and shipment.

5.1.06.05 PREP REQ/IFB/BID TAB/VNDR ENG - PVF AND MISC PIPE

The engineering firm will develop REQ and IFB documents for PVF and miscellaneous pipe. These documents will be sent to OEMs for bidding. Upon receipt of OEM bids, the engineering firm will tabulate and evaluate the bids.

5.1.06.07 AWARD/FAB/SHIP - PVF AND MISC PIPE

Following bid evaluation for the PVF and miscellaneous pipes, bids will be awarded to the selected OEM for fabrication and shipment

5.1.08 INSTRUMENTATION

5.1.08.01 PREP/REVIEW/ISSUE - INSTRUMENT INDEX

5.1.08.03 PREP/REVIEW/ISSUE - I/O LIST

The engineering firm will develop an input/output (I/O) list for the CO2 capture system. This list will be issued to the Client for review

5.1.08.02 PREPARE & REVIEW - LOGIC DIAGRAMS

The engineer will develop logic diagrams for the CO2 capture system.

5.1.08.04 PREP REQ/IFB/BID TAB/VNDR ENG-FLOW ELEMENTS

The engineering firm will develop REQ and IFB documents for flow elements. These documents will be sent to OEMs for bidding. Upon receipt of OEM bids, the engineering firm will tabulate and evaluate the bids.

5.1.08.05 AWARD/FAB/SHIP - FLOW ELEMENTS

Following bid evaluation for the flow elements, bids will be awarded to the selected OEM(s) for fabrication and shipment.

5.1.08.06 PREP REQ/IFB/BID TAB – INSTRUMENTS

The engineering firm will develop REQ and IFB documents for instruments. These documents will be sent to OEMs for bidding. Upon receipt of OEM bids, the engineering firm will tabulate and evaluate the bids.

5.1.08.07 AWARD/FAB/SHIP – INSTRUMENTS

Following bid evaluation for the instruments, bids will be awarded to the selected OEM(s) for fabrication and shipment.

5.1.07 ELECTRICAL

5.1.07.12 PRELIM. ELECT LAYOUT (PANELS / RECEPT ETC.)

An electrical layout drawing, detailing the general layout of electrical panels, receptacles, transformers, etc. will be prepared by the engineering firm and issued for Client review.

5.1.07.08 PRELIM/REVIEW/ISSUE U.G.ELECT DRAWINGS

The engineering firm will revise and issue the underground electrical drawings for Client review.

5.1.07.16 PREP/REVIEW/INSTR/ISSUE GROUNDING DWGS

The engineering firm will develop grounding drawings for the CO2 capture system for Client review.

5.1.07.04 PREP/REVIEW/ISSUE PANEL & CABINET DRAWINGS

Electrical panel and cabinet drawings will be developed for the CO2 capture system. These drawings will be issued for Client review.

5.1.07.13 PREP/REVIEW/ISSUE POWER PLANS

5.1.07.17 PREP/REVIEW/ISSUE I/E INSTRUMENT PLANS

5.1.07.18 PREP/REVIEW/ISSUE I / E INSTALLATION DETAILS

5.1.07.09 3D MODEL/PREP/REVIEW/ISSUE TRAY PLANS

The 3D model for electrical trays will be revised and issued for Client review based on information received from selected OEMs.

5.1.07.03 PREP/REVIEW/ISSUE LOOP DIAGRAMS

Control loop diagrams will be developed for the CO2 capture system. These drawings will be issued for Client review.

5.1.07.14 PREP/REVIEW/ISSUE MOTOR SCHEMATIC DRWGS

The engineering form will prepare motor schematic drawings for the CO2 capture system for Client review and comment.

5.1.07.15 PREP/REVIEW/ISSUE WIRING DIAGRAMS

The engineering firm will develop revise electrical wiring diagrams based on information received from electrical equipment OEMs. These electrical wiring diagrams will be issued for Client review.

5.1.07.20 CONDUIT & CABLE SCHEDULE - (PWR/CNTL)

5.1.07.19 ELECTRICAL MATERIAL TAKE-OFF

The engineering firm will develop MTOs for the electrical equipment of the CO2 capture system.

5.1.07.11 PREP/REVIEW/ISSUE INSTRUMENT WIRING DIA

Instrumentation wiring diagrams will be prepared by the engineering form based on instrumentation equipment data received from OEMs. These instrument wiring diagrams will be issued for Client review.

5.1.07.05 PREP REQ/IFB/BID TAB/VNDR ENG - ELEC BULKS

The engineering firm will develop REQ and IFB documents for other bulk electrical equipment. These documents will be sent to OEMs for bidding. Upon receipt of OEM bids, the engineering firm will tabulate and evaluate the bids.

5.1.07.10 AWARD/FAB/SHIP - ELEC BULKS

Following bid evaluation for the electrical bulk equipment, bids will be awarded to the selected OEM(s) for fabrication and shipment.

5.1.07.01 PREP REQ/IFB/BID TAB/VNDR ENG – TRANSFORMERS

The engineering firm will develop REQ and IFB documents for transformers. These documents will be sent to OEMs for bidding. Upon receipt of OEM bids, the engineering firm will tabulate and evaluate the bids.

5.1.07.06 AWARD/FAB/SHIP – TRANSFORMERS

Following bid evaluation for the transformers, bids will be awarded to the selected OEM(s) for fabrication and shipment.

5.1.07.02 PREP REQ/IFB/BID TAB/VNDR ENG - ELEC SWITCHGEAR

The engineering firm will develop REQ and IFB documents for the electrical switchgear. These documents will be sent to OEMs for bidding. Upon receipt of OEM bids, the engineering firm will tabulate and evaluate the bids.

5.1.07.07 AWARD/FAB/SHIP - ELEC SWITCHGEAR

Following bid evaluation for the electrical switchgear, bids will be awarded to the selected OEM for fabrication and shipment.

5.1.09 MODELING

5.1.09.04 INITIAL EQUIPMENT MODELING IN (3D) MODEL

Based on the bids received from OEMs, the engineering firm will develop a 3D model for the CO2 capture equipment.

5.1.09.05 DEVELOP MODEL TO 3RD STAGE

5.1.09.02 CLIENT MODEL REVIEW

5.1.09.06 DEVELOP MODEL TO FINAL STAGE

The engineering firm will finalize the 3D model of the CO2 capture system.

5.1.09.01 MODEL AUTOROUTER

5.1.09.03 PIPE STRESS ANALYSIS

The engineering firm will update pipe stress analysis calculations.

5.1.04 EQUIPMENT

5.1.04.01 PREP REQ/IFB/BID TAB/VNDR ENG - COMPRESSORS & PLC

The engineering firm will develop REQ and IFB documents for air compressors. These documents will be sent to OEMs for bidding. Upon receipt of OEM bids, the engineering firm will tabulate and evaluate the bids.

5.1.04.02 AWARD/FAB/SHIP - COMPRESSORS & PLC

Following bid evaluation for the vessel air comprewsors, bids will be awarded to the selected OEM(s) for fabrication and shipment.

5.1.04.05 PREP REQ/ISB/BID TAB/VNDR ENG - VESSEL INTERNALS

The engineering firm will develop REQ and IFB documents for Rectisol vessel internals. These documents will be sent to OEMs for bidding. Upon receipt of OEM bids, the engineering firm will tabulate and evaluate the bids.

5.1.04.06 AWARD/FAB/SHIP - VESSEL INTERNALS

Following bid evaluation for the vessel internals, bids will be awarded to the selected OEM(s) for fabrication and shipment.

5.1.04.07 PREP REQ/IFB/BID TAB/VNDR ENG – PUMPS

The engineering firm will develop REQ and IFB documents for pumps. These documents will be sent to OEMs for bidding. Upon receipt of OEM bids, the engineering firm will tabulate and evaluate the bids.

5.1.04.08 AWARD/FAB/SHIP – PUMPS

Following bid evaluation for the pumps, bids will be awarded to the selected OEM(s) for fabrication and shipment.

5.1.04.09 PREP REQ/IFB/BID TAB/VNDR ENG - SHOP FAB PRESSURE VESSELS

The engineering firm will develop REQ and IFB documents for shop fabricated pressure vessels. These documents will be sent to OEMs for bidding. Upon receipt of OEM bids, the engineering firm will tabulate and evaluate the bids.

5.1.04.10 AWARD/FAB/SHIP - SHOP FAB PRESSURE VESSELS

Following bid evaluation for the shop fabricated pressure vessels, bids will be awarded to the selected OEM(s) for fabrication and shipment.

5.1.04.12 PREP REQ/IFB/BID TAB/VNDR ENG - FIELD ERECTED TANKS

The engineering firm will develop REQ and IFB documents for shop field erected tanks. These documents will be sent to OEMs for bidding. Upon receipt of OEM bids, the engineering firm will tabulate and evaluate the bids.

5.1.04.13 AWARD/FAB/SHIP - FIELD ERECTED TANKS

Following bid evaluation for the field erected tanks; bids will be awarded to the selected OEM(s) for fabrication and shipment.

5.1.04.14 PREP REQ/IFB/BID TAB/VNDR ENG - HEAT EXCHANGERS

The engineering firm will develop REQ and IFB documents for heat exchangers. These documents will be sent to OEMs for bidding. Upon receipt of OEM bids, the engineering firm will tabulate and evaluate the bids.

5.1.04.15 AWARD/FAB/SHIP - HEAT EXCHANGERS

Following bid evaluation for the heat exchangers, bids will be awarded to the selected OEM(s) for fabrication and shipment.

5.1.11 SUBCONTRACT PACKAGES

5.1.11.02 INQUIRE/QUOTE/BID TAB/AWARD - GENERAL CONTRACTOR

The engineering firm will develop REQ and IFB documents for general construction contractors. These documents will be sent to general construction contractors for bidding. Upon receipt of contractor bids, the engineering firm will tabulate and evaluate the bids. Based on the bids received from general construction contractors, the general contractor scope for the CO2 capture system will be awarded to the selected contractor.

5.1.12 CONSTRUCTION

5.1.19.01 CONSTR - MOBILIZE & SITEWORK

The selected contractor will mobilize, stage equipment, and prepare to commence the construction of underground civil works.

5.1.12.01 CONSTR – UNDERGROUND

The selected contractor will commence the construction of underground civil works.

5.1.18.01 CONSTR - INSULATE & PAINT

Upon completion of aboveground piping erection, the selected contractor will finish painting of piping and equipment as required and insulate.

5.1.21.01 CONSTR - FINAL MECH / TEST

The selected contractor will conduct final checks and conduct piping hydro tests for design compliance.

5.1.21.02 MECHANICAL COMPLETION

This task defines the mechanical completion of the Rectisol unit.

5.1.12.02 SITE FOUNDATION PILING

The selected contractor will cast pilings to support the CO2 capture equipment.

5.1.13.01 EXC, F/R/P FOUNDATION COMPRESSORS TRAINS 1 & 2

This task includes the excavation, forming, rebaring, pouring of the air compressor foundations for the Rectisol Trans 1 & 2. The selected contractor will be responsible for this task.

5.1.13.04 EXC, F/R/P FOUNDATIONS FOR ELECTRICAL EQUIPMENT

This task includes the excavation, forming, rebaring, pouring of the electrical equipment foundations for the CO2 capture system. The selected contractor will be responsible for this task.

5.1.14.01 SET TRANSFORMERS

The CO2 capture system's transformers will be set (placed, bolted, etc.) on their respective foundations by the selected contractor.

5.1.16.02 DRESS TRANSFORMERS

Following transformer setting, the transformers for the CO2 capture system will be dressed by the selected contractor.

5.1.16.14 INSTALL ISOPHASE BUSS

The isophase bus ducts will be installed by the selected contractor in preparation for switchgear connection.

5.1.14.02 SET SWITCHGEAR

The switchgear for the CO2 capture system will be set by the selected contractor.

5.1.16.03 INSTALL CABLE TRAY

This task will include the installation of the cable trays for the CO2 capture system. The selected contractor will be responsible for this task.

5.1.16.08 ELECTRICAL CONDUIT

This task includes the installation of the electrical conduit the Rectisol unit. The selected contractor shall be responsible for the execution of this task.

5.1.16.15 PULL AND TERMINATE

Electrical wire and cabling will be pulled and terminated for the Rectisol unit systems and subsequently connected to the associated electrical equipment.

5.1.16.01 SWITCHYARD CONTRACTOR

The switchyard contractor will prepare the space required for switchyard installation and erect the switchyard. The CO2 capture system loads will be connected to the switchyard.

5.1.20.01 CONSTR – BUILDING

5.1.13.06 EXC, F/R/P FND PUMPS TRAINS 1 & 2

This task includes the excavation, forming, rebaring, pouring of the foundations for the pumps for Rectisol Trains 1&2. The selected contractor will be responsible for this task.

5.1.13.12 PUMPS GROUNDING

This task includes the electrical grounding of the Rectisol unit pumps. The selected contractor shall be responsible for the execution of this task.

5.1.13.16 PUMPS STEEL & PLATFORMS

This task includes the installation and erection of steel and platforms for Rectisol unit pumps. The selected contractor shall be responsible for the execution of this task.

5.1.15.03 PUMPS PIPING

This task includes the piping installation for the Rectisol unit pumps. The piping installation for these pumps will be conducted by the selected contractor.

5.1.15.08 HYDRO TEST PUMPS

This task includes hydro testing for the Rectisol unit pumps. The testing will be conducted by the selected testing contractor.

5.1.16.05 SET PUMPS

This task includes the setting (placement, bolt, etc.) of the Rectisol unit pumps. The selected contractor shall be responsible for the execution of this task.

5.1.16.11 PUMPS ELECTRICAL

This task includes the installation of electrical equipment for the Rectisol unit pumps. The electrical equipment installation for these pumps will be conducted by the selected contractor.

5.1.17.03 PUMPS INSTRUMENTATION

This task includes the installation of instrumentation equipment for the Rectisol unit pumps. The instrument installation will be conducted by the selected contractor.

5.1.13.07 EXC, F/R/P FND FIELD ERECTED TANKS TRAINS 1 & 2

This task includes the excavation, forming, rebaring, pouring of the foundations for the field erected tanks for Rectisol Trains 1&2. The selected contractor will be responsible for this task.

5.1.13.13 FIELD ERECTED TANKS GROUNDING

This task includes the electrical grounding of the Rectisol unit field erected tanks. The selected contractor shall be responsible for the execution of this task.

5.1.13.17 FIELD ERECTED TANKS STEEL & PLATFORMS

This task includes the installation and erection of steel and platforms for Rectisol field erected tanks. The selected contractor shall be responsible for the execution of this task.

5.1.15.04 FIELD ERECTED TANKS PIPING

This task includes installation of piping associated to the Rectisol unit field erected tanks. The selected contractor shall be responsible for the execution of this task.

5.1.15.09 HYDRO TEST FIELD ERECTED TANKS

This task includes hydro testing the Rectisol unit field erected tanks. The selected testing contractor shall be responsible for the execution of this task.

5.1.16.06 SET FIELD ERECTED TANKS

This task includes setting (placement, bolting, etc.) of the Rectisol unit field erected tanks. The selected contractor shall be responsible for the execution of this task.

5.1.16.12 FIELD ERECTED TANKS ELECTRICAL

This task includes installation of electrical equipment associated to the Rectisol unit field erected tanks. The selected contractor shall be responsible for the execution of this task.

5.1.13.13 EXC, F/R/P - FOUNDATION PIPERACK

The task is for constructing the complete foundation system for the piperack, to include excavation, forming, rebar and embed placement, pouring concrete, curing and form stripping of the various foundation elements.

5.1.13.14 STEEL ERECTION PIPERACK

The task is for constructing the complete structural steel system for the piperack, to include erection, alignment, bolt up and/or welding of the structural elements of the system.

5.1.13.15 LB PIPE FOR PIPERACK

The task is for erecting of large bore piping in the piperack, including spool piece and fitting placement, support and hanging, fit-up and completing all threaded and welded joints for each large bore line routed in the piperack.

5.1.13.16 INSTRUMENTATION PIPERACK

The task is for installation of all in-line instrumentation in the pipe lines routed in the piperack including field installed thermalwells.

5.1.13.17 SB PIPE FOR PIPERACK

The task is for erecting of small bore piping in the piperack, including spool piece and fitting placement, support and hanging, fit-up and completing all threaded and welded joints for each small bore line routed in the piperack.

5.1.17.04 FIELD ERECTED TANKS INSTRUMENTATION

This task includes instrumentation installation associated to the Rectisol unit field erected tanks. The selected testing contractor shall be responsible for the execution of this task.

5.1.16.04 SET HEAT EXCHANGERS

This task includes setting (placement, bolting, etc.) of the Rectisol unit heat exchangers. The selected contractor shall be responsible for the execution of this task.

5.1.13.11 HEAT EXCHANGERS GROUNDING

This task includes the electrical grounding of the Rectisol heat exchangers. The selected contractor shall be responsible for the execution of this task.

5.1.13.15 HEAT EXCHANGERS STEEL & PLATFORMS

This task includes the installation and erection of steel and platforms for Rectisol heat exchangers. The selected contractor shall be responsible for the execution of this task.

5.1.15.02 HEAT EXCHANGERS PIPING

This task includes installation of piping associated to the Rectisol unit heat exchangers. The selected contractor shall be responsible for the execution of this task.

5.1.16.10 HEAT EXCHANGERS ELECTRICAL

This task includes the installation of electrical equipment for the Rectisol unit heat exchangers. The electrical equipment installation for these heat exchangers will be conducted by the selected contractor.

5.1.17.02 HEAT EXCHANGERS INSTRUMENTATION

This task includes instrumentation installation associated to the Rectisol unit heat exchangers. The selected contractor shall be responsible for the execution of this task.

5.1.15.07 HYDRO TEST HEAT EXCHANGERS

This task includes hydro testing the Rectisol unit air compressors. The selected testing contractor shall be responsible for the execution of this task.

5.1.14.05 SET COMPRESSORS

This task includes setting (placement, bolting, etc.) of the Rectisol unit air compressors. The selected contractor shall be responsible for the execution of this task.

5.1.13.20 COMPRESSORS GROUNDING

This task includes the electrical grounding of the Rectisol unit air compressors. The selected contractor shall be responsible for the execution of this task.

5.1.13.19 COMPRESSORS STEEL ERECTION

This task includes erection of the Rectisol unit steel for the air compressors. The selected contractor shall be responsible for the execution of this task.

5.1.15.11 COMPRESSORS PIPING

This task includes the piping installation for the Rectisol unit air compressors. The piping installation for these air compressors will be conducted by the selected contractor.

5.1.16.16 COMPRESSORS ELECTRICAL

This task includes the installation of electrical equipment for the Rectisol unit air compressors. The electrical equipment installation for these compressors will be conducted by the selected contractor.

5.1.17.06 COMPRESSORS INSTRUMENTATION

This task includes instrumentation installation associated to the Rectisol unit air compressors. The selected contractor shall be responsible for the execution of this task.

5.1.15.12 HYDRO TEST COMPRESSORS

This task includes hydro testing the Rectisol unit field erected tanks. The selected testing contractor shall be responsible for the execution of this task.

5.1.20.1 PULL AND TERMINATE

Electrical wire and cabling will be pulled and terminated for the Rectisol unit systems and subsequently connected to the associated electrical equipment.

5.1.20.2 ELECTRICAL CONDUIT

This task includes the installation of the electrical conduit the Rectisol unit. The selected contractor shall be responsible for the execution of this task.

5.1.20.3 INSULATE & PAINT

This task includes the insulation and painting of the Rectisol unit. The selected contractor shall be responsible for the execution of this task.

5.1.13.13 FIELD ERECTED TANKS GROUNDING

This task includes the electrical grounding of the Rectisol unit field erected tanks. The selected contractor shall be responsible for the execution of this task.

5.1.16.06 SET FIELD ERECTED TANKS

This task includes setting (placement, bolting, etc.) of the Rectisol unit field erected tanks. The selected contractor shall be responsible for the execution of this task.

5.1.13.17 FIELD ERECTED TANKS STEEL & PLATFORMS

This task includes the installation and erection of steel and platforms for Rectisol field erected tanks. The selected contractor shall be responsible for the execution of this task.

5.1.15.04 FIELD ERECTED TANKS PIPING

This task includes installation of piping associated to the Rectisol unit field erected tanks. The selected contractor shall be responsible for the execution of this task.

5.1.16.12 FIELD ERECTED TANKS ELECTRICAL

This task includes installation of electrical equipment associated to the Rectisol unit field erected tanks. The selected contractor shall be responsible for the execution of this task.

5.1.17.04 FIELD ERECTED TANKS INSTRUMENTATION

This task includes instrumentation installation associated to the Rectisol unit field erected tanks. The selected testing contractor shall be responsible for the execution of this task.

5.1.15.09 HYDRO TEST FIELD ERECTED TANKS

This task includes hydro testing the Rectisol unit field erected tanks. The selected testing contractor shall be responsible for the execution of this task.

5.1.13.25 SET EQUIPMENT SHOP FAB PRESSURE VESSELS

This task includes setting (placement, bolting, etc.) of the Rectisol unit shop fabricated pressure vessels. The selected contractor shall be responsible for the execution of this task.

5.1.13.10 SHOP FAB PRESSURE VESSELS STEEL ERECTION

This task includes erection of the Rectisol unit steel for the shop fabricated pressure vessels. The selected contractor shall be responsible for the execution of this task.

5.1.15.01 SHOP FAB PRESSURE VESSELS PIPING

This task includes installation of piping associated to the Rectisol unit shop fabricated pressure vessels. The selected contractor shall be responsible for the execution of this task.

5.1.16.09 SHOP FAB PRESSURE VESSELS ELECTRCIAL

This task includes installation of electrical equipment associated to the Rectisol unit shop fabricated pressure vessels. The selected contractor shall be responsible for the execution of this task.

5.1.17.01 SHOP FAB PRESSURE VESSELS INSTRUMENTATION

This task includes the hydro testing of the Rectisol unit shop fabricated pressure vessels. The selected contractor shall be responsible for the execution of this task.

5.1.15.06 HYDRO TEST SHOP FAB PRESSURE VESSELS

This task includes the hydro testing of the Rectisol unit shop fabricated pressure vessels. The selected testing contractor shall be responsible for the execution of this task.

5.1.13.25 SHOP FAB PRESSURE VESSELS GROUNDING

This task includes the electrical grounding of the Rectisol unit shop fabricated pressure vessels. The selected contractor shall be responsible for the execution of this task.

5.1.13.12 PUMPS GROUNDING

This task includes the electrical grounding of the Rectisol unit pumps. The selected contractor shall be responsible for the execution of this task.

5.1.16.05 SET PUMPS

This task includes the setting (placement, bolt, etc.) of the Rectisol unit pumps. The selected contractor shall be responsible for the execution of this task.

5.1.13.16 PUMPS STEEL & PLATFORMS

This task includes the installation and erection of steel and platforms for Rectisol unit pumps. The selected contractor shall be responsible for the execution of this task.

5.1.15.03 PUMPS PIPING

This task includes the piping installation for the Rectisol unit pumps. The piping installation for these pumps will be conducted by the selected contractor.

5.1.16.11 PUMPS ELECTRICAL

This task includes the installation of electrical equipment for the Rectisol unit pumps. The electrical equipment installation for these pumps will be conducted by the selected contractor.

5.1.17.03 PUMPS INSTRUMENTATION

This task includes the installation of instrumentation equipment for the Rectisol unit pumps. The instrument installation will be conducted by the selected contractor.

5.1.15.08 HYDRO TEST PUMPS

This task includes hydro testing for the Rectisol unit pumps. The testing will be conducted by the selected testing contractor.

5.1.14.03 SET VESSEL INTERNALS

This task includes the setting of the internals (packing etc.) for the Rectisol unit. The setting of the internals will be conducted by the selected contractor.

5.1.13.09 VESSEL INTERNALS FIELD DRESS

This task includes the installation of the internals (packing etc.) for the Rectisol unit. The installation of the internals will be conducted by the selected contractor

.

5.1.13.25 SHOP FAB PRESSURE VESSELS GROUNDING

This task includes grounding of the shop fabricated vessels for the Rectisol unit. The grounding will be conducted by the selected contractor.

5.1.21.01 CONSTR - FINAL MECH / TEST

This task includes the final mechanical testing for Rectisol. The testing will be conducted by the selected testing contractor.

5.1.21.02 MECHANICAL COMPLETION

This task defines mechanical completion for the Rectisol.

TASK 5.2 COMPRESSION CONSTRUCTION

5.2.01 CONSTRUCTABILITY REVIEW - EQUIPMENT LAYOUT

The engineering firm will conduct a constructability review to determine equipment layout for the CO2 compression system.

5.2.02 ENGINEERING 95% COMPLETE

This task is the 95% engineering complete milestone.

5.2.03 SYSTEM

5.2.03.01 P&ID INSTRUMENT EXTRACT

5.2.03.02 P.H.A. (HAZOP)

The engineering firm will conduct a hazard and operability (HAZOP) study for the CO2 compression system. Meetings will be held with the Client to discuss this study

5.2.03.03 OPERATION MANUALS

To ensure safe operation of the CO2 system, the engineering firm will develop and issue operation manuals to the Client.

5.2.05 CIVIL & STRUCTURAL

5.2.05.08 CIVIL UG DRWGS (SEWER)

The engineering firm will develop drawings for underground civil structures. The underground civil drawings will be issued for Client review.

5.2.05.04 INPUT/REVIEW/ISSUE UNDERGROUND PIPING

The engineering firm will develop underground piping arrangement drawings. The underground piping drawings will be issued for Client review.

5.2.05.02 ISSUE AND REVIEW BUILDING LAYOUT & REQ (PRE-FAB)

The engineering firm will develop the CO2 compressor building layout with associated pre-fabricated buildings. The layout will be issued for Client review.

5.2.05.12 ENG DESIGN/INPUT/REVIEW/ISSUE - PLATFORM STEEL

The engineering firm will develop the design for CO2 compression system platform steel. The platform steel design will be issued for Client review.

5.2.05.13 ENG DESIGN/INPUT/REVIEW/IS - MISC PLTFRM & SUPT STL

The engineering firm will develop the design for miscellaneous platform and support steel for the CO2 compression system. The miscellaneous platform and support steel will be issued for Client review.

5.2.05.09 ENG DESIGN/INPUT/REVIEW/ISSUE-PIPE/ELECT SUPT FDNS

The engineering firm will develop the foundation design for pipe and electrical supports. The pipe and electrical support foundation design will be issued for Client review.

5.2.05.10 SCOPE WRITE-UP FOR CIVIL/STRUCTURAL

The engineering firm will develop a write-up for the civil/structural scope of the CO2 compression system.

5.2.05.05 ENG DESIGN/REVIEW/ISSUE – PILING

The engineering firm will develop piling design to support the CO2 compression buildings and equipment. The piling design will be issued for Client review.

5.2.05.06 ENG DESIGN/INPUT/REVIEW – BUILDING

Engineering design for the CO2 compressor building will be developed with input from the selected building vendor. Building design will be issued for Client review.

5.2.05.07 ENG DESIGN/INPUT/REVIEW/ISSUE - TOWER / VESSEL FDNS

The engineering firm will develop foundation design for towers and vessels. The tower and vessel foundation design will be issued for Client review.

5.2.05.14 ENG DESIGN/INPUT/REVIEW/ISSUE - PIPE/ELECT SPRTS

The engineering firm will develop the design for pipe and electrical supports for the CO2 compression system. The miscellaneous pipe and electrical support design will be issued for Client review.

5.2.05.01 ENG DESIGN/INPUT/REVIEW/ISSUE - ELECT EQUIP FDTNS

The engineering firm will develop the design for the all electrical equipment foundations for the CO2 compression system. The design will subsequently be sent to the Client for review.

5.2.05.03 ENG DESIGN/INPUT/REVIEW/ISSUE - MJR EQUIP FDNS

The engineering firm will develop the major equipment foundation design based on OEM bids received. The major equipment foundation design will be issued for Client review.

5.2.05.15 PREP REQ/IFB/BID TAB/VNDR ENG – BUILDINGS

The engineering firm will develop REQ and IFB documents for the CO2 compressor building. These documents will be sent to OEMs for bidding. Upon receipt of OEM bids, the engineering firm will tabulate and evaluate the bids.

5.2.05.11 PREP REQ/IFB/BID TAB/VNDR ENG - STR. STEEL

The engineering firm will develop REQ and IFB documents for the structural steel required for the CO2 compression system. These documents will be sent to OEMs for bidding. Upon receipt of OEM bids, the engineering firm will tabulate and evaluate the bids.

5.2.05.16 AWARD/FAB/SHIP – BUILDINGS

Following bid evaluation, the CO2 compressor building will be awarded to the selected OEM for fabrication and shipment.

5.2.06 PIPING

5.2.06.02 VESSEL PLATFORM & NOZZLE ORIENTATION

The engineering firm will determine vessel platform and nozzle orientation to support the CO2 compression system.

5.2.06.14 ISSUE ISOMETRICS

Following pipe stress calculations, the engineering firm will issue isometrics for Client review.

5.2.06.10 PIPE STRESS ANALYSIS

The engineering firm will conduct pipe stress analyses.

5.2.06.04 TIE-IN DWGS

The engineering firm will develop tie-in drawings for the CO2 compression equipment.

5.2.05.15 MES RUN – MTO

5.2.06.11 SCOPE WRITE-UPS – MECHANICAL

The engineering firm will develop a write-up for the mechanical scope of the CO2 compression system.

5.2.06.12 SCOPE WRITE-UPS – INSULATION

The engineering firm will develop a write-up for the insulation scope of the CO2 compression system.

5.2.06.13 SCOPE WRITE-UPS – PAINTING

The engineering firm will develop a write-up for the painting scope of the CO2 compression system.

5.2.06.01 PREP REQ/IFB/BID TAB/VNDR ENG - TAGGED VALVES

The engineering firm will develop REQ and IFB documents for tagged valves. These documents will be sent to OEMs for bidding. Upon receipt of OEM bids, the engineering firm will tabulate and evaluate the bids.

5.2.06.03 AWARD/FAB/SHIP - TAGGED VALVES

Following bid evaluation for the tagged valves, the tagged valves will be awarded to the selected OEM for fabrication and shipment.

5.2.06.16 PREPARE REQ/IFB/BID/TAB - PIPE SPECIALS (TRAPS ETC.)

The engineering firm will develop REQ and IFB documents for pipe specials such as strainers and traps. These documents will be sent to OEMs for bidding. Upon receipt of OEM bids, the engineering firm will tabulate and evaluate the bids.

5.2.06.17 AWARD/FAB/SHIP - PIPE SPECIALS (TRAPS ETC.)

Following bid evaluation, the pipe specials will be awarded to the selected OEM(s) for fabrication and shipment.

5.2.06.18 FINAL REQUISITION - BULK PIPE

5.2.06.06 PREP REQ/IFB/BID TAB/VNDR ENG - SHOP FAB PIPE

The engineering firm will develop REQ and IFB documents for shop fabricated pipe. These documents will be set to the OEMs for bidding. Upon receipt of OEM bids, the engineering firm will tabulate and evaluate the bids.

5.2.06.09 AWARD/FAB/SHIP - SHOP FAB PIPE

Following bid evaluation for the shop fabricated pipe, bids will be awarded to the selected OEM for fabrication and shipment.

5.2.06.05 PREP REQ/IFB/BID TAB/VNDR ENG - PVF AND MISC PIPE

The engineering firm will develop REQ and IFB documents for PVF and miscellaneous pipe. These documents will be sent to OEMs for bidding. Upon receipt of OEM bids, the engineering firm will tabulate and evaluate the bids.

5.2.06.07 AWARD/FAB/SHIP - PVF AND MISC PIPE

Following bid evaluation for the PVF and miscellaneous pipes, bids will be awarded to the selected OEM for fabrication and shipment

5.2.08 INSTRUMENTATION

5.2.08.01 PREP/REVIEW/ISSUE - INSTRUMENT INDEX

The engineering firm will develop an instrument index for the CO2 compression system. This list will be issued to the Client for review.

5.2.08.03 PREP/REVIEW/ISSUE - I/O LIST

The engineering firm will develop an input/output (I/O) list for the CO2 compression system. This list will be issued to the Client for review

5.2.08.02 PREPARE & REVIEW - LOGIC DIAGRAMS

The engineer will develop logic diagrams for the CO2 compression system.

5.2.08.04 PREP REQ/IFB/BID TAB/VNDR ENG-FLOW ELEMENTS

The engineering firm will develop REQ and IFB documents for flow elements. These documents will be sent to OEMs for bidding. Upon receipt of OEM bids, the engineering firm will tabulate and evaluate the bids.

5.2.08.05 AWARD/FAB/SHIP - FLOW ELEMENTS

Following bid evaluation for the flow elements, bids will be awarded to the selected OEM(s) for fabrication and shipment.

5.2.08.06 PREP REQ/IFB/BID TAB – INSTRUMENTS

The engineering firm will develop REQ and IFB documents for instruments. These documents will be sent to OEMs for bidding. Upon receipt of OEM bids, the engineering firm will tabulate and evaluate the bids.

5.2.08.07 AWARD/FAB/SHIP – INSTRUMENTS

Following bid evaluation for the instruments, bids will be awarded to the selected OEM(s) for fabrication and shipment.

5.2.07 ELECTRICAL

5.2.07.12 PRELIM. ELECT LAYOUT (PANELS / RECEPT ETC.)

An electrical layout drawing, detailing the general layout of electrical panels, receptacles, transformers, etc. will be prepared by the engineering firm and issued for Client review.

5.2.07.08 PRELIM/REVIEW/ISSUE U.G.ELECT DRAWINGS

The engineering firm will revise and issue the underground electrical drawings for Client review.

5.2.07.16 PREP/REVIEW/INSTR/ISSUE GROUNDING DWGS

The engineering firm will develop grounding drawings for the CO2 compression system for Client review.

5.2.07.04 PREP/REVIEW/ISSUE PANEL & CABINET DRAWINGS

Electrical panel and cabinet drawings will be developed for the CO2 compression system. These drawings will be issued for Client review.

5.2.07.13 PREP/REVIEW/ISSUE POWER PLANS

The engineering firm will develop power plans for the CO2 compression system. These plans will be issued for the Client review.

5.2.07.17 PREP/REVIEW/ISSUE I/E INSTRUMENT PLANS

The engineering firm will develop instrument and wiring plans for the CO2 compression system. These plans will be issued for the Client review.

5.2.07.18 PREP/REVIEW/ISSUE I / E INSTALLATION DETAILS

The engineering firm will develop details for the CO2 compression system electrical and instrument installation. These details will be issued for the Client review.

5.2.07.09 3D MODEL/PREP/REVIEW/ISSUE TRAY PLANS

The 3D model for electrical trays will be revised and issued for Client review based on information received from selected OEMs.

5.2.07.03 PREP/REVIEW/ISSUE LOOP DIAGRAMS

Control loop diagrams will be developed for the CO2 compression system. These drawings will be issued for Client review.

5.2.07.14 PREP/REVIEW/ISSUE MOTOR SCHEMATIC DRWGS

The engineering form will prepare motor schematic drawings for the CO2 compression system for Client review and comment.

5.2.07.15 PREP/REVIEW/ISSUE WIRING DIAGRAMS

The engineering firm will develop revise electrical wiring diagrams based on information received from electrical equipment OEMs. These electrical wiring diagrams will be issued for Client review.

5.2.07.20 CONDUIT & CABLE SCHEDULE - (PWR/CNTL)

The engineering firm will develop a revised conduit and cable schedule. This schedule will be issued for Client review.

5.2.07.19 ELECTRICAL MATERIAL TAKE-OFF

The engineering firm will develop MTOs for the electrical equipment of the CO2 compression system.

5.2.07.11 PREP/REVIEW/ISSUE INSTRUMENT WIRING DIA

Instrumentation wiring diagrams will be prepared by the engineering form based on instrumentation equipment data received from OEMs. These instrument wiring diagrams will be issued for Client review.

5.2.07.05 PREP REQ/IFB/BID TAB/VNDR ENG - ELEC BULKS

The engineering firm will develop REQ and IFB documents for other bulk electrical equipment. These documents will be sent to OEMs for bidding. Upon receipt of OEM bids, the engineering firm will tabulate and evaluate the bids.

5.2.07.10 AWARD/FAB/SHIP - ELEC BULKS

Following bid evaluation for the electrical bulk equipment, bids will be awarded to the selected OEM(s) for fabrication and shipment.

5.2.07.01 PREP REQ/IFB/BID TAB/VNDR ENG – TRANSFORMERS

The engineering firm will develop REQ and IFB documents for transformers. These documents will be sent to OEMs for bidding. Upon receipt of OEM bids, the engineering firm will tabulate and evaluate the bids.

5.2.07.06 AWARD/FAB/SHIP – TRANSFORMERS

Following bid evaluation for the transformers, bids will be awarded to the selected OEM(s) for fabrication and shipment.

5.2.07.02 PREP REQ/IFB/BID TAB/VNDR ENG - ELEC SWITCHGEAR

The engineering firm will develop REQ and IFB documents for the electrical switchgear. These documents will be sent to OEMs for bidding. Upon receipt of OEM bids, the engineering firm will tabulate and evaluate the bids.

5.2.07.07 AWARD/FAB/SHIP - ELEC SWITCHGEAR

Following bid evaluation for the electrical switchgear, bids will be awarded to the selected OEM for fabrication and shipment.

5.2.09 MODELING

5.2.09.04 INITIAL EQUIPMENT MODELING IN (3D) MODEL

Based on the bids received from OEMs, the engineering firm will develop a 3D model for the CO2 compression equipment.

5.2.09.05 DEVELOP MODEL TO 3RD STAGE

Complete the 3D model with all design information.

5.2.09.02 CLIENT MODEL REVIEW

The 3D model will be issued for Client Review.

5.2.09.06 DEVELOP MODEL TO FINAL STAGE

The engineering firm will finalize the 3D model of the CO2 compression system.

5.2.09.01 MODEL AUTOROUTER

5.2.09.03 PIPE STRESS ANALYSIS

The engineering firm will update pipe stress analysis calculations.

5.2.04 EQUIPMENT

5.2.04.01 PREP REQ/IFB/BID TAB/VNDR ENG - CO2 GAS COMP & PLC

The engineering firm will develop requests for quotation (REQ) and invitation for bid (IFB) documents for the CO2 gas compressors. These documents will be sent to OEMs for bidding. Upon receipt of OEM bids, the engineering firm will tabulate and evaluate the bids.

5.2.04.04 AWARD/FAB/SHIP - CO2 GAS COMP & PLC

Following bid evaluation, the CO2 compressors will be awarded to the selected OEM for fabrication and shipment.

5.2.11 SUBCONTRACT PACKAGES

5.2.11.03 INQUIRE/QUOTE/BID TAB/AWARD - GENERAL CONTRACTOR

The engineering firm will develop REQ and IFB documents for general construction contractors. These documents will be sent to general construction contractors for bidding. Upon receipt of contractor bids, the engineering firm will tabulate and evaluate the bids. Based on the bids received from general construction contractors, the general contractor scope for the CO2 compression system will be awarded to the selected contractor.

5.2.19 CONSTRUCTION

5.2.19.01 CONSTR - MOBILIZE & SITEWORK

The selected contractor will mobilize, stage equipment, and prepare to commence the construction of underground civil works.

5.2.12.01 CONSTR – UNDERGROUND

The selected contractor will commence the construction of underground civil works.

5.2.18.01 CONSTR - INSULATE & PAINT

Upon completion of aboveground piping erection, the selected contractor will finish painting of piping and equipment as required and insulate.

5.2.21.01 CONSTR - FINAL MECH / TEST

The selected contractor will conduct final checks and conduct piping hydro tests for design compliance.

5.2.12.02 SITE FOUNDATION PILING

The selected contractor will cast pilings to support the CO2 compression equipment.

5.2.13.01 EXC, F/R/P FOUNDATION CO2 GAS COMPRESSOR

The selected contractor will excavate and form the site, install rebar, and pour concrete for the CO2 Gas Compressor foundation.

5.2.14.05 SET CO2 GAS COMPRESSOR

This task includes the setting of the CO2 Gas Compressor (placement, bolting, etc.) for the CO2 compression system. The selected contractor will be responsible for the execution of this task.

5.2.13.12 CO2 GAS COMPRESSOR STEEL ERECTION

This task includes the installation and erection of steel and platforms for the CO2 Gas Compressor. The selected contractor shall be responsible for the execution of this task.

5.2.13.13 CO2 GAS COMPRESSOR GROUNDING

Upon setting the CO2 Gas Compressor, the selected contractor will fit up with the grounding grid.

5.2.15.07 CO2 GAS COMPRESSOR PIPING

The selected contractor will fit up the CO2 Gas Compressor with the surrounding erected piping and complete all other miscellaneous compressor piping.

5.2.16.11 CO2 GAS COMPRESSOR ELECTRICAL

The selected contractor will tie in the CO2 Gas Compressor to the electrical system.

5.2.17.04 CO2 GAS COMPRESSOR INSTRUMENTATION

The selected contractor will complete the CO2 Gas Compressor instrumentation installation and wiring.

5.2.15.08 HYDRO TEST CO2 GAS COMPRESSOR PIPING

The selected contractor will perform a hydro test of the CO2 Gas Compressor erected piping.

5.2.13.02 EXC, F/R/P FDN COMPRESSOR DISCHARGE COOLERS

The selected contractor will excavate and form the site, install rebar, and pour the Compressor Discharge Cooler's foundation.

5.2.14.03 SET COMPRESSOR DISCHARGE COOLERS

This task includes the setting of the Compressor Discharge Coolers (placement, bolting, etc.) for the CO2 compression system. The selected contractor will be responsible for the execution of this task.

5.2.13.08 COMPRESSOR DISCHARGE COOLERS STEEL ERECTION

This task includes the installation and erection of steel and platforms for the Compressor Discharge Coolers. The selected contractor shall be responsible for the execution of this task.

5.2.15.01 COMPRESSOR DISCHARGE COOLERS PIPING

The selected contractor will fit up the Compressor Discharge Coolers with the surrounding erected piping and complete all other miscellaneous piping.

5.2.16.06 COMPRESSOR DISCHARGE COOLERS ELECTRICAL

The selected contractor will tie in the Compressor Discharge Coolers to the electrical system.

5.2.17.01 COMPRESSOR DISCHARGE COOLERS INSTRUMENTATION

The selected contractor will complete the Compressor Discharge Coolers instrumentation installation and wiring.

5.2.15.04 HYDRO TEST COMPRESSOR DISCHARGE COOLER PIPING

The selected contractor will perform a hydro test of the Compressor Discharge Cooler erected piping.

5.2.13.03 EXC, F/R/P FOUNDATION SUCTION KO DRUMS

The selected contractor will excavate and form the site, install rebar, and pour the Suction Knockoff Drum's foundation.

5.2.14.04 SET EQUIPMENT SUCTION KO DRUMS

This task includes the setting of the Suction Knockoff Drums (placement, bolting, etc.) for the CO2 compression system. The selected contractor will be responsible for the execution of this task.

5.2.13.09 SUCTION KO DRUMS STEEL ERECTION

This task includes the installation and erection of steel and platforms for the Suction Knockoff Drums. The selected contractor shall be responsible for the execution of this task.

5.2.15.02 SUCTION KO DRUMS PIPING

The selected contractor will fit up the Suction Knockoff Drums with the surrounding erected piping and complete all other miscellaneous piping.

5.2.16.07 SUCTION KO DRUMS ELECTRCIAL

The selected contractor will tie in the Suction Knockoff Drums to the electrical system.

5.2.17.02 SUCTION KO DRUMS INSTRUMENTATION

The selected contractor will complete the Suction Knockoff Drums instrumentation installation and wiring.

5.2.15.05 HYDRO TEST SUCTION KO DRUM PIPING

The selected contractor will perform a hydro test of the Suction Knockoff Drums erected piping.

5.2.13.05 EXC, F/R/P FND CUSTODY TRANSFER METERING SKID

This task includes the excavation, forming, rebaring, pouring of the custody transfer metering skid foundations for the CO2 compression system. The selected contractor will be responsible for this task.

5.2.16.04 SET CUSTODY TRANSFER METERING SKID

This task includes the setting of the custody transfer metering skid (placement, bolting, etc.) for the CO2 compression system. The selected contractor will be responsible for the execution of this task.

5.2.13.11 CUSTODY TRANSFER METERING SKID STEEL & PLATFORMS

This task includes the installation and erection of steel and platforms for the custody transfer metering skid. The selected contractor shall be responsible for the execution of this task.

5.2.13.10 CUSTODY TRANSFER METERING SKID GROUNDING

The custody transfer metering skid for the CO2 compression system will be grounded by the selected contractor.

5.2.15.03 CUSTODY TRANSFER METERING SKID PIPING

This task includes the piping installation for the CO2 compression custody transfer metering skid.

5.2.16.08 CUSTODY TRANSFER METERING SKID ELECTRICAL

This task will include the installation of electrical equipment and wiring associated to the custody transfer metering skid for the CO2 compression system. The selected contractor will provide the electrical installation.

5.2.17.03 CUSTODY TRANSFER METERING SKID INSTRUMENTATION

This task will include the installation of instrumentation equipment and wiring associated to the custody transfer metering skid for the CO2 compression system. The selected contractor will provide the instrumentation installation.

5.2.15.06 HYDRO TEST CUSTODY TRANSFER METERING SKID

This task includes hydro testing for the custody transfer metering skid. The selected testing contractor will be responsible for this task.

5.2.13.04 EXC, F/R/P FOUNDATIONS FOR ELECTRICAL EQUIPMENT

This task includes the excavation, forming, rebaring, pouring of the electrical equipment foundations for the CO2 compression system. The selected contractor will be responsible for this task.

5.2.14.01 SET TRANSFORMERS

The CO2 compression system's transformers will be set (placed, bolted, etc.) on their respective foundations by the selected contractor.

5.2.16.02 DRESS TRANSFORMERS

Following transformer setting, the transformers for the CO2 compression system will be dressed by the selected contractor.

5.2.16.09 INSTALL ISOPHASE BUSS

The isophase bus ducts will be installed by the selected contractor in preparation for switchgear connection.

5.2.14.02 SET SWITCHGEAR

The switchgear for the CO2 compression system will be set by the selected contractor.

5.2.16.03 INSTALL CABLE TRAY

Cable trays for the CO2 compression system will be installed by the selected contractor.

5.2.16.05 ELECTRICAL CONDUIT

Electrical conduit will be installed by the selected contractor.

5.2.16.10 PULL AND TERMINATE

Electrical wire and cabling will be pulled and terminated for the CO2 compression's electrical systems and subsequently connected to the CO2 system's electrical equipment.

5.2.16.01 SWITCHYARD CONTRACTOR

The switchyard contractor will prepare the space required for switchyard installation and erect the switchyard. The CO2 compression system loads will be connected to the switchyard.

5.2.20.01 CONSTR - BUILDING

This task includes the construction of the buildings for the CO2 compression system. The selected contractor will construct the buildings.

5.3 PIPELINE CONSTRUCTION

5.3.1 Procurement

5.3.1.1 Procure Pipe and Long Lead Material/Equipment

The sub-recipient and its engineering firm will competitively bid the pipe and long-lead material and equipment to manufacturers and pipe mills. The bids will be reviewed, summarized and documented. The bids will be compared against the original estimated pricing for each major component. Significant price differences will be communicated to the sub-recipient and evaluated for project cost impact.

5.3.1.2 Procure Miscellaneous Materials

The sub-recipient and its engineering firm will procure miscellaneous pipe, fittings, valves, transmitters, measurement and communication equipment, etc. These items typically have an 8-week delivery or less and will be procured at the latter part of Sub-phase 2a.

5.3.1.3 Procure Cathodic Protection Materials

The sub-recipient and its engineering firm will procure all materials associated with the installation of the cathodic protection system on the pipeline.

5.3.1.4 Right-of-Way and Site Acquisition

The sub-recipient ROW/Land group and its contract agents (or ROW agents within the engineering firm) will extend good faith offers to landowners for the purchase of the pipeline easement and aboveground appurtenances, advance property damage payments, temporary construction work space and permanent personnel access to aboveground appurtenances, etc. Negotiations will also address any landowner restrictions concerning construction activities, such as movement of vehicles, restoration of property to pre-existing condition, and movement of equipment on private farm roads. The ROW/Land group will also participate in securing possible material laydown areas unless a third party logistics firm is retained for managing of material transportation and handling. Further, the ROW/Land group is also charged with acquiring permits from all railroads, as well as all jurisdictional government and quasi-government entities, to allow for construction across public roads, creeks, rivers, and canals.

5.3.1.5 Conduct Landowner Condemnation(s)

In the event good faith negotiations with a landowner fails on any tract of land and no easement has been acquired, the sub-recipient ROW/Land group and its attorneys will file petitions with county or parish authorities to begin condemnation proceedings for that tract.

5.3.1.6 Travel – Monitor Construction and Post Construction

The sub-recipient ROW/Land group will monitor the construction of the pipeline across public and private lands, and act as liaison between the construction contractor and the landowners in monitoring construction clean-up of the permanent and temporary work areas to ensure all contractual obligations have been met, and if necessary, negotiate damage settlements and obtain Releases on all tracts. The ROW/Land group will also contact all landowners to notify them of final survey for as built plats and alignment sheets.

5.3.2 Bid & Award Construction

The sub-recipient will select multiple qualified contractors for inclusion in a competitive bid process for the pipeline and facility construction. The sub-recipient will host a pre-bid meeting typically on or near the construction location and address contractor questions and clarify project scope. Bidders are typically provided with two weeks to provide the requested cost data in writing. The sub-recipient will then evaluate and summarize the bid, sub-contractor and safety information for each company and make a final mainline contractor selection. The sub-recipient and the selected contractor will execute the required contract and discuss additional project information in a subsequent kick-off meeting.

5.3.3 Receive Material and Equipment

The sub-recipient and its mainline contractor(s) will receive the material and equipment at predetermined laydown yards along the pipeline route and the purchased facility

location(s). The laydown yards will include contract personnel to off-load, receive, inventory, inspect and handle the pipe, equipment and various materials.

5.3.4 Inspection

The sub-recipient will retain a third party inspection company to monitor daily construction activities along the route. The representatives of the inspection company will review and correct non-compliant environmental controls, trenching and excavation, wetland crossings, pipe handling and coating issues, safety procedures, utility crossings, etc. The inspectors keep daily logs of all activities and report issues to the sub-recipient's project manager and mainline contractor superintendent. These tasks are concurrent with the pipeline construction tasks below.

5.3.5 Pipeline Construction

5.3.5.1 Final Route Survey and Staking

The sub-recipient and its engineering and survey firms will conduct a final route survey prior to the start of construction. A construction survey consists of measurements made prior to or concurrent with the several construction phases of a pipeline project to control the horizontal and vertical position, dimension and configuration of the pipeline, its stations, sites and appurtenances.

5.3.5.2 ROW Clearing

The sub-recipient's mainline contractor and/or subcontractor will begin clearing vegetation along the proposed route. The boundaries of clearing operations are specified by the construction survey and staking performed prior to construction mobilization. Clearing operations are also dictated by various environmental permit restrictions and requirements, as well as negotiated restrictions by landowners along the route. Vegetation removed from the route will be handled according the state and local requirements, which generally limit treatment of the removed tree branches and vegetation to use of chipping machines and timber sales where appropriate.

5.3.5.3 Trenching and Horizontal Directional Drills (HDDs)

The sub-recipient's mainline contractor will mobilize its construction equipment and begin excavating a trench on the pipeline route centerline. The dimensions of the trench are dictated by soil conditions, pipe diameter, and pipe depth of cover requirements. A subcontractor will also perform the horizontal bores and HDDs required for crossing of highways, roads, rivers and large water bodies.

5.3.5.4 Pipe Stringing

The sub-recipient's mainline contractor will arrange for transport of the pipe materials from the pipe mill or project laydown yards to the pipeline route and offload the pipe adjacent to the open trench. The pipe will be identified, inventoried and inspected for possible damage.

5.3.5.5 Welding and Tie-ins

The sub-recipient's contractor will perform all welding activities required to join the pipe segments and tie in mainline valves stations, bored crossings, and HDDs sections.

5.3.5.6 X-ray and Inspection

The sub-recipient's contractors will conduct non-destructive testing of the pipeline welds using radiographic X-ray and inform the mainline contractor of any weld locations that must be repaired or cut out and re-welded. The pipe and weld coatings will be re-inspected prior to backfilling of the excavated trench.

5.3.5.7 Backfill and ROW Clean-up

The sub-recipient's mainline contractor will begin backfilling the excavated trench once sections of the pipeline have been successfully welded, inspected, X-rayed, and surveyed. The mainline contractor will also perform clean-up activities along the route to minimize impacts to landowners.

5.3.5.8 Perform Mainline Hydrostatic Test(s)

The sub-recipient's mainline contractor will perform the hydrostatic or pressure tests to comply with 39 CFR Part 195 requirements for establishing safe operating pressures. The mainline contractor will notify the sub-recipient in advance of each hydrostatic or pressure test event during construction to allow for water supply, discharge permits and sample acquisition, as well as to provide ROW/Land adequate time to notify adjacent landowners of the pressuring of the line segments.

5.3.6 Facility Construction

5.3.6.1 Site Clearing

The sub-recipient and its contractor will remove the vegetation from the facilities sites and dispose of any rock and timber materials in a manner that complies with state and local disposal requirements.

5.3.6.2 Civil and Foundation Work

The sub-recipient and its facility contractor (or its civil subcontractor) will complete the grading and compaction work required for permanent access to the site and installation of equipment. The grading plan will comply with any applicable FEMA and EPA stormwater management requirements. The facility contractor will then install any foundations or supports required for pigging and measurement equipment, valves and piping, and communications buildings.

5.3.6.3 Site Fence Installation

The sub-recipient and its facility contractor (or its fencing subcontractor) will install a chainlink fence and locking gate around the facility site to secure all materials during construction.

5.3.6.4 Fabrication, Welding and Installation

The sub-recipient and its facility contractor will complete all fabrication, welding, and installation of equipment, piping, valves, and measurement devices. For measurement

facilities located within the operating boundaries of the industrial complex, the facility contractor will coordinate all construction and hot work activities with the safety and operating personnel of the host industrial complex.

5.3.6.5 Instrumentation and Electrical Install

The sub-recipient and its facility contractor will install the instrumentation for and electrical power to the measurement facilities. The instrumentation includes, but it is not limited to, pressure and temperature transmitters, CO2 moisture analyzer, hydrogen sulfide analyzer, gas chromatograph, flow computer, motor control center (MCC) for actuated valves, and communications equipment. Power will be supplied to many of the instrumentation listed above.

5.3.6.6 X-ray, Inspection, and Painting

The sub-recipient and its inspection subcontractor will complete all nondestructive testing required to assess the integrity of fabricated welds, as well as inspect the installation of the equipment, orientation of valves, pipe support placement and adjustment, etc. The facility contractor or a qualified subcontractor will also paint all piping and valves to protect against external corrosion.

5.3.7 Complete Pipeline As-built Survey

The sub-recipient's engineering firm and/or a subcontracted survey firm will complete an as-built survey of the installed pipeline. An as-built survey consists of horizontal and vertical measurements to determine the constructed and final location of the pipeline to obtain the essential dimensions and to inventory the as-built or as-constructed pipeline, its stations, sites and appurtenances.

5.3.8 Pipeline and Equipment Commissioning

The sub-recipient and its mainline contractor will complete a start-up checklist of inspection activities prior to the start-up of the pipeline and equipment. These activities include, but are not limited to, checking each mainline valve station for an open valve position, activation of all electric valve actuators, calibrating all measurement equipment, checking all flange connections for proper bolting and closure, transferring flow from the industrial source into the pipeline in multiple pressure stages to check the line for leaks, etc.

5.3.9 Complete Pipeline and Facility As-built Drawings/Alignments

The sub-recipient's engineering firm will finalize all facility drawings and pipeline alignment sheets with data collected in earlier tasks above. The engineering firm will also transfer all survey, ROW/Land, and as-built information into a Sequel database for integration into the sub-recipient's existing GIS system.

5.3.10 ROW Damage Settlement, Road Repairs

The sub-recipient ROW/Land group and its contract agents will negotiate settlement payments with landowners who have encountered property damage beyond what may have been previously expected and agreed to. Negotiations and payment may include

repairing fence gaps, reseeding due to cons truction during wet conditions, and repairing driveway damage, etc.

5.3.11 Complete Project Job Books and Final Pipeline Technical Report

The sub-recipient and its engineering firm will prepare the final project reports, including a final cost and labor account ing, pipe and m aterial in ventory, and overall project narrative. The engine ering f irm will a lso c ompile all calcu lations, equipm ent data , installation specif ications, drawings, bills of materials, etc. f or inclusion in the f inal project job books, which are retained for the life of the pipeline asset.

5.4 MVA Construction

5.4.1 Commercial Flood Monitoring - Well Review and Remediation

Denbury will define the mechanical status of every wellbore within the possible plume area of the injected CO2. Wells with mechanical problems, which won't allow isolation of the CO2 within the targeted reservoir being flooded, will be re-plugged or remediated prior to the start of injection. This work will be done as part of commercial field development project, at no cost to the research MVA project. Denbury will prepare a letter report of well status showing compliance with regulations.

5.4.2 Logging-Baseline Surveillance of idle wells

Sandia will conduct a survey beyond that conducted by Denbury using an array of tools to critically evaluate condition of wells, especially with regard to potential for natural or anthropogenic fluid migration behind casing. This data will provide a baseline to show any changes that occur as the field is flooded. Sandia, in conjunction with Denbury will select, a sample of representative wells that can be accessed. BEG estimates that 8 may be found in or near the research project area. Sandia will prepare a letter report with methods and results.

5.4.3 Soil Gas-Site & Borehole preparation for surveillance of P&A wells

BEG in consultation with Denbury, will select P&A wells to assess using the methods recommended above and develop characterization data such as samples and access tubes, shallow wells or other infrastructure needed. BEG will prepare a letter report with as built construction and field notes.

5.4.4 Soil Gas-Baseline surveillance of P&A wells

BEG will conduct, in consultation with Denbury, data collection on soil gas sites that were developed. Results will be critically assessed to provide information on the value of this approach to documenting well integrity. BEG will prepare a letter report of methods and data.

5.4.5 Ground Water Monitoring -Well preparation

Denbury and BEG will select four wells that will be completed in the USDW interval and monitored for CO2 migration. Denbury plans to recomplete existing wells. BEG will prepare a letter report showing as-built construction and field notes.

5.4.6 Ground Water Monitoring -Baseline

BEG will purchase a pump and sample and than analyze the groundwater wells installed in Task 13. Four sets of samples will be collected to established a baseline before CO2 injection starts. BEG will prepare a letter report including methods, field notes and data table.

5.4.7 Reservoir Modeling-Upgraded

BEG will incorporate the data to predict range of plume sizes and magnitude and areas of pressure elevation and provide to Denbury for review. This result will be used to modify and adjust the risk assessment and monitoring strategy as needed. BEG will prepare a letter report showing changes in model parameters, revised predictions on area of CO2 plume and distribution and magnitude of pressure change.

5.4.8 AZ MI-Well Completions

Denbury will complete the two AZMI wells from in the above zone to keep the perforations open during testing, and install any constructed-in temperature monitoring equipment. Denbury will prepare a letter report containing field notes and as-built construction.

5.4.9 AZMI-Instrument Monitoring Wells

Sandia will install and maintain pressure gauges on monitoring wells completed in Task 15 in AZMI. Completions are designed to be simple, without tubing and packer, and pressure gage hung in the water column. Pressure data will be available via cell phone or data logger. If workover are used, some of the funds saved from well drilling will be used in this task to install tubing and packer, so that well integrity can be monitored. Sandia will prepare a letter report containing field notes.

5.4.10 Hydrologic testing and Baseline geochemical sampling

Sandia, in consultation with Denbury, will conduct pressure interference test to show hydrologic communication and the area over which the AZMI provides evidence of containment. BEG will collect and analyze pre injection fluids and gases for geochemical samples. Sandia and BEG will prepare a letter Report providing methods and field notes.

5.4.11 VSP - Baseline

Denbury, in coordination BEG, will plan and conduct a baseline VSP survey as an augmented measure of flood conformance. Each proposed 4D-VSP will illuminate an area approximately 1 sqmi. We should plan for five 3DVSP's in the project area to image CO2 fillup through the reservoir and above/below the reservoir and along faults. With high resolution 3D-VSP seismic data we hope to resolve sand units as thin as 10ft. When these 3D-VSP's are repeated we will map where the reservoir changes based on density and pressure changes in the seismic response. Costs for surveys include the surveys, well operations, permitting for seismic sourcing on the surface, and processing. The seismic will require a baseline plus 4 repeats in Phase 2C. Denbury will prepare a letter report providing the details of the field deployment.

5.4.12 Gravity-Baseline

Denbury may conduct gravity survey as an augmented measure of conformance. John Ferguson at UT Dallas was successful in monitoring water migration during the Delhi Field water flood and is studying a model for Hastings. The density variance between CO2 and reservoir fluids in Hastings should be more significant than the density variance of the injected water and oil in the reservoir during the Delhi water flood, so gravity monitoring of the Hastings CO2 flood is expected to be successful in defining the

location of the CO2 plume. Gravity logging will quantify CO2 saturations in the boreholes where porosity is well constrained. Denbury may monitor above/below the reservoir and through the reservoir. The baseline is planned to be followed by 4 repeats in Phase 2C. Denbury will prepare a letter report documenting field notes and data tables.

5.4.13 Measure Out-Of-Pattern Migration (Completion of downdip wells)

As the flood is being developed, two wells outside that phase will be completed by Denbury and used to monitor the possible migration of the CO2 and elevation of pressure outside the completed patterns. Denbury will prepare a letter report including well completion diagrams and daily records of well-head pressure.

5.4.14 Decision Point, Risk Assessment & Updated MVA plan and cost distribution

BEG in consultation with Denbury will update the risk assessment and research MVA plan and cost distribution in consideration of the results of previous data collection efforts, and will make adjustments to the research MVA program to supplement Denbury's commercial field development program. BEG will prepare a formal report containing Phase 2C recommendations.

6.1.01 OPERATION-CO2 CAPTURE

6.1.01.01 START UP

Following construction completion, the engineering firm will provide start up support to the Client.

6.2.01 OPERATION-CO2 COMPRESSION

6.2.01.01 START UP

Following construction completion, the engineering firm will provide start up support to the Client.

6.4 MVA Operation

6.4.1 Commercial Flood Monitoring-Injection and Production Volumes

Denbury will report to the research MVA project the results of commercial flood monitoring, quantifying all injected and produced fluids (including recycle), wellhead pressure, and intermittent injection profiles. This commercial monitoring program will account of purchase and recycle volumes giving the volume of CO2 in the reservoir and the amount of methane produced and recycled with the CO2. This work will be done as part of commercial project but is the most essential monitoring data. BEG will prepare a monthly report providing details on the distribution of the stored CO2.

6.4.2 Commercial Flood Monitoring-Best Practice Mitigation

Denbury will provide to the research MVA project information about mitigation for poor well performance to document how conformance is attained commercially. For example if a well will not accept the planned injection rate at field pressure, Denbury may acidize, reperforate, or inject at a higher rate in other parts of pattern. This work will be done as part of the commercial field development project.

6.4.3 Commercial Flood Monitoring-Pressure Maintenance

Denbury will perform normal well surveillance including monitoring casing pressures in both producers and injectors. Denbury will use remediation procedures to repair wells with compromised integrity. Denbury will provide the results of this work done as part of the commercial project.

6.4.4 Commercial Flood Monitoring-IWR Calculation

Denbury will calculate material balance from data for each pattern on a monthly basis to define changes in reservoir performance. Significant changes in IWR identify potential problem wells within the pattern (i.e. mechanical problems with injectors or inactive wells which are causing the loss of CO2 out of the pattern, or a mechanical problem with the producer(s) within that pattern). The problem wells will be identified and repaired (re-plugged or remediated). This work will be done as part of commercial project.,

6.4.5 Logging-Time lapse surveillance of idle wells

Sandia will conduct a logging and surveillance program on 8 idle wells for which baseline data was collected. This data will be compared to the baseline to show any changes that occur as the field is flooded.. Sandia will prepare a letter report with methods and results will be prepared.

6.4.6 Soil Gas Time lapse surveillance of P&A wells

BEG will follow baseline data collected with repeat data collection over two years on soil gas sites that were developed. Results will be critically assessed to provide information on the value of this approach to documenting well integrity. BEG will prepare a letter report containing data tables and field notes.

6.4.7 Groundwater Monitoring-Time lapse surveillance

BEG will sample and then analyze the groundwater wells for which baseline was collected. Samples will be collected to look for changes as CO2 injection starts. BEG will prepare a letter report containing data tables and field notes.

6.4.8 VSP-Time lapse surveys

Denbury will conduct 4 repeat VSP surveys over the two-year period following the baseline run. This data will be used to show that the flood is conforming to the expected patterns, including providing data about out-of zone migration. Denbury will prepare a formal report including methods and results of surveys on annual basis

6.4.9 Gravity Time lapse surveys

Denbury will conduct 4 repeat gravity surveys over the two-year period following the baseline run in Phase 2B. This data will be used to show that the flood is conforming to the expected patterns and to quantify the volume distribution. Denbury will prepare a formal report including methods and results of surveys on annual basis.

6.4.10 Real Time BHP-Well Preparation

Sandia will deploy bottom hole pressure gage(s) on a real time read out in one well in the injection interval(s). This type of data has proven valuable to assess the nature of the flood. We have budgeted for an elaborate well-based monitoring array. The detailed plan for the well will be designed in M19. Sandia will prepare a letter report showing as-built well schematics.

6.4.11 Real Time BHP-Sandia

Sandia will maintain and back up data collected in the deployment. Sandia will prepare a letter report containing data tables and field notes.

6.4.12 Logging-Time lapse Surveillance

Denbury will augmented measures of conformance to provide data for match to the model by logging about half the injectors and producers in the patterns every half year focusing on the 31 wells in the expansion area but including 10 wells from other parts of the field. Combination temperature and tracer surveys will be run on injection wells twice per year per well. Producers will have spinner, temperature, and capacitance tools run twice a year per well, assuming a 6 month delay in start up in producing the wells, while

each of the injectors would have a series of four logs run. Testing of additional log types is possible. Denbury will prepare a letter report containing data tables and field notes.

6.4.13 Natural geochemical tracers-Collected at wellhead

BEG will, with the assistance of Denbury, collect wellhead fluid samples from producers that serve as augmented measures of conformance. For example, the fluid chemistry will be evaluated for evidence of dissolution and rock-water interaction. BEG will prepare a letter report containing data tables and field notes.

6.4.14 Time lapse geochemical sampling & hydrologic testing

Sandia will conduct a time-lapse hydrologic sampling program of the AZMI wells via pumping. The BEG will collect and analyze fluid samples to look for any geochemical evidence of out of zone migration of CO2 as part of the above -zone monitoring program. The BEG will prepare a letter report containing data table and field notes.

6.4.15 Measure Out-Of-Pattern Migration

In this task, Denbury will report observation of the wells, including first year of pressure change at well heads. This should provide one year of data before beginning of flood near these wells. Denbury will prepare a letter report of pressure data and provide it to BEG for including history match of well head pressure.

6.4.16 Reservoir Modeling-Updated

BEG will aggregate data from 2C activities to history match plume size and pressure elevation and test if flood conformance to model expectation was achieved. This will focus on CO2 and pressure quantification, not oil production. Denbury will review the formal report prepared by the BEG.

6.4.17 Overview and Evaluation report

BEG will prepare and Denbury review a report of the results of this study. BEG and Denbury will determine what, if any, added value the research program added to the commercial program in terms of confidence in the long-term permanence of storage. BEG will recommend any actions that may be informative to future regulations or policies related to storage monitoring at EOR sites. This will be a formal report.

THE LAKE CHARLES CCS PROJECT
PHASE 1 TOPICAL REPORT

APPENDIX 10

Environmental Information Volume

INTRODUCTION

Leucadia Energy, LLC ("Leucadia") and Denbury Onshore, LLC ("Denbury") are submitting this Environmental Information Volume (EIV) as part of the Phase 2 Renewal Application for the Lake Charles CCS Project. This EIV has been prepared to assist DOE in the evaluation of the potential environmental impacts of the proposed Lake Charles CCS Project. The Lake Charles CCS Project will involve the capture and compression of over 85% of the carbon dioxide (CO_2) produced at the LCC Gasification Project. The compressed CO_2 will be transported via an 11.6-mile pipeline (the "Connector Pipeline") from the fenceline of the LCC Gasification Project to the Green Pipeline, which is owned by Denbury and an affiliate of Denbury. The Lake Charles CCS Project CO_2 will be used in independent commercial enhanced oil recovery (EOR) at Denbury's Gulf Coast oilfields. Denbury will implement a research monitoring, verification, and accounting (MVA) program at the Hastings Field in Texas to demonstrate the effectiveness of long-term geologic storage of the CO_2. This EIV is divided into three parts to cover each of the project components for which DOE funding is sought: Part I covers the CO_2 capture and compression facilities at the LCC Gasification Project; Part II covers the 11.6-mile Connector Pipeline; and Part III covers the MVA activities at the Hastings Field in Texas.

Part I. Capture and Compression Facilities

The Lake Charles CCS Project will include the capture and compression of over 85% of the CO_2 produced from the Leucadia subsidiary Lake Charles Cogeneration LLC's ("LCC's") petroleum coke to chemicals ("LCC Gasification Project") industrial source to be located in Calcasieu Parish, Louisiana, near the city of Lake Charles, Louisiana. The CO_2 capture facilities proposed for NETL funding as part of the Lake Charles CCS project consist of the two Lurgi Rectisol Selective Acid Gas Removal (AGR) units where CO_2 is separated from the process syngas. The CO_2 compression facilities include two CO_2 compressors, the building in which the compressors are housed (approximately 80 x 140 ft), and a meter station to monitor the volume of CO_2 exported. In this EIV, these facilities will be collectively referred to as the "Capture and Compression Facilities". The Lake Charles CCS Project will co-locate state-of-the-art capture, compression and control equipment on the LCC Gasification Project site to capture more than 4.4 million tons of compressed CO_2 annually. Part I of this EIV describes the environmental impacts of the CO_2 Capture and Compression facilities at the LCC Gasification Project.

Part II. Transportation

The Lake Charles CCS Project will build an 11.6-mile CO_2 pipeline (the "Connector Pipeline") from the fenceline of the LCC Gasification Project to the Green Pipeline in Louisiana. The Connector Pipeline will enable the transportation of the Lake Charles CCS Project CO_2 to the Green Pipeline owned by Denbury and an affiliate of Denbury so that it can be used for enhanced oil recovery (EOR) on the Gulf Coast. Denbury and an affiliate of Denbury are in the process of constructing the Green Pipeline from Louisiana to the Hastings Field in Brazoria County, south of Houston, Texas. Part II of this EIV

describes the environmental impacts of the construction and operation of the Connector Pipeline.

Part III. Sequestration and Monitoring, Verification, and Accounting (MVA)

The Lake Charles CCS Project CO$_2$ will be used for EOR at the Hastings Field in Brazoria County, Texas. A research MVA program will be conducted for at least 2 million tons of CO$_2$ per year at a site within Denbury's Hastings Field. The research MVA activities will supplement privately-funded, on-going monitoring activities conducted in conjunction with Denbury's commercial EOR operations. Only the research MVA activities will be considered in this EIV. The following MVA activities will be conducted:

- ***Well Integrity Testing*** – Logging of existing idle production wells and testing of plugged and abandoned (P&A) wells to detect CO_2 leakage through non-sealing well bores.
- ***Flood Conformance Testing*** – Augmentation of measurements to observe and model movement of CO_2 in subsurface formations during the EOR flood operations.
- ***Above-Zone Monitoring*** – Monitoring of pressures and geochemical parameters in the formations above the confining layer to detect CO_2 leakage beyond the injection zone.

Research MVA activities will be conducted on a periodic or continual basis during active commercial EOR flood operations from 2012 through 2015. Part III of this EIV describes the environmental impacts of Denbury's MVA activities at the Hastings Field.

LAKE CHARLES CCS PROJECT

ENVIRONMENTAL INFORMATION VOLUME
PART I - CO_2 CAPTURE AND COMPRESSION FACILITIES AT THE LAKE CHARLES GASIFICATION PROJECT

A. ENVIRONMENTAL INFORMATION DESCRIBING THE PROJECT AND THE PROJECT SITE(S).

This section of the Environmental Volume shall contain a detailed, self-contained description that summarizes the proposed action, its alternatives, and, most importantly, the existing environment.

1. Summary

This section shall contain a succinct summary of the proposed project and its potential environmental, safety, health, and socioeconomic impacts. A brief description of any construction and operation activities, including the duration and schedule shall also be provided. The summary shall focus on both beneficial and detrimental impacts, as well as any major risks associated with constructing, operating, maintaining, and dismantling/disposing of the proposed test facility, if applicable.

This Part I of the Environmental Information Volume (EIV) provides information regarding the CO_2 capture and compression components of the Lake Charles Cogeneration, LLC (LCC) Carbon Capture and Sequestration (CCS) Project. The CO_2 capture and compression facilities are part of a larger industrial facility, the LCC petroleum coke to chemicals project ("LCC Gasification Project"). However, only the capture and compression facilities are being proposed for NETL funding as part of the LCC CCS Project. This EIV Part I will provide environmental information regarding the capture and compression facilities that comprise part of the Lake Charles CCS Project. This Part will also provide information on the larger LCC Gasification Project to provide context and background, although the LCC Gasification Project is not part of the LCC CCS Project proposed for NETL funding.

The CO_2 capture facilities proposed for NETL funding as part of the Lake Charles CCS project consists of the two Lurgi Rectisol Selective Acid Gas Removal (AGR) units where CO_2 is separated from the process syngas. The CO_2 compression facilities include two CO_2 compressors, the building in which the compressors are housed (approximately 80 x 140 ft), and a meter station to monitor the volume of CO_2 exported. In this EIV, these facilities will be collectively referred to as the "Capture and Compression Facilities". Additional ancillary equipment and systems supporting the Capture and Compression Facilities include load commutated inverters (LCI) for starting the compressors, switchgear and substation, cooling water system including supply and return piping, remote controls, external fire protection system, instrument air system, CO_2 piping between units, and underground CO_2 piping to the battery limits. All ancillary systems are provided by the LCC Gasification Project through capacity expansion or infrastructure modification prepared in advance of installation of the CO_2 Capture and Compression Facilities. Foundation and civil works necessary to support the AGR

and CO_2 compressors and building are also managed within the LCC Gasification Project design and construction to facilitate installation within the overall project construction plan. As ancillary services and civil infrastructure are provided by the LCC Gasification Project, the LCC CCS project's on-site scope is limited to the design, procurement and installation and testing of the AGR units and CO_2 compressors, building and metering station.

The Capture and Compression Facilities will be contained within the larger LCC Gasification Project, a petroleum coke gasification plant to be constructed on the Calcasieu River in Calcasieu Parish adjacent to the Port of Lake Charles in Lake Charles, Louisiana. The LCC Gasification Project is located in a highly industrialized area at the end of Bayou D'Inde Road. Figure 1: *Site Location Map*, illustrates the location of the plant with respect to the Calcasieu River and immediate surroundings. Figure 2, *Plot Plan*, shows the general arrangement of the units within the gasification facility including the Capture and Compression Facilities.

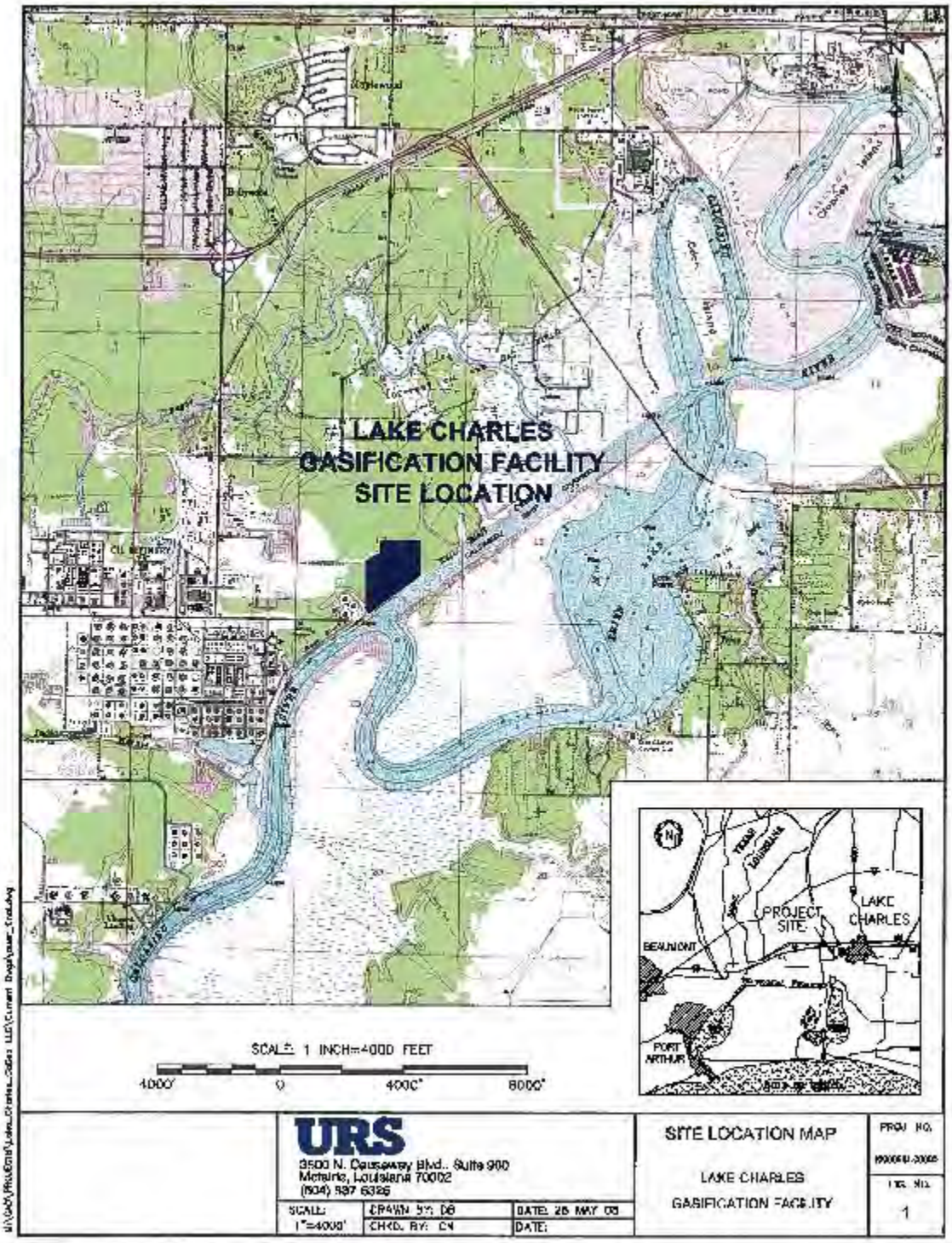
The LCC Gasification Project will utilize a state-of-the-art process wherein petroleum coke is gasified to produce syngas that will be converted into methanol (MeOH). The LCC Gasification Project is projected to gasify 2.6 million (MM) tons per year (TPY) of petroleum coke to produce over 2 million metric tons of methanol. The LCC Gasification Project will consist of five General Electric (GE) Quench Gasifiers and two trains of syngas processing, including sour shift conversion, two Lurgi Rectisol Selective Acid Gas Removal units, a methanol unit, and Haldor Topsoe wet sulfuric acid production. At design plant capacity, four GE Quench Gasifiers will be operating at their design rate which allows one gasifier to be on hot standby or shut down for maintenance. See Figure 3, *Block Flow Diagram* for a block diagram of the gasification facility, inclusive of the AGR and CO_2 compression areas.

A portion of the raw syngas flows through two shift conversion trains where almost all of the carbon monoxide is reacted with water vapor over a catalyst converting carbon monoxide and water into hydrogen and carbon dioxide. Hydrogen sulfide, carbonyl sulfide and carbon dioxide will be selectively removed from the syngas in the AGR units. The CO_2 removed from the syngas will be compressed on-site and then transported via pipeline for use in enhanced oil recovery (EOR). If either CO_2 compressor is not operating (i.e., during maintenance cycles), its CO_2 stream will be redirected to one of two regenerative thermal oxidizers which will thermally destruct 99+% of the carbon monoxide, hydrogen sulfide, carbonyl sulfide, and methanol contained in the CO_2. The facility is currently permitted for continuous operation of the thermal oxidizers.

The Port of Lake Charles infrastructure will be used for petroleum coke storage and handling and bulk transport needs and the petroleum coke will be transferred to the LCC Gasification Project via a conveyor system. Steam generated by energy recovery within the processes will be utilized to generate power via steam turbines to provide a significant portion of the energy needs of the LCC Gasification Project for plant operations. There are no gas turbine generators. The MeOH will be delivered to industrial customers.

The proposed LCC Gasification Project is a state-of-the-art facility for which significant pollution prevention and reduction has been incorporated on the basis of rigorous engineering design and environmental evaluation, and at significant increased costs to the project. The facility is able to

make use of the coke feed stocks that are pres ent in the area and convert them into high-value products. Purchases of petroleum coke from local refineries will help support othe r industries an d create additional value-added to locally made products rather than having these products exported to other areas of the count ry or th e worl d. In a ddition, gul f coa st petr oleum coke which is prese ntly being



exported wi ll now be us ed by CC for maki ng clean e nergy for dome stic use t hereby reducing energy imports from many unstable areas of the world. The proposed facility will provide m any short-term and long-term socio-economic benefits for the local area, including jobs.

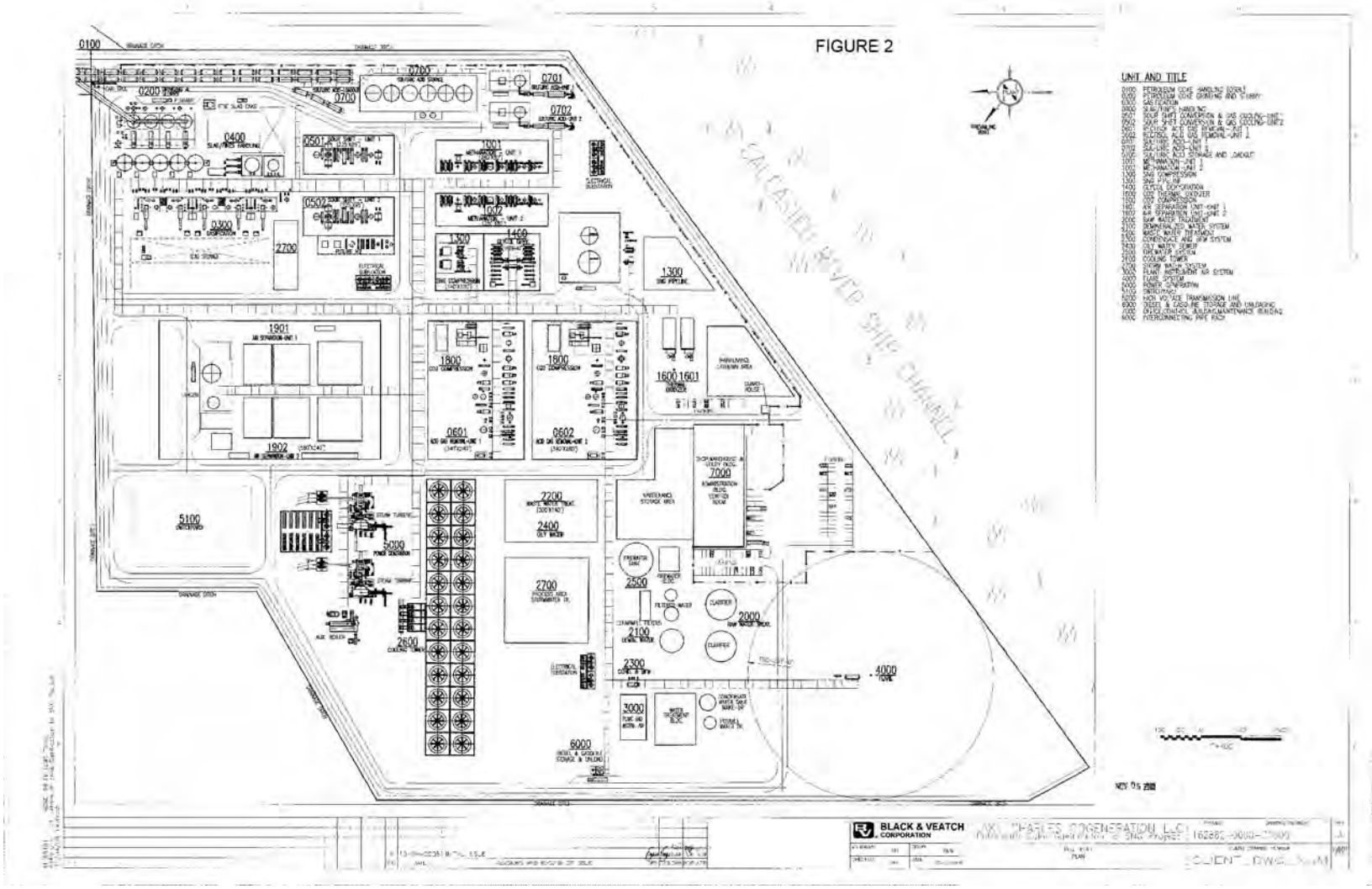
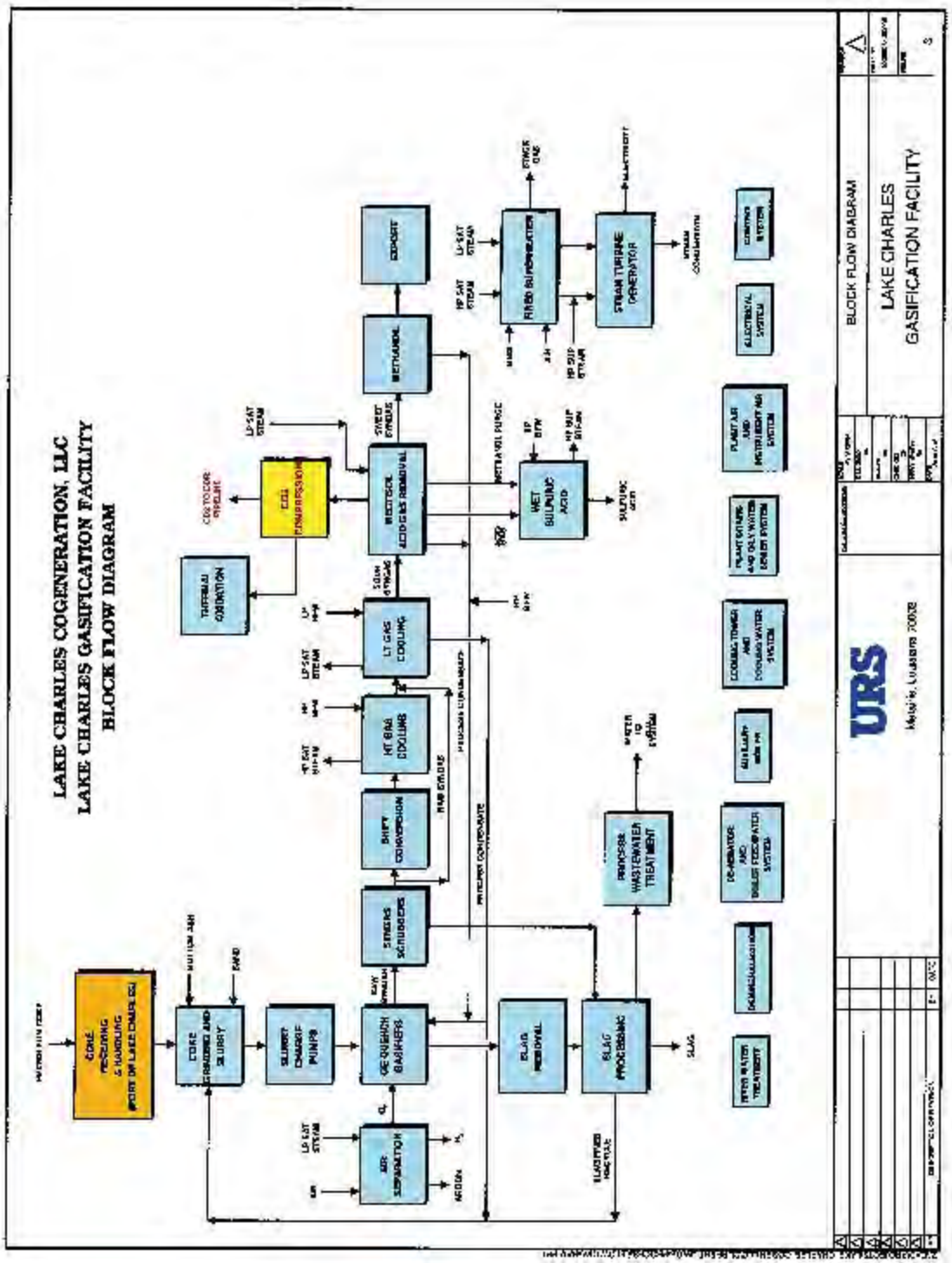


FIGURE 2
UNIT AND TITLE
CALCASIEU RIVER SHIP CHANNEL
BLACK & VEATCH CORPORATION


LAKE CHARLES COGENERATION, LLC
LAKE CHARLES GASIFICATION FACILITY
BLOCK FLOW DIAGRAM
BLOCK FLOW DIAGRAM
LAKE CHARLES
GASIFICATION FACILITY
URS

2. Proposed Project and Its Alternatives

a. Proposed Project

This section shall discuss the objectives of the proposed project, and shall describe the proposed site, system, and/or process. It shall also describe the work to be performed, the schedule, associated requirements (e.g., land, natural resources), and any changes that will be necessary to the existing site, system, or process.

The description shall include a project site plan and topographic map of the area. Any off-site facility requirements shall also be identified in this section.

Site Description

The petroleum coke gasification plant is to be constructed on the Calcasieu River in Calcasieu Parish adjacent to the Port of Lake Charles in Lake Charles, Louisiana (see Figure 1: *Site Location Map*). Figure 2, *Plot Plan*, is the general arrangement for the overall project, including the Capture and Compression Facilities. The existing site topography will be modified by raising the elevation to an approximate elevation of 14 feet mean sea level (MSL) and the site design will enable drainage of upstream areas around the site. Figure 3, *Block Flow Diagram*, is a block diagram showing the various processes for the overall project including the AGR units and CO_2 compression.

Process/Systems Description

The Capture and Compression Facilities include two 50% AGR units and two 50% multi-stage compressors discharging at approximately 2,200 psig. CO_2 exits the AGR at multiple pressures and is fed to the CO_2 compressor, exiting as a supercritical fluid. The compressed fluid is cooled to 100-120°F, combined, piped to the facility fence-line, then metered prior to introduction into the CO_2 transportation pipeline owned and operated by Denbury Onshore, LLC. The off-site CO_2 pipeline is discussed in Part II of this EIV. The AGR units and CO_2 compressors are designed for continuous full load operation, with export capacity reduced during process or compressor maintenance cycles. The compressors are driven by electric motors, each approximately 30,000 Hp.

The AGR units and compressors are intercooled via heat exchange with cooling water from the auxiliary cooling water loop. As described above, additional ancillary equipment and systems supporting the AGR and compression include load commutated inverters (LCI) for starting the compressors, switchgear and substation, cooling water system including supply and return piping, remote controls, external fire protection system, instrument air system, CO_2 piping between units, and underground CO_2 piping to the battery limits. All ancillary systems are provided by the LCC Gasification Project through capacity expansion or infrastructure modification prepared in advance of installation of the AGR and CO_2 compression system. Foundation and civil works necessary to support the AGR and CO_2 compressors and building are also managed within the LCC Gasification Project design and construction to facilitate installation within the overall project construction plan. As ancillary services and civil infrastructure are provided by the LCC Gasification Project, the CCS project's on-site scope is limited to the design, procurement and installation of the AGR units and CO_2 compressors, building and metering station.

Project Schedule

The projected date for initiating construction of the LCC Gasification Project is the 4th Quarter of 2010, and the start of operations is scheduled for 2014.

b. Alternatives to Proposed Project

A complete description of likely alternatives to the project, including a "no action" alternative, shall be provided. The description shall address technology-specific aspects of the action, such as process design configurations, and site-specific considerations, such as alternative waste disposal sites, etc.

This project proposes to separate CO_2 from the process syngas in the AGR and compress the CO_2 stream from the LCC Gasification Project Rectisol Unit via two electric-driven multistage compressors. As described in Parts II and III of this EIV, the compressed CO_2 will be transported via pipeline for off-site EOR use by Denbury Onshore, LLC.

Under a "no action" alternative, the Compression Facilities would not be constructed or operated. Under the no action alternative, LCC would route the CO_2 stream to the Regenerative Thermal Oxidizers (RTO) to thermally destruct 99+% of the carbon monoxide, hydrogen sulfide, carbonyl sulfide, and methanol contained in the CO_2 stream prior to discharge to the atmosphere. The LCC Gasification Project is currently permitted for continuous operation of the thermal oxidizers and release of the CO_2 stream to atmosphere.

The no action alternative would result in the following:

1. approximately 5 million tons/yr CO_2 vented to atmosphere;
2. lower capital cost related to negating compression, power, electronics, cooling, controls, and piping;
3. lower operating costs (approximately 48MW compressor load);
4. lower operating and maintenance costs;
5. approximately 5% less makeup water use (cooling water);
6. approximately 6% lower wastewater discharge quantity (cooling tower blowdown);
7. slightly lower cooling water tower particulate emissions; and
8. potentially lower noise levels.

3. Existing Environment

This section shall discuss the existing environment at the project location(s). The principal proposer and all proposed subcontractors shall discuss the following:

a. Land Use

This section shall provide a description of the affected land area and its dimensions; a discussion of current land usage (e.g., farming, industrial, etc.); characterization of any existing landforms (i.e., waterfalls, runoff areas, etc.); and descriptions of nearby pipelines and transmission lines, as well as transportation access (by rail, road, barge, etc.).

The proposed Lake Charles Gasification Facility is located on an approximately 70-acre parcel of land in Calcasieu Parish, Louisiana owned by and adjacent to the Lake Charles Harbor and Terminal District ("Port of Lake Charles") on the right-descending bank of the Calcasieu River in the region known as Rose Bluff. The site is primarily undeveloped land originally covered by pine forest on the higher elevations and cypress-tupelo and emergent freshwater marsh in the lower elevations at the center and eastern portions of the property.

The Capture and Compression Facilities will be located within the battery limits of the LCC Gasification Project. No additional land will be disturbed or used for the Capture and Compression Facilities. Each AGR unit area is approximately 500 x 300 ft. The aggregate size of the compressor building is approximately 80 x 140 ft. Ancillary systems required for support of the AGR and compressors are provided by the LCC Gasification Project as an expansion of the cooling tower or electrical systems or piping infrastructure within the LCC Gasification Project battery limits, with the compressed CO_2 delivery system terminating at a meter station located at the project fenceline. Part II of this EIV addresses Denbury Onshore, LLC's off-site CO_2 pipeline to which the facility interconnects.

The LCC Gasification Project property is located in a heavy industrial area at the end of Bayou D'Inde Road. Adjoining and surrounding properties are occupied by the City of Sulphur Wastewater Treatment Plant, Halliburton, Louisiana Pigment Company, Basell USA, the Port of Lake Charles, ConocoPhillips and CITGO Petroleum Corporation. Other industries in the immediate area are the Cit-Con Lube Plant, Firestone Synthetic Rubber and Latex, Westlake Polymers, Westlake Petrochemicals, Warren Petroleum, Conoco and Grace Davison.

The nearest residential zoned area is approximately one mile to the east across the Calcasieu River and Prien Lake. However, there are a few residents located approximately 0.75 miles north of the proposed site and north of the Louisiana Pigment plant.

Most raw materials for the LCC Gasification Project will be received at the Port of Lake Charles either by truck or barge and transported to the LCC Gasification Project site via conveyor. LCC Gasification Project products will be transported off-site via pipeline, barge or truck. CO_2 will be transported off-site via the CO_2 pipeline discussed in Part II of this EIV.

The LCC Gasification Project site can be accessed via:

- Roads – Bayou D'Inde road is adjacent to the site;
- Barge – the Port of Lake Charles has facilities adjacent to the site for barge access;
- Rail – existing rail spurs are also located adjacent to the property for transporting materials to the Port facility. Should facility plans dictate, a spur can easily be routed into the project site for shipment of certain products.

The physical address of the property has not been established, but will be in the 3500 numbering for Bayou D'Inde Road, Westlake, Louisiana 70669.

b. Atmospheric Conditions/Air Quality

This section shall identify the air quality control regions where the project is located; and describe the local climate and existing air quality conditions in the immediate vicinity of the proposed site.

Calcasieu Parish is designated as "attainment" for all PSD pollutants. The pollutant of main concern in the past is ozone as monitoring results approach closely to the NAAQS current standard 8-hour standard (80 ppb).

The monitoring sites in Calcasieu Parish (EPA AQS code 22 019 0002, 0008, and 0009) have been in operation since October 1983, September 1992 and October 1992 respectively and have operated in accordance with the requirements of 40 CFR 58 and the EPA-approved Quality Assurance Program Plan.

The NAAQS for 8-hour ozone is based on the three-year average of the fourth-highest daily maximum 8-hour average ozone concentrations measured at each monitor within an area. An 8-hour monitor reading of 85 ppb is considered an exceedance of the 8-hour ozone standard and a reading of 84 ppb is considered as meeting the standard. The area has monitored attainment for the latest six complete three-year periods for Carlyss and Westlake, and has monitored attainment for the latest four complete three-year periods for Vinton.

To demonstrate continued compliance with the ozone standard, the state has requested a maintenance plan. The maintenance plan must demonstrate that the area will remain in compliance with the 8-hour ozone standard for the ten (10) year period following the effective date of designation. The end projection year for the maintenance plan is ten (10) years from the effective date of the attainment designation. The maintenance demonstration is satisfied if the state demonstrates that future emissions inventories are less than the attainment or baseline inventory. Calcasieu Parish has an effective date of designation of June 15, 2004, which means that maintenance must be demonstrated through 2014.

The State has identified the level of precursor emissions in Calcasieu Parish that is sufficient to attain the NAAQS, i.e. the 2002 attainment inventory, and established interim emission projections of ozone precursors for the years 2008, 2011 and 2014 to demonstrate maintenance. A comparison of emission growth projections for VOC and NOx through 2014 to the 2002 attainment inventory for the parish indicates a downward trend in VOC while NOx emissions are projected to increase.

The State has also implemented enforceable emission control regulations to ensure continued maintenance of the ozone standard. Control measures also have been developed, promulgated and implemented at the federal level to reduce ozone-forming emissions of VOC and NOx. Development and subsequent implementation of other federal measures will result in additional emission reductions of VOC and NOx during the 10-year maintenance period. Federal measures which have been implemented or are currently in some phase of implementation include, but are not limited to:

- National VOC Emission Standards for Automobile Refinish Coatings (63 FR

48806)
- National VOC Emission Standards for Consumer Products (63 FR 48819)
- National VOC Emission Standards for Architectural Coatings (63 FR 48848)
- Tier 2 Motor Vehicle Emission Standards and Gasoline Sulfur Control Requirements (65 FR 6697)
- Heavy-Duty Engine and Vehicle Standards and Highway Diesel Fuel Sulfur Control Requirements (66 FR 5002)
- Control of Emissions from Nonroad Diesel Engines and Fuels (69 FR 38958)
- Clean Air Interstate Rule (70 FR 25162)

EPA has proposed new 1-hr NAAQS for SO_2 and NOx, anticipated to become final in the summer of 2010. These new standards will be more stringent than existing standards.

In accordance with Section 107(d) of the Clean Air Act Amendments of 1990, designation recommendations for the 2008 8-hr Ozone NAAQS (0.075 ppm) were published on March 27,2008 (73 FR 16436). These LDEQ designation recommendations are based on a review of the quality-assured ozone monitoring data for the period 2006-2008.

EPA is also considering a new 8-hr standard for ozone (less than the current 0.075 ppm standard). It is possible that an increased number of parishes may be classified as non-attainment for ozone in Louisiana.

c. Hydrologic Conditions/Water Quality

This section shall identify any watersheds and downstream drainage, surface and groundwater quality (nearby aquifers and the depth of groundwater) in the project area, existing floodplains, unique aquatic habitats, recreational areas, public water supplies; describe any constraints on water availability imposed by treaties, court decree, state and Federal water laws; and identify existing wastewater treatment and/or disposal facilities.

The subject property is a 70 acre parcel on the right descending bank of the Calcasieu River that was occupied by mixed pine forest on the higher elevations with 26 aces of cypress-tupelo fresh emergent freshwater marsh in the lower elevations at the center and eastern portions of the property. The site was primarily undeveloped land that has approximately 2,200 feet of shoreline along the Calcasieu River Ship Channel.

There are currently no wastewater treatment or disposal activities on the site. LCC has received a LPDES permit to discharge future industrial wastewater at the proposed site. The existing LCC Gasification Project wastewater discharge permit as received includes provisions for cooling water discharges associated with operation of the CO_2 compression system.

The following describes hydrology, watersheds, groundwater/surface water quality and availability, aquatic habitats, recreational areas, and public water supplies in the project area.

<u>Public Water Supplies</u>

There are no public water supplies located on this site. The northern boundary of the subject property is partially occupied by the publicly-owned treatment works (POTW) serving the City of Sulphur, City of Westlake, Calcasieu Sewer District No. 8 and Calcasieu Sewer District No. 12. Louisiana Department of Environmental Quality (LDEQ) permits for the facility have been issued to the Public Works Department for the City of Sulphur. The discharge from the POTW is identified as the drainage ditch on the northeast and eastern side of the subject property that allows the effluent to reach the Calcasieu Ship Channel. The POTW was originally constructed in the early 1980s.

Watershed/Recreational Areas

There are no recreational areas located on this site. The Lake Charles Cogeneration petroleum coke gasification plant will be located on the Calcasieu River in Calcasieu Parish adjacent to the Port of Lake Charles as shown on Figure 1, *Site Location Map*. The outfalls for the LCC Gasification Project's discharge will be to subsegment 030301 of the Calcasieu River and Ship Channel, for which the designated uses are primary contact recreation, secondary contact recreation, and fish and wildlife propagation. The Calcasieu River is not a source of drinking water.

There are no state or federal parks, wildlife refuges, scenic streams, or Wildlife Management Areas at or near the proposed project site.

Hydrology

The subject property is located west of Prien Lake and the Calcasieu Ship Channel. The stratigraphic sequence in the area consists of unconsolidated deltaic and near-shore marine sediments ranging in age from Holocene to Miocene. The site is situated on Pleistocene deposits possibly overlain by a thin veneer of Holocene deposits. At relatively shallow depths these deposits consist of clayey silts, sandy silts, silty clays, and silty sands.

The surface hydrology of the area was modified when the Calcasieu Ship Channel was dredged to straighten the Calcasieu River in the area of the subject property. Along the shoreline of the Calcasieu Ship Channel and in the area of wetlands (in center of the property) the elevation is approximately sea level. The surrounding elevations rise to height of approximately 13 to 15 feet above sea level on the north, and west. The soils in the wet areas are identified as a frequently flooded Basile-Guyton silt loam and Kinder-Messer silt loam on the higher elevations. Surface water hydrology is directed to the east and to the Calcasieu River via several drainage ditches and through the wetlands area in the center of the site.

Surface waters from north and west of the site drain through the site to the shipping channel. Site development plans will raise the elevation of the site property. Off-site flows currently following the natural topography of the site will be diverted to either the drainage easement on the north side of the site or to a perimeter conveyance system on the west side of the site and into the ship channel via outlet in the vicinity of the southeast and southwest corners of the project site.

Wetland Delineation

A jurisdictional wetland delineation was previously conducted by the U.S. Army Corps of Engineers (COE) and, based on this delineation, the Port of Lake Charles mitigated 26.2 acres of the wetlands through an agreement with the COE and Streameam Wetland Services, LLC. Permitting through the COE to develop the site has been completed and the latest permit was issued on August 18, 2008.

Groundwater

Groundwater in the area typically includes upper sandy / silty strata that are separated from the much deeper drinking water aquifers by clay layers and by a significant distance as described below. The shallow water-bearing zones encountered above the Chicot aquifer are not considered potential sources of water supply, either potable or non-potable, given the shallowness of these zones, and the presence of proven supplies of good quality groundwater from the Chicot aquifer. According to the Louisiana Department of Transportation and Development, water wells in these upper sands are not being utilized, and are not planned to be utilized, as drinking water sources. All water supply wells are screened in the deeper sands (200-800 feet) of the Chicot aquifer. There are no wells screened in the upper sands other than for groundwater monitoring, dewatering or recovery purposes. This is also supported by information presented in the document "*Quality of Water in Freshwater Aquifers in Southwestern Louisiana*" (USGS 1989). The USGS confirms that the shallow sands in this area and in the vicinity of the Lake Charles Gasification Facility site (i.e., such as the upper sands, the most shallow water-bearing units) are not currently being utilized, and are not planned to be utilized, as drinking water sources.

Groundwater for potable purposes in the Lake Charles area is obtained from the Chicot Aquifer System. The Chicot Aquifer System has been subdivided into the "200-foot," "500-foot," and "700-foot" sands. The strata above the "200-foot" sand are primarily composed of relatively low permeability sediments.

The "200-Foot" Sand is thick and extensive throughout the region, and it deepens toward the south. In the vicinity of the Lake Charles Gasification Facility site, the "200-Foot" Sand is encountered approximately 175 ft below land surface (bls) and the sand varies from about 75 to 150 feet in thickness.

The "500-Foot" Sand is the most prolific sand of the Chicot Aquifer and serves as the principal source of fresh water for industries and agriculture throughout most of Calcasieu Parish. The "500-Foot" Sand is encountered approximately 400 feet bls in the vicinity of the site and the sand averages about 100 to 125 feet in thickness.

The "700-Foot" Sand supplies the City of Lake Charles with drinking water, as well as some farms and industrial plants in southern and central Calcasieu Parish. In the vicinity of the site, the "700-Foot" Sand is encountered approximately 625 feet bls. Locally, the sand is divided into two zones, with a total thickness of about 225 feet.

Unique Habitats

Based upon information reviewed from the Louisiana Department of Wildlife and Fisheries (LDWF, May 2009), no rare, threatened or endangered species or critical habitats are anticipated for this proposed project. LDEQ's February 2010 list of threatened and endangered species includes only the red cockaded woodpecker as endangered in Calcasieu Parish; no aquatic species are listed. According to LDEQ's 2009-2010 Implementation Strategy for the Memorandum of Understanding between LDEQ and the U.S Fish and Wildlife Service, there are no federally listed threatened or endangered species on the Calcasieu River that are dependent on aquatic habitat. No other rare, threatened, or endangered species or critical habitat is known to exist at the project site or within a radius of 1,000 feet of the proposed site. In addition, there are no state or federal parks, wildlife refuges, scenic streams, or Wildlife Management Areas at or near the proposed project site.

Raw Water Supply

Raw water will be supplied by pipeline from the Sabine River. LCC has contracted for an annual average maximum of 8,500 GPM of Sabine River water. The water from the Sabine River Authority (SRA) will be provided through the existing SRA intake structure on the Sabine River Diversion Canal. The existing pump house contains three bays of which two are utilized, each sized for approximately 300 percent of the capacity LCC will take from the canal. All three bays are connected to a common intake structure. LCC will install a pump house and interconnect its sump to the existing un-utilized bay in the SRA pump house. In this manner LCC will use the existing intake structure yet still not increase flow through the structure above its original design capacity. It is designed and capable of providing the quantity of water needed by LCC. The project will not increase flow through the structure above its original design capacity. Thus, the provisions of 40 CFR Part 125, Subpart I (Clean Water Act Section 316b requirements for new intake structures) are not applicable. The LCC Gasification Project will supply water to the CO_2 Capture and Compression Facilities' cooling system as part of the ancillary services, therefore, this activity is not part of the CO_2 capture and compression project. The water consumed in the AGR and CO_2 cooling system is approximately 10% of the project raw water consumption and 13% of the cooling tower capacity.

d. Geologic/Soil Conditions

This section shall describe the topographic stability (e.g., formations and/or faulting), the productivity of soil, any unique soil species, and the soil's susceptibility to erosion.

Site geology

A number of borings primarily near the river shore taken for an investigation of the new sea-wall indicate a layer of organic clay overlying high plasticity clay inter-layered with sand. An investigation encompassing areas throughout the site will be performed to provide data to accurately describe the overall site geology. There are no unique soil species present at this site.

The following is a discussion of the geologic setting in the vicinity of the site down to a depth of approximately 10,000 feet below ground surface (bgs) and specific geologic investig ations performed at the site.

The upper approximately 175 feet of the subsurface is composed of Holocene to Pleistocene Age sediments. These sed iments are characterized by clay s and silty clays intersected by discontinuous layers of silts and sands. They are alluvial in nature, probably fluvial and deltaic.

The upper 75 feet of the subsurf ace typically includes both Holocene to Pleistocene Ag e sediments. These sed iments are characterized by clays and silty clays intersected by layers and lenses of silt and sand, som e more continuous than others. Between approximately 75 and 175 feet bgs, the Pleis tocene age sed iments encoun tered are co mposed predom inantly of clays and sandy clays with sporadic occurrences of thin, discontinuous lenses of silt and sand.

The Pleistocene strata encountered between ap proximately 175 and 800 feet bgs are com posed predominantly of thick sand and gravel deposits, with individua l sand and gravel for mations separated by thick clay interval s. These formations are latera lly continuous in the region. In southwestern Louisiana, including the Lake Charle s area, this sequence of sediments is referred to as the Chicot Aquif er System. In the Lake Ch arles area, the Chicot Aquifer System contains three major water producing zones, known as the "200-Foot Sand", the "500-Foot Sand", and the "700-Foot Sand", based on their general depth of o ccurrence. In the vicinity of the site, the 200-Foot Sand (the Montgom ery fo rmation) is encountered appr oximately 175 feet bgs and the thickness varies from about 75 to 150 feet. The 500-Foot Sand is the most prolific sand of the Chicot Aquifer. The 500-Foot Sand (the Bentley formation) serves as th e principal source of fresh water for industries and ag riculture throughout m ost of Ca lcasieu Parish. The 500-Foot Sand is encountered approximately 400 feet bgs and averages about 100 to 125 feet in thickness. The 700-Foot Sand supplies the City of Lake Charle s with drinking water, as well as som e farms and industrial plants in southern an d central Calcasieu Parish. The 700-Foot Sand (the W illiana formation) is encountered at approximately 625 feet bgs.

Natural groundwater flow within the sands of the Chicot Aquifer is to the south, toward the Gulf of Mexico. However, substantial pumpage of groundwater from these sands over the last several decades has significantly altered the local flow di rection, forming cones of depression within the Lake Charles Industrial Area.

Below the Pleisto cene age sedim ents (to dept hs exceedin g 10,000 feet bgs) are sedim ents, in descending order, of Pliocene, Miocene, and Oligocene age. The Pliocene age deposits generally consist of a series of fine to medium grained sand, silt, and clay of gray to blue-black color, often containing lignite. The Pliocene deposits dip to the south, i.e., toward the Gulf of M exico. The base of the Pliocene deposits is approxim ately 2,500 feet bgs in the vicinity of the project site. The deposits of Pliocene age are generally referred to as the Evangeline Aquifer. Miocene ag e deposits consist of interf ingering beds of sand, si lt, and clay. The base of the Miocene deposits is approximately 7,500 feet bgs in the vicinity of the project site. Oligoc ene age deposits consist of thicke r interva ls of clay o r sh ale with in terfingering beds of sand a nd silt. T he Oligocene extends to depths below 10,000 feet bgs in the area of the project site. Regional dip of these two deposits is consistent with the upper units.

Groundwater within the Pliocene and Miocene strata, commonly referred to as the Evangeline Aquifer in the vicinity of the project site, generally exhibits total dissolved solids concentrations in excess of 10,000 mg/L, thus making it unsuitable for human consumption. No water supply wells are known to penetrate the Evangeline Aquifer in Calcasieu Parish.

Soil conditions at the proposed site were investigated by performing soil borings and geotechnical laboratory testing of recovered samples. Thirteen soil borings were advanced in the vicinity of the eastern boundary of the site, down to an approximate elevation of 100 feet MSL (See Figure 4, *Boring Layout*). As shown on cross-sections developed using these soil boring data (See Figures 5 and 6), the stratigraphy consists of very soft to soft organic clays extending to approximately -13 feet MSL, underlain by loose to very dense sands and stiff to very stiff Pleistocene clays.

Shallow sediment conditions were investigated in the interior wetlands area where small channels direct stormwater to the river. The investigations included the collection of 18 sediment samples from these areas of the property (See Figure 7, *Phase II Sampling Locations*). Sediment samples collected varied from a black silty muck in upper reaches of the channels, to stiff clays in the lower reaches as the channels converge prior to confluence with the Calcasieu River. The extent of loose sediment overlaying stiffer clay soils appeared to be influenced by the velocity of water in the channels. Thicker sediments were observed on the point bar and less sediment was observed in the cut bank. However, when flow decreased in more linear stretches, the sedimentation was generally uniform.

e. Vegetation and Wildlife Resources

This section shall describe any indigenous flora and fauna, state and Federally listed endangered or threatened species and their habitats, and sensitive habitats such as wetlands, floodplains, or other ecologically sensitive terrain.

The proposed Lake Charles Gasification Facility is located on an approximately 70-acre parcel of land on the right-descending bank of the Calcasieu River in the region known as Rose Bluff. The site is primarily undeveloped land that is covered by pine forest on the higher elevations and cypress-tupelo and emergent freshwater marsh in the lower elevations at the center and eastern portions of the property.

A jurisdictional wetland delineation was previously conducted by the U. S. Army Corps of Engineers (COE) and, based on this delineation, the Port of Lake Charles mitigated 26.2 acres of the wetlands through an agreement with the COE and Streamwetland Services, LLC. Permitting through the COE to develop the site has been completed and the latest permit was issued on August 18, 2008.

Based upon information reviewed from the Louisiana Department of Wildlife and Fisheries (LDWF, May 2009), no rare, threatened or endangered species or critical habitats are anticipated for this proposed project. LDEQ's February 2010 list of threatened and endangered species includes only the red cockaded woodpecker as endangered in Calcasieu Parish; no aquatic species are listed. According to LDEQ's 2009-2010 Implementation Strategy for the Memorandum of Understanding between LDEQ and the U.S Fish and Wildlife Service, there are

no federally listed threatened or endangered species on the Calcasieu River that are dependent on aquatic habitat. No other rare, threatened, or endangered species or critical habitat is known to exist at the project site or within a radius of 1,000 feet of the proposed site. In addition, there are no state or federal parks, wildlife refuges, scenic streams, or Wildlife Management Areas at or near the proposed project site.

Figure 4

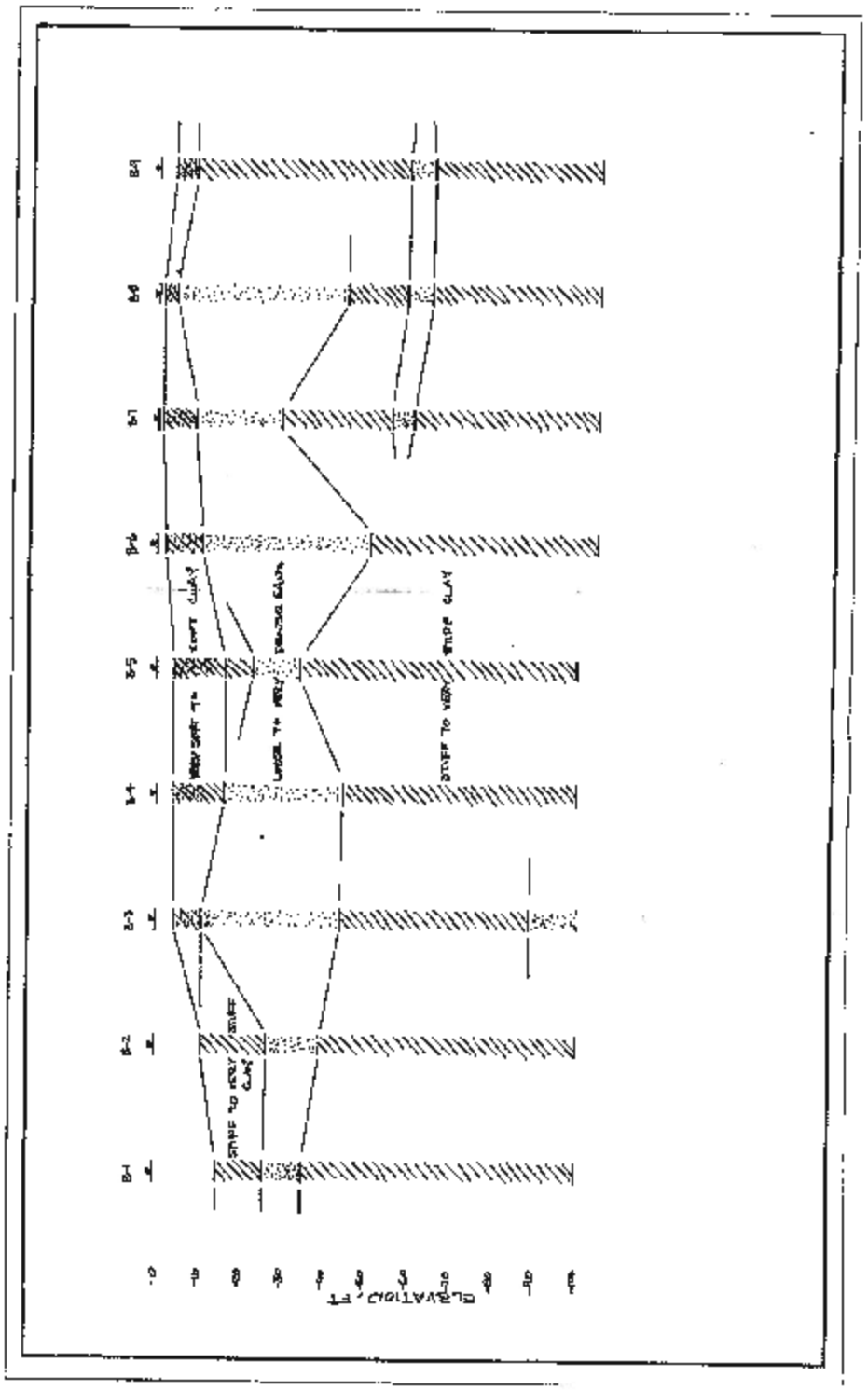


Figure 5

Figure 6

f. Socioeconomic Conditions

This section shall discuss the population in the project area, and shall describe the employment and labor mix.

Population

Sulphur, Louisiana is located entir ely within Calcasieu n the southwestern part of the state. Sulphur boasts a population of 20,512 peopl e (2000 US Census population estim ate). The population data is broken down into various categories in the following sections.

Ethnicity

Sulphur is a comm unity that is m ainly white in population at 93.4 percent. The second highest bloc group is Black or African Am erican at 4.4 percent with Hi spanic and Two or More Race groups comprising the final 2.6 percent. The breakdown is presented in the table below.

Table – Races in Sulphur, Louisiana

Races in Sulphur, Louisiana		
Race	Number	Percentage of Population
White Non-Hispanic	19165	93.4
Black 905		4.4
Hispanic 305		1.5
Two or More Races	217	1.1

2000 Estimates – US Census

Socioeconomics

Economic characteristics show a labor force in Sulphur as 62.3 percent of the population. The estimated median incomes are represented in the table below.

Table – Estimated Median Household Income

Estimated Median Income	
Median Income	
Household	$38,247
Family	$45,455

2000 Estimates – US Census

Social Demographic Data

The following sections contain social demographic data relating to:

- Percent of population 25 years old and over without a high school diploma;
- Percent of population over 65 years of age;
- Percent of population under 5 years of age; and
- Percent of population under the poverty level.

Education Attainment

According to the 2000 US Census approximately 80.3 percent of the population aged 25 years or more graduated High School or attained higher levels of education. These data are presented in the table below.

Table – Education

Educational Attainment of Population Aged 25+		
	Number	Percentage
Total Aged 25+ Years	13031	
High School Graduate (incl. equiv.)	10459	80.3
Bachelor's Degree or Higher	2426	18.6

2000 Estimates – US Census

Percent of Population Over 65 and Under 5 Years of Age

According to the 2000 US Census, persons over 65 years of age comprise 13.4 percent of the Sulphur Population while persons under 5 years of age comprise 7.4 percent. These data are presented in the table below.

Table – Population Over 65 and Under 5 Years of Age

Population over 65 and Under 5 Years of Age		
Age Num	ber	Percentage of Population
Over 65	2754	13.4
Under 5	1511	7.4

2000 Estimates – US Census

Percent of Population Below the Poverty Level

According to the 2000 US Census the 13.3 percent of the population in Sulphur, LA lives under the poverty level. Compared to the State level of 18.5 percent it remains ahead of the state poverty level. These data are presented in the table below.

Table – Percent of Population Below the Poverty Level

Percent of Population Below the Poverty Level	
Percentage	of Population
Sulphur, LA	13.3
State of Louisiana	18.5

2000 Estimates – US Census

g. Historic/Cultural Resources

The section shall describe any historic and/or cultural places in the project area, as well as archeological sites.

The LCC Gasification Project has prepared a cultural resources study as required by the State Department of Cultural, Recreation & Tourism, Office of Cultural Development. A prior study by Earth Search, Inc. in 2001 identified a Rangia shell midden associated with Site 16CU29 that potentially extended into the southwest corner of the proposed project site. A Phase I Cultural Resources Survey was performed for this site and a report was issued to Louisiana State Historic Preservation Officer (SHPO). The SHPO reviewed this updated information and issued a letter noting that field investigations resulted in the delineation of expanded boundaries for this site and the assessment concluded that the site was not eligible for listing on the National Register of Historic Places due to a lack of depositional integrity and limited research potential. The SHPO concurred with the assessments conducted and concluded that additional assessments are not warranted. Refer to Appendix A for a copy of the Phase I Cultural Resources Survey Report and the letter from the Louisiana State Historic Preservation Officer.

h. Visual Resources

This section shall describe any scenic vistas or existing aesthetic landscaping in the project area.

There are no scenic rivers, vistas or existing aesthetic landscaping that will be affected by the Lake Charles Gasification Facility. The land that is being utilized for this facility is owned by the Port of Lake Charles and has been under their ownership for many years. The project site is

located in a heavy industrial setting and the visual landscape of the area is already marked with industrial structures of various types.

i. Health and Safety Factors

*This section shall discuss **current** emissions (toxic and non-toxic), effluents, and noise levels at the project area.*

There are no current facility emissions (toxic or non-toxic) or effluents, as the proposed Lake Charles Gasification Facility has not been constructed.

During construction of the proposed facilities, noise would be generated by construction equipment such as bulldozers, trucks, backhoes, cranes, pumps, air compressors, and front-end loaders. Noise levels during construction would be typical of industrial plant construction. Steam blowdown / clearing of piping and equipment toward the end of the construction phase will result in a few brief noise peaks that would attenuate to acceptable levels at greater distances from the site.

There are exhaust emissions from site clearing equipment and transport of debris. There will also be dust emissions associated with debris removal. Best management practices for site construction are also being utilized to minimize impacts from these activities.

The current activities are under the jurisdiction of OSHA requirements, as well as the health and safety requirements of LCC and their contractor(s) for the safety and protection of the site workers.

B. ENVIRONMENTAL IMPACTS OF THE WORK TO BE PERFORMED.

This section of the Environmental Volume shall describe the anticipated environmental impacts from the project. It shall describe all impacts and consequences of the project (at the selected site[s] and the alternative site[s], if appropriate). The existing environment (described in Section A.3) shall be evaluated in terms of the potential impacts from any construction, operation/testing, and disposition activities. Any mitigative measures that will address these impacts shall also be identified.

The description shall address the environmental categories listed below. Please ensure that all direct, indirect, short-term, and long-term impacts resulting from project activities are identified clearly.

1. Land Use

This section shall describe land use impacts from any construction and operation activities; waste disposal problems (for non- toxic, toxic, and/or hazardous substances); and effluent discharges requiring the development of settling ponds.

It is not anticipated that the LCC Gasification Project or the Capture and Compression Facilities will have any impacts on land use at the site or on surrounding land uses.

The proposed Lake Charles Gasification Facility will be located within the existing property owned by the Port of Lake Charles and will be constructed on approximately 70 acres. The area is zoned

I-2 (heavy industrial) and proposed operations are compliant with this designation. The proposed site is surrounded by land primarily used for heavy industrial operations. The site is not located near schools, hospitals, residential areas, or public buildings. The property has not been developed previously with the exception of an area that was built up with fill material.

A jurisdictional wetland delineation was previously conducted by the U. S. Army COE and, based on this delineation, the Port of Lake Charles mitigated 26.2 acres of the wetlands through an agreement with the COE and Stream Wetland Services, LLC. Permitting through the COE to develop the site has been completed and the latest permit was issued on August 18, 2008.

Surface water from north and west of the site, drain through the site to the shipping channel. Site development plans will raise the elevation of the site property; however, off-site flows currently following the natural topography of the site will be diverted to either the drainage easement on the north side of the site or to a perimeter conveyance system on the west side of the site and into the ship channel via an outlet in the vicinity of the southeast and southwest corners of the project site.

There will be no settling ponds constructed for this project. The LCC Gasification Project has already obtained required effluent discharge permits from the LDEQ. No disposal of solid or hazardous waste will be conducted at this site. Any wastes generated from operations will be properly managed and disposed of off-site at an appropriately permitted facility. Thus, no wastes will remain permanently on-site. General office wastes are expected to be less than 100 cubic yards per year and will be disposed in a permitted municipal or sanitary landfill by a licensed transporter.

The Capture and Compression Facilities will be internal to the LCC Gasification Project's developed area. There will be no additional land use required for this part of the overall project.

2. Atmospheric Conditions/Air Quality

This section shall discuss projections in air quality changes; estimated process emissions (e.g., stack emissions); construction emissions from land disturbance or the operation of machinery equipment, solid waste disposal operations, coal handling, etc.; and the source, emission rate, duration, and frequency of all emissions.

The Capture and Compression Facilities will not impact air quality, as the units' pumps and compressors are electric driven and generate no emissions to the atmosphere. The impacts on air quality that may be caused by ancillary systems supporting the CO_2 capture and compression were included and incorporated within the LCC Gasification Project air permits described below.

The LCC Gasification Project has obtained Title V and Prevention of Significant Deterioration (PSD) Air Permits, as required under the Clean Air Act. The permits are for emissions associated with the production of substitute natural gas (SNG). Subsequent to the permits' issuance, LCC has determined that the LCC Gasification Project will produce methanol instead of or in addition to SNG. Further design work is required to complete characterization of the methanol process, but the facility's emissions are not expected to vary significantly with the production of methanol. Any emission changes associated with the methanol process will be incorporated with other design clarifications in the permit modification process.

The overall project total facility emissions from the production of SNG are presented in Table B2-1 below. These overall emissions represent the Title V and PSD permitted emissions.

Table B2-1
Total Facility Emissions

Pollutant	Proposed Emissions (TPY)	PSD Significance Thresholds (TPY)
Particulate Matter (PM_{10})	33.38	15
Sulfur Dioxides (SO_2)	262.27	40
Nitrogen Oxides (NO_x)	218.76	40
Carbon Monoxide (CO)	701.00	100
Volatile Organic Compounds (VOC)	24.69	40
Hydrogen Sulfide (TAP)	0.86	10
Sulfuric Acid (TAP)	55.83	7

To demonstrate compliance with LAC 33:III. Chapter 51 Louisiana state regulations, an Air Toxics Analysis was performed for all toxic air pollutants (TAPs) over their respective Minimum Emission Rates (MER). The overall project total facility emissions with the production of SNG resulted in a classification as a major source of toxic air pollutants (TAPs), as the emission rate of sulfuric acid exceeded the 10 TPY major source threshold. The LCC Gasification Project will emit only Class III TAPs. With the production of methanol, the methanol emissions may exceed the respective MER. The LCC Gasification Project will comply with applicable provisions of the Louisiana Toxic Air Pollutant Emissions Control Program (LAC 33:III.Chapter 51).

3. Hydrologic Conditions/Water Quality

This section shall describe any changes in groundwater/surface water quality and quantity, stream diversion resulting from construction, runoff from storage piles (source, discharge rate, discharge frequency and duration), leachates from waste disposal sites; and wastewater treatment and discharges.

Construction and operation activities at the LCC Gasification Project, including the Capture and Compression Facilities, are not anticipated to have any significant impacts on the quality or quantity of groundwater or surface water in the area.

The LCC Gasification Project will not utilize groundwater as a raw water source. Groundwater in this area typically includes upper sandy / silty strata that are separated from the much deeper drinking water aquifers by clay layers and by a significant distance as described below. The shallow water-bearing zones encountered above the Chicot aquifer are not considered potential sources of groundwater, either potable or non-potable, given the shallowness of these zones, and the presence of proven supplies of good quality groundwater from the Chicot aquifer. According to the Louisiana Department of Transportation and Development, water wells in these upper sands are not being utilized, and are not planned to be utilized, as drinking water sources. All water supply wells are screened in the deeper sands (200-800 feet) of the Chicot aquifer. There

are no wells screened in the upper sands other than for groundwater monitoring, dewatering or recovery purposes. This is also supported by information presented in the document "*Quality of Water in Freshwater Aquifers in Southwestern Louisiana*" (USGS 1989). The USGS confirms that the shallow sands in this area and in the vicinity of the Lake Charles Gasification Facility site (i.e., such as the upper sands, the most shallow water-bearing units) are not currently being utilized, and are not planned to be utilized, as drinking water sources.

Best management practices during construction will be implemented to prevent turbidity and sedimentation associated with surface water runoff that could influence water quality.

There will be no storage piles or waste disposal sites at the facility, hence no storage pile runoff or leachate.

Raw water will be supplied by pipeline from the Sabine River. During operation, all process wastewater will be recycled to achieve zero liquid discharge (ZLD). Discharge of non-process wastewater and storm water will be to the Calcasieu River via permitted outfalls (the permit has been received from the LDEQ). The following gives further details regarding water quality, water use, and wastewater treatment and discharges.

Source (Intake) Water (Sabine River Water)

The LCC Gasification Project has contracted for an annual average maximum of 8,500 GPM of Sabine River water. The water from the Sabine River Authority (SRA) will be routed to the project site via pipeline. The water will be provided through the existing SRA intake structure on the Sabine River Diversion Canal. Water required for cooling the CO_2 compression system will be provided as an ancillary system by the LCC Gasification Project. Water supply systems are not part of the CO_2 compression project. The water consumed in the CO_2 compression cooling system is approximately 5% of the project raw water consumption and 6.5% of the cooling tower capacity.

Sabine River water will be treated for plant use. Secondary containment will be provided for water treatment chemicals. Equipment lube oil leaks will be contained and routed to the oily water sewer.

Wastewater Treatment, Flow, and Discharge

The LCC Gasification Project proposes to implement zero liquid discharge (ZLD) for the gasification process wastewater through utilization of filtration, steam stripping, evaporation, and crystallization. The wastewater generated in the gasification process will be treated / recycled to achieve ZLD. Filtered solids and dewatered salts will be disposed of off-site at permitted facilities. The following are permitted to be discharged to the Calcasieu River at the southern plant property line: non-contact cooling water blowdown, water treatment reject and regeneration water, oil/water separator water (plant and equipment drains) and low-contamination potential storm water runoff.

Outfall 001 - Non-Contact Utility Water

Outfall 001 discharge will consist of non-contact utility water, including cooling water blowdown, boiler blowdown, and RO/demineralizer reject water. Non-contact cooling tower blowdown and boiler blowdown will be treated for reduction of chlorine residual and RO/demineralization reject water may require neutralization prior to discharge through Outfall 001.

Outfall 002 - Oil/Water Separator Water

Wastewater from equipment drains will be treated in an oil/water separator and then be discharged through Outfall 002. Scavenged oil will be collected and properly disposed of off-site by a licensed contractor.

Storm Water Management

Prior to construction, off-site flows currently following the natural topography of the site will be diverted to either the drainage easement on the north side of the site or to a perimeter conveyance system on the west side and into the ship channel via outlets in the vicinity of the Southeast and Southwest corners of the property.

Storm water that will contact the LCC Gasification Project facility is categorized as follows:

- Storm water from Gasification Process Area (no discharge);
- Storm water in excess of the first one inch from process areas with low potential to become contaminated;
- Storm water from non-contact (uncontaminated) areas; and
- Storm water from secondary containment areas.

Storm water falling in the gasification process area will collected in the concrete gasification storm water tank. All flow into this tank will be recycled and reused within the process.

Secondary containment areas will be located throughout the site to isolate spills and any contaminated runoff from its surrounding area. Those serving to contain oil will route spills and storm water runoff to the oily water separator for treatment prior to discharging off-site. Storm water falling into isolated chemical containment areas will be managed in accordance with the Storm Water Pollution Prevention Plan (SWPPP) that will be developed for the facility.

Low Contamination Potential Storm Water

Process areas with a potential for contamination will have dedicated drains. Storm water falling in these process areas will be routed to a collection sump. When the measured cumulative flow into the collection sump exceeds the first flush the water will overflow the collection sump into an open channel for discharge from the site along with the clean non-contact area runoff. The water collected in the process area storm water tank will be used as plant makeup water.

Storm Water from Non-Contact Areas

The CO_2 compression unit area and other areas that do not have exposed liquid or solid materials that can contact storm water will have secondary containment of any potential contaminants. Chemical storage tanks will have containment dikes. Equipment containing oil will be within curbed areas that drain to the oily water sewer. Storm water falling on these areas and all remaining non-process areas (parking lots, open areas, administration buildings, etc.) of the facility is considered non-contact storm water and will be conveyed directly to the Calcasieu River.

Sanitary Wastewater

Sanitary wastewater will be routed to the City of Sulphur municipal treatment system for treatment and disposal.

4. Geologic/Soil Conditions

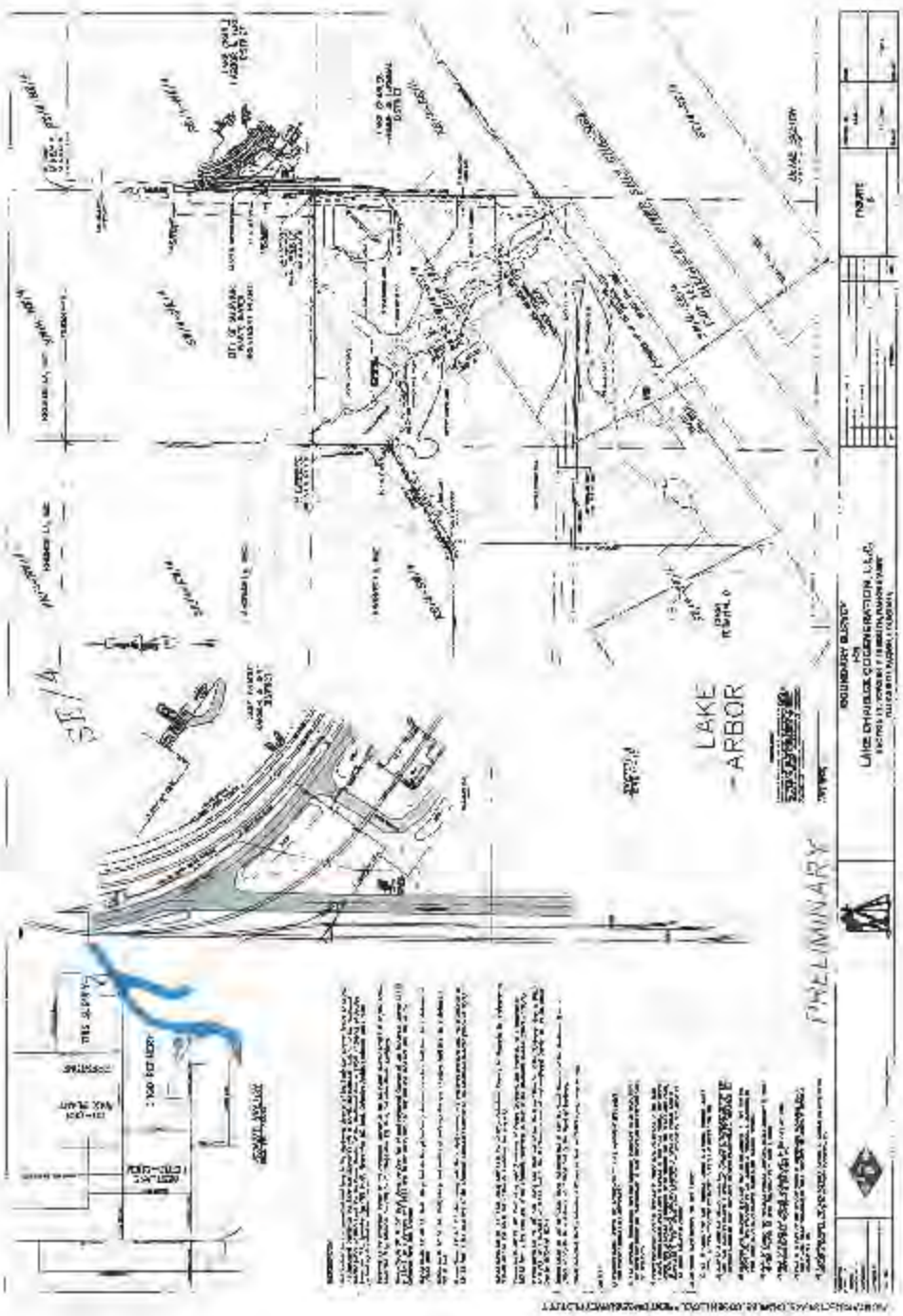
This section shall describe any subsidence that might be caused by construction; any possible erosion, stream diversion, floodplain and wetland intrusion, and any increases or decreases in soil permeability and filtration.

Sections of the Lake Charles Gasification Facility site are within the 100-year or 500-year flood plains (Reference Figure 8, *Boundary Survey*). However, construction of the Lake Charles Gasification Facility will include installation of a sheet pile bulkhead along the southern border of the property at the Calcasieu River that is approximately 2,180 feet long and an elevation of between 11 and 12 ft. The existing site elevation is approximately 7 feet; however, the existing elevation adjacent to the ship channel varies from approximately -2 to -13 feet MSL. The site construction will include the addition of fill material resulting in final site elevations that will vary from 10 feet near the bulkhead to 16 feet at the highest elevation. These elevations are significantly above the local 100-year and 500-year base flood elevations. The sheet pile wall located along the eastern site boundary will retain the proposed fill.

Subsidence of coastal Louisiana is well documented. Regional data suggests movements on the order of 2 to 3 cm per year. Geotechnical borings and testing of obtained soils is being conducted and evaluated to determine appropriate engineering and construction for the site. Construction of this project is not anticipated to significantly alter the subsidence characteristics of the project site, nor influence the larger surrounding area.

The site fill material will include clay soils, and on-site soils will also be utilized from certain areas. The soil permeability and characteristics of these sources are anticipated to be similar to the clay soils currently present, and will be superior in character to some of the soils in the marsh areas. Due to the amount of fill that will be present after construction, as well as the presence of low permeability structures that are part of the facility, infiltration rates would be anticipated to be reduced over much of the project area. This reduction will not have an adverse effect on the shallow groundwater and will not influence the much deeper aquifers in the area that are used for industrial and potable purposes.

Surface water from north and west of the site, drain through the existing site to the shipping channel. Site development plans will raise the elevation of the site property; however, off-site flows currently following the natural topography of the site will be diverted to either the drainage easement on the north side of the site or to a perimeter conveyance system on the west side of the site and into the ship channel via an outlet in the vicinity of the southeast and southwest corners of the project site.



Wetlands are discussed below.

5. Vegetation and Wildlife Resources

This section shall describe any impacts to indigenous flora and fauna, state and Federally listed endangered species and their habitats, and sensitive habitats such as wetlands, floodplains, or other ecologically sensitive terrain.

Based upon information reviewed from the Louisiana Department of Wildlife and Fisheries (LDWF, May 2009), no rare, threatened or endangered species or critical habitats are anticipated for this proposed project. LDEQ's February 2010 list of threatened and endangered species includes only the red cockaded woodpecker as endangered in Calcasieu Parish; no aquatic species are listed. According to LDEQ's 2009-2010 Implementation Strategy for the Memorandum of Understanding between LDEQ and the U.S Fish and Wildlife Service, there are no federally listed threatened or endangered species on the Calcasieu River that are dependent on aquatic habitat. No other rare, threatened, or endangered species or critical habitat is known to exist at the project site or within a radius of 1,000 feet of the proposed site. In addition, there are no state or federal parks, wildlife refuges, scenic streams, or Wildlife Management Areas at or near the proposed project site.

A jurisdictional wetland delineation was previously conducted by the U. S. Army Corps of Engineers (COE), and the Port of Lake Charles mitigated 26.2 acres of the wetlands through agreement with the COE and Stream Wetland Services, LLC. Permitting through the COE to develop the site has been completed and the latest permit was issued on August 18, 2008. No other wetlands will be impacted by the proposed project.

6. Socioeconomic Conditions

This section shall describe any increases/decreases in labor requirements or changes in labor mix.

The proposed Lake Charles Gasification Facility is a state-of-the-art facility that will represent a significant capital investment for the region. The construction phase of the project will result in a large number of local and in-state expenditures and will create a large number of employment opportunities. Construction of the LCC Gasification Project will occur over an approximate four year period. The CO_2 Capture and Compression Facilities will be constructed simultaneously with the LCC Gasification Project.

Operation of the LCC Gasification Project will result in approximately 180 jobs, most of which will be high-quality, high-paying positions.

Purchases of petroleum coke from local refineries will help support other industries and create additional value-added to locally made products rather than having these products exported to other areas of the country or the world. In addition, gulf coast petroleum coke which is presently being exported will now be used by the LCC Gasification Project for making clean energy for domestic use thereby reducing energy imports from many unstable areas of the world.

Overall, the LCC Gasification Project will generate over $1.3 billion in capital expenditures and over 12,000 direct and indirect jobs during construction. This results in annual average of $340 million and 3,000 jobs. Some 30 percent of the total expenditure impacts are expected to occur in

the greater Lake Charles area, with a large portion of the remainder occurring in other portions of the state.

Economic Impacts During Construction						
	Output (million $)			Employment		
Impacts	Lake Charles	Rest of Louisiana	Total Louisiana	Lake Charles	Rest of Louisiana	Total Louisiana
Direct	$362.0	$543.0	$ 905.0	1,335	5,787	7,123
Indirect $	17.8	$203.2	$ 221.0	203	1,905	2,108
Induced $	25.6	$203.6	$ 229.2	374	2,622	2,996
Total	**$405.4**	**$949.8**	**$1,355.3**	**1,912**	**10,314**	**12,226**

Economic Impacts (Annual Operations and Maintenance)						
	Output (million $)			Employment		
Impacts	Lake Charles	Rest of Louisiana	Total Louisiana	Lake Charles	Rest of Louisiana	Total Louisiana
Direct	$ 67.0	$ 1.0	$ 68.0	150	--	150
Indirect	$ 32.6	$ 14.0	$ 46.6	127	87	214
Induced	$ 8.4	$ 7.0	$ 15.4	123	79	202
Total	**$108.0**	**$ 22.1**	**$130.1**	**400**	**166**	**566**

Property Value Impacts / Economic Development of the Area

The Lake Charles Gasification Project is not anticipated to have an adverse affect on property values in the surrounding area, or to hinder economic development of the area by other industries, as the area is zoned for heavy industrial purposes.

7. Historic/Cultural Resources

This section shall describe any disturbance to historical or archeological sites caused by construction, interference with Native American tribal or other religious practices or sites; impacts on local community character.

The LCC Gasification Project has prepared a cultural resources study as required by the State Department of Cultural, Recreation & Tourism, Office of Cultural Development. A prior study by Earth Search, Inc. in 2001 identified a Rangia shell midden associated with Site 16CU29 that potentially extended into the southwest corner of the proposed project site. A Phase I Cultural Resources Survey was performed for this site and a report was issued to Louisiana State Historic Preservation Officer (SHPO). The SHPO reviewed this updated information and issued a letter noting that field investigations resulted in the delineation of expanded boundaries for this site and the assessment concluded that the site was not eligible for listing on the National Register of Historic Places due to a lack of depositional integrity and limited research potential. The SHPO concurred with the assessments conducted and concluded that additional assessments are not warranted. Refer to Appendix A for a copy of the Phase I Cultural Resources Survey Report and the letter from the Louisiana State Historic Preservation Officer.

8. Visual Resources

This section shall describe any impacts to scenic vistas or existing aesthetic landscaping.

There are no scenic rivers, vistas or existing aesthetic landscaping that will be affected by the Lake Charles Gasification Facility. The land that is being utilized for this facility is owned by the Port of Lake Charles and has been under their ownership for many years. The project site is located in a heavy industrial setting and the visual landscape of the area is already marked with industrial structures of various types.

9. Health and Safety Factors

This section shall discuss occupational hazards of project activities; exposure to toxic/hazardous substances; and increases in ambient noise, odor, and heat.

Materials Storage/Handling

The LCC Gasification Project will receive petroleum coke as the primary feedstock to produce methanol, steam and electricity (i.e., for balancing the energy needs for this facility). The materials handling operations (i.e., petroleum coke and fluxant) will be conducted with significant controls to minimize particulate emissions. Petroleum coke will be received off-site at the Port of Lake Charles. The coke will be transported via covered conveyor to the LCC Gasification Project site and stored in feed bins. The fluxant (bottom ash and sand) will be transported by enclosed truck and pneumatically conveyed to separate silos.

There are some ancillary fuels, feed materials, and facility products handled or stored on-site in order to maintain operations. These materials include the following:

- diesel fuel for firewater pumps and emergency generators;
- gasoline for plant vehicles;
- aqueous ammonia storage for the SCR in the Sulfuric Acid Plant;
- sulfuric acid product storage;
- glycol storage for gas dehydration; and
- methanol storage associated with the Rectisol unit.

All of these materials will be stored and managed in accordance with all applicable requirements and BMPs to prevent impacts to the environment. This includes appropriate containment, curbing, routine spill inspections, and compliance, where applicable, with SPCC requirements and a stormwater pollution prevention program. None of these materials will be handled or stored at the Capture and Compression Facilities.

Noise

Operational Noise -- The CO_2 Capture and Compression Facilities will have minimal noise impacts as they are inside the larger proposed LCC Gasification Project. The compressor building is designed to minimize the impact on ambient noise. Workers will be required to wear hearing protection when inside the compressor building. All applicable OSHA standards and requirements will also be implemented for site workers entering the compressor area and building.

During operation of the proposed LCC Gasification Project, the principal sound sources would include equipment such as the steam turbine/ generator, heat recovery systems, steam blowdowns, cooling tower, petcoke crusher, petcoke mill, pumps, fans, and compressors, as well as noise from piping flow and flared gas. Most of these sound sources would be at least partially enclosed and acoustically insulated. Noise levels within some areas of the plant will require worker hearing protection, but the magnitude of the noise will attenuate to minor levels beyond the facility boundaries.

Noise during proposed facility operations, with proper mitigating measures, is anticipated to represent only a small addition to noise levels in the areas surrounding the site. The facility noise will be similar in character to existing noise from other nearby industrial facilities.

Increased truck traffic coming to and leaving from the facility would create increased frequency of traffic noise.

Construction Noise -- During construction of the LCC Gasification Project and CO_2 Capture and Compression Facilities, noise would be generated by construction equipment such as cranes, air compressors, and front-end loaders. Noise levels during construction would be typical of industrial plant construction.

Emergency Response Procedures

Emergency response procedures will also be developed for the facility in accordance with the requirements of OSHA, Emergency Planning and community Right-to-Know Act (EPCRA), and CAA provisions. Such procedures will include plant evacuation procedures, procedures for notification to local fire and law enforcement agencies, procedures for notification to state and local officials and US EPA. Emergency response procedures will identify individuals/positions responsible for decision-making and notification and will include provisions for periodic training for plant management and employees.

10. Solid and Hazardous Wastes

This section shall describe any and all waste material that is generated from project activities. This description shall include the source/type of any and all wastes produced (e.g., fly ash, bottom ash, scrubber sludge, etc.), and the approximate weight, density, and volume of the waste, and its method of disposal, location, and any permitting requirements necessary.

The CO_2 Capture and Compression Facilities will not produce significant quantities of solid waste. The wastes produced by the Capture and Compression Facilities will include lubricating oils and filters commonly utilized in operation of sophisticated rotating equipment. Typical

waste would consist of one or two large canister oil filters changed once per year and replacement of 500 to 1000 gallons of console oil every turnaround (3 years).

No solid or hazardous waste will be disposed of at the LCC Gasification Project. Any wastes generated from operations or maintenance will be properly managed and disposed of off-site at an appropriately permitted facility.

The wastes generated by the LCC Gasification Project are summarized in the table below.

Lake Charles Cogeneration Project Solid Waste Characteristics 7,400 STPD Petroleum Coke Gasification to SNG			
Description	Estimated Quantities	Frequency Produced	Hazardous
Air Filters for ASU	< 4,000 ft3/yr	Yearly	No
Spent ASU molecular sieve and activated alumina	<1000 ft3/yr	5-10 years	No
Spent catalyst (Shift, Methanation, WSA)	<10,000 ft3/yr	2-9 years	Yes, will be reclaimed
Water Treatment Clarifier Sludge Filter Cake (from treating river water)	<2,000 tpy	continuous	No
Water Treatment spent media	< 5 tpy	Weekly	No
Description	Estimated Quantities	Frequency Produced	Hazardous
Heavy Metals Precipitate	8 tpd	continuous	Yes, will go to off-site hazardous waste landfill
Salts from evaporation and crystallization of process wastewater	2 tpd	continuous	No

In addition, slag, the vitrified (glassy) solid product of gasification, may be disposed of as a waste. Slag is formed in the gasifier due to operation at temperatures above the melting point of the mineral matter associated with the feed materials. Approximately 420 tons per day of slag will be produced by the LCC Gasification Project. The slag can be disposed of as a non-hazardous by-product or sold to various commercial markets. Analysis of the slag material from various gasification processes has consistently shown the slag to be a non-hazardous material (U.S. DOE 2000).

11. Impacts on Regional or Local Plans

This section shall describe any impacts to regional or local plans for fuel, water resources, solid waste, land, air quality, and labor force; commitment of resources and opportunities to reuse and recycle resources (wastes, water).

Located within the LCC Gasification Project, the CO_2 Capture and Compression Facilities will not materially affect the overall regional or local plans.

The development of the LCC Gasification Project is directly related to the energy development and technology goals of the state's economic development blueprint: *Vision 2020* and the most recent *2004 Action Plan. Under Vision 2020's goal of creating a "Culture of Innovation," Section 2.1 specifically seeks to "retain, modernize and grow Louisiana's existing industries and grow emerging technology-based buinesses through cluster-based development practices."*

The proposed state-of-the-art facility is able to make use of the coke feed stocks that are present in the area and convert them into high-value products. Purchases of petroleum coke from local refineries will help support other industries and create additional value- added to locally made products rather than having these products exported to other areas of the country or the world. In addition, gulf coast petroleum coke which is presently being exported will now be used by the LCC Gasification Project for making clean energy for domestic use thereby reducing energy imports from many unstable areas of the world.

As noted in prior sections, solid and hazardous materials generated by this facility will be transported and disposed off-site at permitted facilities. The quantities of these wastes will not place a burden on the capacities of these facilities nor restrict the needs for disposal of the region.

Air quality of the area and region has been rigorously evaluated and appropriate PSD and Title V permits have been issued by the LDEQ.

Similarly, water resources of the area and region will be protected. The LCC Gasification Project has contracted with the Sabine River Authority to receive an annual average maximum of 8,500 GPM of Sabine River water. The water from the Sabine River Authority (SRA) will be routed to the project site via pipeline. The SRA is a river water source authority that manages the resources from this supply.

The design of the facility incorporates zero liquid discharge (ZLD) for the gasification process wastewater through utilization of filtration, steam stripping, evaporation, and crystallization. The process wastewater generated in the gasification process will be treated / recycled to achieve ZLD. Filtered solids and dewatered salts will be disposed of off-site at permitted facilities.

Overall, the project represents a considerable capital investment for the region, and over its four year development period, will provide thousands of local and state employment opportunities.

The project has the opportunity to support an emerging market for carbon sequestration primarily through enhanced oil recovery.

C. POTENTIAL LIABILITY TO DOE OF EXISTING CONDITIONS AT THE SITE(S).

*This section shall discuss any potential conditions for exposing the DOE to **previous** liability. It should detail any previous research, development, construction, and/or demonstration testing that could potentially have impacts on the existing project site(s) and therefore, the proposed project.*

The site is not anticipated to involve any exposure for DOE due to existing conditions. As detailed below, there is some limited contamination at the site. However, any required remediation or response will be the responsibility of the site owner, the Port of Lake Charles, and will be performed, if necessary, prior to construction of the LCC Gasification Project.

In November 2007, URS Corporation performed a Phase I Environmental Site Assessment (ESA) of the 70 acre property currently owned by the Port of Lake Charles in Westlake, Louisiana (Subject Property) (see Figure 1). The Phase I ESA identified historical sampling activities on the property which revealed elevated levels of constituents that are suspected not to be naturally-occurring. Releases from the Sulphur Wastewater Treatment Plant (WWTP) noted in the records of the LDEQ may have migrated along the northern boundary ditch between the Subject Property and the Sulphur WWTP property and in the ditch that flows to the Calcasieu Ship Channel on the eastern boundary of the Subject Property. Additionally, a larger channel, known as the Himont ditch, constructed in the late 1950s, has discharged wastewater effluent from the Basell facility to the west of the subject property, along with possible discharges from the LA Pigment facility on the northern side of the subject property. The topographic features of the areas route flow from the west and north through the existing wetlands areas to the Calcasieu River. It was noted that these discharges from upgradient industrial facilities may have impacted bottom sediments of the water bodies on the subject property.

Further investigation and evaluation of the previously reported sediment impacts was conducted by URS in accordance with the Louisiana Risk Evaluation/Corrective Action Program (RECAP) document, dated October 20, 2003. Sediment samples were collected in an attempt to confirm the results of a 1989 investigation performed by others. Groundwater sample collection was proposed on the subject property once access to the more inaccessible areas is available.

URS collected 18 sediment samples from the meandering channels and/or open ponded areas throughout the wetlands areas of the Subject Property. URS also collected sediment samples in the two ditches which have been indicated to carry the discharge effluent from the Sulphur WWTP to the Calcasieu Ship Channel.

Sediment samples in the upper six inches of the bottom surface of channels or ponds were collected for analysis. Analytical testing of each sediment sample included the following analyses:

- Metals (13 Priority Pollutant metals plus aluminum, vanadium and titanium)
- Volatile Organic Compounds (VOCs)
- Semi-volatile Organic Compounds (SVOCs)
- Petroleum Hydrocarbons Fractions (VPH & EPH)

The results of the analyses of the sediment samples indicate the presence of several organic compounds and metals in the sediment on the subject property. The site owner, the Port of Lake Charles, will work with LDEQ to determine whether any further sampling, monitoring or remediation is necessary. Additional follow-up activities will be performed, if necessary, prior to construction of the LCC Gasification Project.

D. ABILITY TO MEET COMPLIANCE REQUIREMENTS AT THE SITE(S).

This section shall identify all of the environmental laws and regulations (Federal, state, and local) for which compliance would be necessary. It should include, but should not be limited to the Resource Conservation and Recovery Act, the Comprehensive Environmental Response, Compensation, and Liability Act, Toxic Substance Control Act, Water Pollution Control Act, Clean Air Act, and Occupational Safety and Health Act. Any necessary permits, manifest, etc., shall be discussed.

The proposer's strategy for meeting all compliance requirements shall be discussed in detail. Identify the best available control technology and feasible practices for compliance with Federal air, land use, and water quality statutes. In addition, whether the proposed site is in attainment or non-attainment with current standards shall be discussed.

RCRA/Hazardous Materials Regulations

The CO_2 Capture and Compression Facilities will not produce hazardous wastes.

The LCC Gasification Project will not require a RCRA Permit, as there will be no storage or treatment of hazardous wastes on site. LCC does not anticipate that any TSCA or CERCLA requirements will be applicable to the LCC Gasification Project.

Clean Air Act Permits

The Capture and Compression Facilities will have no air emissions, as the AGR units and CO_2 stream compressors are electric driven.

As discussed in earlier sections, the LCC Gasification Project has obtained Title V and Prevention of Significant Deterioration (PSD) Air Permits for emissions associated with the production of substitute natural gas. The emissions are expected to be similar for the production of methanol.

Clean Water Act

As described above, the ancillary systems required to support the CO_2 Capture and Compression Facilities are provided through the LCC Gasification Project. All provisions required to comply with the Clean Water Act are incorporated within the LCC Gasification Project, without further modification upon incorporation of the CO_2 Capture and Compression Facilities.

The LCC Gasification Project is permitted to implement zero liquid discharge (ZLD) for the gasification process wastewater. The wastewater generated in the gasification process will be treated / recycled to achieve ZLD. Filtered solids and dewatered salts will be disposed of off-site

at permitted facilities. The following will be discharged to the Calcasieu River at the southern plant property line: non-contact cooling water blowdown, water treatment reject and regeneration water, oil/water separator water (plant and equipment drains) and low-contamination potential storm water runoff.

Discharge of storm water during construction activities will require submittal of a Large Construction Notice of Intent (LCNOI) 30 days prior to start of construction. The LCNOI must include an SWPPP and a USGS quad map showing the site location.

United States Army Corps of Engineers (US COE)

All provisions for compliance with US COE regulations including compliance with Section 404 of the Clean Water Act of 1972, are incorporated within the design and permitting process for the LCC Gasification Project project. The CO_2 Capture and Compression Facilities do not require modification of the permit.

A Section 404 permit was issued by the US COE in August 2008 supported by a 401 Water Quality Certification (WQC) issued by the LDEQ. The US COE determined that a Section 10 permit was not required.

A jurisdictional wetland delineation was previously conducted by the US COE and, based on this delineation, the Port of Lake Charles mitigated 26.2 acres of the wetlands through an agreement with the U S COE and Stream Wetland Services, LLC. Permitting through the US COE to develop the site has been completed and the latest permit was issued on August 18, 2008.

Coast Guard Review

Due to the fact that the Calcasieu Ship Channel is a federally maintained channel, any activity within the channel, may need to undergo Coast Guard review. During the planning and design process, a description and map of the facility, including a letter of intent, would be sent to this agency for its approval and clearance. The COE permit notes that:

- You must install and maintain, at your expense, any safety lights, signs, and signals prescribed by the U.S. Coast Guard, through regulations or otherwise, on your authorized facilities, and

- If the proposed project, or future maintenance work, involves the use of floating construction equipment (barge mounted cranes, barge mounted pile driving equipment, floating dredge equipment, dredge discharge pipelines, etc.,) in the waterway, you are advised to notify the U.S. Coast Guard, Marine Safety Office, Waterways Management Section so that a Notice to Mariners, if required, may be prepared.

Coordination with the Coast Guard regarding the construction of the planned structures (bulkhead) in accordance with the above will be implemented for this project to ensure that all requirements are satisfied.

Endangered Species Act

The Endangered Species Act of 1973 (7USC 136; 16 USC 460 et seq.), as amended, provides for the USFWS to manage rare plants and wildlife to prevent further declines in their populations and to protect their habitat. The USFWS maintains lists of rare plants and wildlife known to be potentially present in each county of the United States. This list is based on historical site records and existing habitat on and near the site that corresponds with preferred habitats of these species. The Endangered Species Act also states that coordination with the United States Fish and Wildlife Service (USFWS) is required to ensure that "actions do not jeopardize listed species or destroy or adversely modify critical habitat". The USFWS shares responsibility with the National Marine Fisheries Service (NMFS), when marine or estuarine species are involved, for implementing the ESA.

Based upon information reviewed from the Louisiana Department of Wildlife and Fisheries (LDWF, May 2009), no rare, threatened or endangered species or critical habitats are anticipated for this proposed project. LDEQ's February 2010 list of threatened and endangered species includes only the red cockaded woodpecker as endangered in Calcasieu Parish; no aquatic species are listed. According to LDEQ's 2009-2010 Implementation Strategy for the Memorandum of Understanding between LDEQ and the U.S Fish and Wildlife Service, there are no federally listed threatened or endangered species on the Calcasieu River that are dependent on aquatic habitat. No other rare, threatened, or endangered species or critical habitat is known to exist at the project site or within a radius of 1,000 feet of the proposed site. In addition, there are no state or federal parks, wildlife refuges, scenic streams, or Wildlife Management Areas at or near the proposed project site.

National Historic Preservation Act

Under Section 106 of the National Historic Preservation Act of 1966 (NHPA), the lead federal agency with jurisdiction over a federal undertaking must consider impacts to historic properties. This requirement is applicable to programs such as the Project, which receive federal funding or that require a federal permit, license, or approval. A historic property is defined as any district, archeological site, building, structure, or object that is either listed, or is eligible for listing, in the National Register of Historic Places (NRHP). The intent of Section 106 is for federal agencies to take into account adverse effects on any historic properties situated within the APE of the proposed undertaking; and to afford the Advisory Council on Historic Preservation (ACHP), State Historic Preservation Officers (SHPO), recognized Native American tribal offices, and any other interested parties an opportunity to comment on the proposed action. 36 CFR Part 800 specifies that certain parties must be consulted during the cultural resource review process. These parties include each SHPO whose state physically includes any portion of the APE.

The project has prepared a cultural resources study as required by the State Department of Cultural, Recreation & Tourism, Office of Cultural Development. A prior study by Earth Search, Inc. in 2001 identified a Rangia shell midden associated with Site 16CU29 that potentially extended into the southwest corner of the proposed project site. A Phase I Cultural Resources Survey was performed for this site and a report was issued to the SHPO. The SHPO reviewed this updated information and issued a letter noting that field investigations resulted in the delineation of expanded boundaries for this site and the assessment concluded that the site was not eligible for listing on the National Register of Historic Places due to a lack of depositional integrity and limited research potential. The SHPO concurred with the assessments conducted and additional assessments are not warranted. Refer to Appendix A for a copy of the

Phase I Cultural Resources Survey Report and the letter from the Louisiana State Historic Preservation Officer.

Emergency Management Requirements

The facility may also be subject to certain emergency management requirements under the Emergency Planning and Community Right-to-Know Act (EPCRA) and Spill Prevention Control and Countermeasure (SPCC) requirements (40 CFR 112).

Emergency response procedures will be developed for the facility in accordance with the requirements of Occupational Safety and Health Administration (OSHA), EPCRA, and CAA provisions. Such procedures will cover plant evacuation notification to local fire and law enforcement agencies, notification to state and local officials and US EPA. Emergency response procedures will identify individuals/positions responsible for decision-making and notification and will include provisions for periodic training for plant management and employees.

Local Permits

The Project is anticipated to require building permits and a flood zone management permit from local regulators. Coordination on these requirements is being implemented.

E. EXPERIENCE AND APPROACH TO THE IDENTIFICATION AND RESOLUTION OF ENVIRONMENTAL ISSUES.

This section of the Environmental Volume shall consist of a discussion of the following areas:

1. All directly related education/experience of key project members in each of the following areas:

- ❑ *Air quality management*
- ❑ *Surface water and ground water management*
- ❑ *Solid and liquid waste management and disposal practices*
- ❑ *Noise, land use, ecological resources, archaeological, cultural, and historical resources Management*
- ❑ *Environmental permit applications, amendments, and renewals*

LCC employs several individuals who are responsible for preparing the Operations and Maintenance procedures and selecting staff suitable for the LCC Gasification Project. LCC O&M personnel have managed and operated the only U.S. based gasification facility producing ammonia and UAN utilizing GE's gasification technology, the gasification facility in Coffeyville, Kansas. Their work included participating in development of the construction and operating environmental permits for the facility which started up in early 2000. This experience includes management of all environmental compliance and reporting related to the gasification and related downstream facilities. The LCC Gasification Project staffing plan includes the position of an Environmental/PSM Coordinator who is charged with training the plant staff on all local, state, and federal environmental requirements. The on-site technical staff will also be charged with auditing compliance with all permits.

2. The offeror's experience in addressing and resolving environmental concerns during the performance of past projects of similar size and complexity including the obtaining of necessary permits.

The LCC team includes the following key members with experience in environmental issues at similar projects:

Scott Pierce
Mr. Pierce has been involved in chemical plant operations and maintenance for over 30 years. He has held positions as Operation/Maintenance Manager on two Greenfield projects and participated in acquiring and complying with construction and PSD permits for both. From 1999-2009, Mr. Pierce was Operations Manager of the Coffeyville Resources Gasification facility in Coffeyville Kansas. During this period he had been involved in almost every environmental aspect of an operating chemical facility.

Robby Collums
Mr. Collums was the Operations Coordinator and a member of operations management at the Coffeyville Resources Gasification facility for nearly 20 years. During this period Mr. Collums was involved in almost every environmental aspect of an operating chemical facility.

Mr. Pierce and Mr. Collums' responsibilities in management of the facilities and employees included:

- writing compliance procedures
- training employees on written environmental air, water, and process procedure
- training employees on procedures for reporting releases to CERCLA/SARA, State and LEPC officials
- writing procedures to minimize and prevent releases and spills
- oversight towards maintaining and complying with the OSHA/Process Safety Management Program and the EPA/Risk Management Program including participation in several internal and external (OSHA/EPA) environmental audits.

Other responsibilities in these facilities included

- training and oversight of employees in testing and monitoring water qualities of the process water, wastewater, cooling water, boiler water, intake and discharge waters
- Preparation of reports for compliance with the facilities water permits.

Under the Hazardous Waste Operations and Emergency Response Standard (HAZWOPER), each member of the operations team was required to complete the initial training level of the OSHA hazardous waste operator course. Mr. Pierce participated on the hazmat team at 3 different facilities for over 15 years. Mr. Collums was a member of the facilities hazmat team for several years and completed the level 1 course in industrial fire fighting and ammonia suppression at LSU and fire fighter 1 course from OSU.

Lawrence Leib, P.E.
Mr. Leib has been responsible for design of multiple cogeneration and process facilities, both domestic and overseas. As process design manager at an engineering design firm with EPC responsibility, Mr. Leib coordinated design and performance characteristics to guarantee compliance with environmental permits obtained by the facility Owner for 12 domestic power projects. This responsibility included development of emissions testing protocols and demonstration of compliance.

As Chief Engineer for project development entities, Mr. Leib has been responsible for determination of project design characteristics and preparation of environmental permit applications for air and water discharges. This work included coordination with design engineering and environmental consulting firms and state and federal regulatory agencies for several domestic and international projects. For Leucadia International, Mr. Leib has coordinated preparation of the PSD/Title V and LPDES permit applications for the Lake Charles Cogeneration facility in Lake Charles, LA. These permits were obtained in 2009.

In addition to the above key project members, LCC will utilize URS and other environmental consultants during the construction and operation of the site.

URS is one of the nation's leading Environmental Sciences and Engineering consulting firms. In the area of water resources, URS provides a broad range of services for water quality, flood control, wetlands and watershed management projects. The URS New Orleans EH&S Group has provided environmental engineering services for the Lake Charles Cogeneration project PSD/Title V and LPDES permits. For over 30 years it has provided full service permitting and compliance assistance to the private and public sectors

3. Any of the offeror's existing written environmental policies, procedures, or plans currently in place and considered essential to the conduct of the offeror's commercial business operation.

LCC has not yet developed the written policies, procedures and plans that will be implemented at the LCC Gasification Project.

Report

Environmental Information Volume

Pipeline Lateral
Lake Charles, Louisiana

Prepared for

Denbury Onshore, Inc.

5100 Tennyson Parkway, Suite 1200
Plano, Texas 75024

March 2010

Contents

Section **Page**

Contents ..... **ii**
Acronyms and Abbreviations ..... **vii**
Executive Summary **ES-1**
Proposed Action and Historical Overview ES-1
Alternatives to Proposed Action ES-2
Summary of Effects ES-2
Mitigation ES-5
1 Purpose and Need for the Proposed Action **1-8**
1.1 Project Description 1-8
1.2 Purpose and Need 1-11
1.3 Project Schedule 1-11
1.4 Resource Requirements and Technical Data 1-11
1.4.1 Land Requirements 1-11
1.5 Interagency Cooperation 1-23
2 Alternatives Including the Proposed Action **2-1**
2.1 Proposed Action (assuming DOE funding) 2-1
2.2 Alternative Action (assuming no DOE funding) 2-3
2.3 No Action Alternative 2-3
3 Affected Environment **3-1**
3.1 Project Area and Topography 3-1
3.2 Climate, Meteorology, and Air Quality 3-1
3.2.1 Climate 3-1
3.2.2 Meteorology 3-5
3.2.3 Air Quality 3-7
3.3 Water 3-9
3.3.1 Surface Water 3-9
3.3.2 Groundwater 3-11
3.3.3 Floodplains 3-11
3.3.4 Wetlands 3-14
3.4 Ecology 3-16
3.4.1 Terrestrial Ecology 3-16
3.4.2 Aquatic Ecology 3-17
3.4.3 Threatened and Endangered Species 3-18
3.5 Solid Waste Disposal 3-19
3.5.1 General Waste 3-19
3.5.2 Known Hazardous Waste Sites 3-19
3.6 Land Use 3-19
3.7 Geology and Soils 3-22
3.7.1 Geology 3-22
3.7.2 Soils 3-24
3.8 Cultural and Archaeological Resources 3-27

3.8.1 Native American Tribal and Religious Practices 3-27
3.8.2 Historic Areas 3-27
3.9 Noise 3-28
3.9.1 Affected Environment 3-28
3.10 Socioeconomics 3-28
3.10.1 Population and Race 3-29
3.10.2 Employment 3-29
3.10.3 Housing 3-31
3.10.4 Environmental Justice 3-31
3.11 Public Resources 3-33
3.12 Transportation 3-33
3.13 Visual 3-35
3.14 Occupational Safety and Health 3-35
3.14.1 Construction 3-35
3.14.2 Operations 3-36
4 Environmental Consequences 4-1
4.1 Project Area and Topography 4-1
4.1.1 Impacts 4-1
4.1.2 Mitigative Measures 4-1
4.2 Climate, Meteorology, and Air Quality 4-2
4.2.1 Existing Source Emissions 4-2
4.2.2 Future Air Emission Sources 4-2
4.2.3 Air Permitting and Compliance 4-2
4.2.4 Impacts 4-4
4.2.5 Mitigative Measures 4-6
4.3 Water Quality 4-6
4.3.1 Surface Water 4-6
4.3.2 Groundwater 4-10
4.3.3 Floodplains 4-11
4.3.4 Wetlands 4-12
4.4 Ecology 4-15
4.4.1 Terrestrial Ecology 4-15
4.4.2 Aquatic Ecology 4-17
4.4.3 Threatened and Endangered Species 4-18
4.5 Solid Waste Disposal 4-18
4.5.1 Impacts 4-19
4.5.2 Mitigative Measures 4-19
4.6 Land Use 4-20
4.6.1 Environmental Consequences 4-20
4.6.2 Impacts 4-20
4.6.3 Mitigative Measures 4-22
4.7 Geology and Soils 4-23
4.7.1 Impacts 4-23
4.7.2 Mitigative Measures 4-23
4.8 Cultural and Archaeological Resources 4-24
4.8.1 Native American Tribal and Religious Practices 4-24
4.8.2 Historic Areas 4-24

4.9 Noise Environmental Consequences 4-25
4.10 Socioeconomics 4-25
4.10.1 Population and Race 4-25
4.10.2 Employment 4-26
4.10.3 Housing 4-26
4.10.4 Environmental Justice 4-26
4.11 Public Resources 4-27
4.11.1 Impacts 4-27
4.11.2 Mitigative Measures 4-27
4.12 Transportation 4-28
4.12.1 Impacts 4-28
4.12.2 Mitigative Measures 4-28
4.13 Visual 4-29
4.13.1 Impacts 4-29
4.13.2 Mitigative Measures 4-29
4.14 Occupational Safety and Health 4-29
4.14.1 Impacts 4-29
4.14.2 Mitigative Measures 4-30
4.15 Cumulative Impacts 4-31
4.16 Summary of Impacts 4-33
5 Potential Liability to DOE of Existing Conditions at the Site 5-15-1
6 Ability to Meet Compliance Requirements at the Site 6-1
6.1 Applicable Regulatory Requirements and Coordination 6-1
6.1.1 Federal Statutes 6-1
6.1.2 Regulations 6-1
6.1.3 Executive Orders 6-2
6.1.4 DOE Policies, Orders and Guidance 6-2
6.1.5 Applicable Permits Required for Proposed Action 6-3
7 Experience and Approach to the Identification and Resolution of Environmental Issues 7-1
7.1 Education/Experience of Key Project Members 7-1
7.2 Denbury's Permitting Experience 7-1
7.3 Denbury's Environmental Policies 7-2
8 References 8-1

List of Agencies Contacted

Tables

ES-1 Comparison of Impacts of Considered Alternatives ES-3
1-1 Summary of Land Requirements for Pipeline Facilities 1-13
1-2 ROW Summary 1-13
3-1 2009 Annual Weather Information for Jefferson County, Texas 3-3
3-2 30-Year Annual Average Weather Information for Jefferson County, Texas 3-3
3-3 Pollutants Contributing to Reduced Visibility in Class I Areas 3-7
3-4 Active Ambient Air Quality Monitors Nearest the Project Site 3-7
3-5 2009 Ambient Air Quality Data for Calcasieu Parish 3-8
3-6 USGS-Mapped Waterways Crossed by the Proposed Project 3-9

3-7 305(b) Water Quality Assessment of Project Area Waterways 3-12
3-8 Common Flora in the Northern Humid Gulf Coastal Prairies Ecoregion 3-16
3-9 Common Fauna in the Northern Humid Gulf Coastal Prairies Ecoregion 3-17
3-10 Fish Species Potentially Occurring in the Northern Humid Gulf Coastal Prairies Ecoregion 3-18
3-11 Federal and State Listed Species Potentially Occurring in Calcasieu Parish 3-18
3-12 Soil Series Properties 3-25
3-13 Population Statistics in the ROI and Reference Areas 3-29
3-14 Population by Race in the ROI and Referenced Areas (2008) 3-29
3-15 Total Employment in the ROI and Reference Areas 3-30
3-16 Unemployment Status for the ROI and Reference Areas 3-30
3-17 Per Capital Income for ROI and Reference Areas 3-31
3-18 Housing for the ROI and References Areas 3-31
3-19 Populations Living Below the Poverty Level by Race within the Referenced Areas 3-32
3-20 Percentage of Population Under age 18 in Referenced Area 3-33
3-21 Major Roadways and Average Daily Traffic in the Vicinity of the Pipeline Lateral 3-33
4-1 2008 Calcasieu Parich Point Source Facility Emissions 4-2
4-2 Uncontrolled Estimated Project Air Emissions 4-5
4-3 Land Use and Potential Habitat Impacts Associated with the Pipeline Lateral 4-16
4-4 Land Use Impacts Associated with the Pipeline Lateral 4-22
4-5 Cumulative Impact Summary 4-32
4-6 Summary of Impacts 4-33
6-1 Applicable Permits for the Proposed Action 6-3

Figures

1-1 Project Location/Greenline Location 1-9
1-2 Valve and Meter Station Locations 1-10
1-3 Project Schedule 1-12
2-1 Site Location Map 2-2
3-1 Project Topographic Map 3-2
3-2 Windrose Chart 3-5
3-3 IMPROVE Aerosol Network Location Map 3-6
3-4 NHD Stream Map 3-10
3-5 Publicly Listed Water Wells 3-13
3-6 FEMA 100-Year Floodplain Map 3-15
3-7 Existing Land Use Map 3-20
3-8 General Geology Map 3-21
3-9 Soils Map 3-23
3-10 Public Resources 3-26
3-11 Recreation Areas Map 3-34
3-12 Denbury's Total Recordable Incident Rate Compared to Oil and Gas Extraction Sector Industry Average 3-37

Appendixes

A Typical Construction ROWs
B Route Maps
C Landowner Lists
E Meteorological Data
F Resume
G Denbury Experience

Acronyms and Abbreviations

%g	percent peak acceleration
AADT	annual average daily traffic
AMSL	above mean sea level
APE	Area of Potential Effect
API	American Petroleum Institute
ATWS	Additional temporary workspace
BLS	Bureau of Labor Statistics
BMPs	best management practices
CAIR	Clean Air Interstate Rule
CCS	carbon capture and sequestration
CEQ	Council on Environmental Quality
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
CFR	Code of Federal Regulations
CO	carbon monoxide
CO_2	carbon dioxide
CWA	Clean Water Act
dBA	A-weighted decibel scale
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
ECP	Environmental Construction Plan
EIV	Environmental Information Volume
EJ	Environmental Justice
EO	Executive Order
EOR	enhanced oil recovery
EPA	U.S. Environmental Protection Agency
EPCRA	Emergency Planning and Community Right-to-Know Act

FEMA	Federal Emergency Management Agency
FHWA	Federal Highway Administration
FIRM	Flood Insurance Rate Maps
FPPA	Farmland Protection Policy Act
GIS	Geographic Information Systems
HDD	horizontal directional drill
HGB	Houston-Galveston-Brazoria
HRVOC	Highly Reactive Volatile Organic Compound
HSE	Health, Safety and Environmental
HUC	Hydrologic Unit Code
IMPROVE	Interagency Monitoring of Protected Visual Environments
km	kilometers
KPI	Key Performance Indicators"
LAC	Louisiana Administrative Code
LA DOTD	Louisiana Department of Transportation and Development
LDEQ	Louisiana Department of Environmental Quality
LDGF	Louisiana Department of Game and Fisheries
LDHH	Louisiana Department of Health and Hospitals
LDOE	Louisiana Department of Education
LDOTD	Louisiana Department of Transportation and Development
LDSS	Louisiana Department of Social Services
Leucadia	Leucadia Energy, LLC
LGS	Louisiana Geologic Survey
LNHP	Louisiana Natural Heritage Program
MACT	Maximum Achievable Control Technology
MCL	maximum contaminant level
MDEQ	Mississippi Department of Environmental Quality
MER	minimum emission rate
MLRA	Major Land Resource Area

MMSCF	million standard cubic feet
MVA	Monitoring, Verification, and Accounting
NAAQS	National Ambient Air Quality Standards
NCDC	National Climatic Data Center
NCSL	National Conference of State Legislatures
NEPA	National Environmental Policy Act
NESHAPs	National Emission Standards for Hazardous Air Pollutants
NFIP	National Flood Insurance Program
NHD	National Hydrography Dataset
NHPA	National Historic Preservation Act
NO_x	nitrogen oxide
NRCS	Natural Resources Conservation Service
NSPS	New Source Performance Standards
NSR	New Source Review
NWI	National Wetlands Inventory
O&M	operation and maintenance
OPS	Office of Pipeline Safety
OSHA	Occupational Safety and Health Administration
PBR	Permit by Rule
PHMSA	Pipeline and Hazardous Materials Safety Administration
PM_{10}	particulate matter
PPC	Preparedness, Prevention and Contingency
psig	pounds per square inch gauge
RCRA	Resource Conservation and Recovery Act
ROI	Region of Influence
ROW	right-of-way
scf/d	standard cubic feet per day
SHPO	State Historic Preservation Office
SO_2	sulfur dioxide

SPCC	Spill Prevention, Control, and Countermeasures
SWPPP	Storm Water Pollution Prevention Plan
THPO	Tribal Historic Preservation Offices
TNC	The Nature Conservancy
tpy	tons per year
TSP	total suspended particulate
TRI	Toxics Release Inventory
TRIR	Total Recordable Incident Rate
TSCA	Toxic Substances Control Act
USACE	U.S. Army Corps of Engineers
USC	United States Code
USCB	United States Census Bureau
USDA	U.S. Department of Agriculture
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
USLE	Universal Soil Loss Equation
VOC	volatile organic compounds
WMP	Waste Management Plan
WSRC	Wild and Scenic Rivers Council

Executive Summary

This Environmental Information Volume (EIV) has been prepared to provide information regarding existing environmental conditions, potential environmental impacts, and mitigative measures associated with an 11.6-mile CO_2 pipeline and associated ancillary equipment (hereafter Pipeline Lateral) that is being proposed as part of a larger carbon capture project.

This EIV was developed using readily available data as part of a desktop analysis. Field verifications were not conducted; nor were outside agencies consulted. The data provided herein is intended for use by the U.S. Department of Energy (DOE) in accordance with the National Environmental Policy Act of 1969 (NEPA). As part of this analysis, the preferred CO_2 pipeline corridor is presented in this EIV.

Sections 1 and 2 of the EIV contain a discussion of the purpose and need for the proposed action and the project alternatives, respectively. Sections 3 and 4 of this EIV contain information on the affected environment, environmental consequences, and measures proposed to mitigate potential impacts from the proposed action.

Proposed Action and Historical Overview

Leucadia Energy, LLC (Leucadia) in conjunction with Denbury Onshore, LLC (Denbury) will demonstrate advanced technologies that capture and sequester more than 4 million tons of carbon dioxide (CO_2) emissions at the Lake Charles cogeneration petroleum coke-to-chemicals (methanol) project (hereafter Project) to be located near Lake Charles, Louisiana. Assuming DOE funds the Project, compressed CO_2 will be transported through new and existing pipeline systems so that it can be used for enhanced oil recovery (EOR) in the Hastings oilfield in Texas.

As part of the Project, and as detailed in this EIV, Denbury is proposing to construct, own and operate an 11.6 mile 20-inch CO_2 pipeline and associated ancillary equipment (hereafter Pipeline Lateral) to Denbury's and an affiliate's Green Pipeline for CO_2 transport to the Hastings oilfield in Texas (Figure 1-1). The Pipeline Lateral will include a 20-inch outside diameter CO2 pipeline (with a maximum allowable operating pressure of 2,200 pounds per square inch gauge), one valve and one meter station (Figure 1-2). The pipeline route will parallel existing ROW (transmission lines, roads, pipelines, railroads, and other linear features) to the extent practicable. The meter station will be located at the terminus of the Pipeline Lateral at the Green Pipeline, and the valve will be located about mid-way between the Leucadia Plant and the Green Pipeline, within the pipeline corridor.

Leucadia, teamed with Denbury, was one of the projects selected by the Department of Energy (DOE) to receive federal funding[1] under the American Recovery and Reinvestment Act for carbon capture and storage research and development. As part of Phase I of the Project, an EIV must be prepared and submitted to DOE in order for DOE to fulfill its

[1] The projects are cost-shared collaborations between the DOE and industry to increase investment in clean industrial technologies and sequestration projects.

responsibilities under the NEPA. DOE is required to conform to the Council on Environmental Quality's regulations for Implementing the Procedural Provisions of the National Environmental Policy Act, 40 Code of Federal Regulations (CFR) Parts 1500 through 1508, and DOE Regulations for Implementation of NEPA (10 CFR Part 1021).

The proposed action will include approximately 11.6 miles of 50-foot-wide permanent pipeline right-of-way (ROW). In addition, up to 45-feet of temporary or construction ROW will be required for pipeline installation. Temporary access roads will be constructed along the proposed pipeline ROW as necessary, although Denbury will seek to utilize the existing road network for access as available. The estimated overall project time frame for the design, permitting and construction of the Pipeline Lateral is approximately 1.5 years. Construction of the Pipeline Lateral is expected to be completed by September 2012, with delivery of CO_2 from the Project source to commence by the 3rd quarter of 2013. Once the Project's CO_2 is flowing, it will supplement and/or replace naturally occurring CO_2 taken from the Jackson Dome in Mississippi and used for CO_2 flooding.

Alternatives to Proposed Action

It may not be economically feasible and environmentally beneficial for Leucadia and Denbury to continue with the proposed Project without DOE providing funding. Alternative actions to the pipeline mode of CO_2 transport could potentially include "CO_2 road transport" and "CO_2 rail transport" scenarios.

In the CO_2 road transport alternative, a truck could hold 20 tons of CO_2 (0.349 million standard cubic feet [MMSCF]) each run, making it possible to have 135 trucks ship CO_2 from the point of origin to the terminus daily. In the rail transport alternative, a rail car holds approximately 60 tons (1.048 MMSCF) of CO_2 each run and would require 45 railcars per day to carry CO_2 to Hastings Field. While removed from the environment at a lower rate, CO_2 would still be sequestered. CO_2, regardless of the mode (pipeline, road, or rail) by which it arrives at Hastings Field, could still be sequestered and used for EOR at that field, or transferred to other fields via Denbury's and an affiliate's Green Pipeline, a 24-inch CO_2 pipeline capable of transporting up to 800 million standard cubic feet of CO_2 per day between Donaldsonville, Louisiana, and Alvin, Texas. A more detailed, quantitative analysis of these sequestration options and the associated impacts would need to be conducted should DOE funding become unavailable and Denbury still wishes to pursue sequestration.

Without DOE cost-sharing funding for the Project, it is unlikely that the Project would be implemented. Consequently with the No Action Alternative, the lack of sequestration would increase the CO_2 in the environment and oil production would decrease at Hastings Field.

Summary of Effects

A summary of potential environmental impacts associated with an 11.6-mile Pipeline Lateral is provided below. Detailed descriptions of the affected environment and environmental consequences are provided in Sections 3 and 4 of this EIV. Table ES-1 summarizes the consequences of the proposed action, the alternative action, and the no action alternative, all of which are discussed below.

TABLE ES-1
Comparison of Impacts of Considered Alternatives
Denbury Onshore, LLC Lake Charles, LA EIV

Resource Area	Proposed Action	Alternative Action	No Action Alternative
Air Quality	Temporary impacts during construction include increased dust and combustion equipment operations. No permanent impacts are anticipated.	Temporary impacts associated with construction of additional road or rail lines (if necessary) to accommodate increased traffic volume. Permanent impacts associated with increased truck or rail related emissions.	Permanent impacts associated with increased CO^2 due to lack of sequestration.
Water Quality/Quantity	Temporary, localized impacts during construction stream crossings; Potential releases to streams during HDD operations; Surface water withdraws for hydrostatic testing.	Temporary impacts associated with construction of additional roads or rail lines (if necessary) to accommodate increased traffic volume.	No Impacts.
Solid Waste Disposal	Temporary construction impacts associated with land clearing, construction supply packing materials, and general refuge; Negligible solid waste generated during operations and maintenance activities.	Temporary impacts during construction of additional roads or rail lines (if necessary) to accommodate increased traffic volume. Minimal permanent impacts associated with general refuge from truck or rail staff.	No Impacts.
Land Use	Temporary impacts to 95 foot wide ROW during construction; Permanent conversion of land to 50 foot wide ROW for operations and maintenance activities; ROW collocates with existing utility ROWs for approximately 90% of route.	Potential permanent conversion of land to additional road or rail lines to accommodate increased traffic volume and access to CO_2 delivery point.	No Impacts.
Noise	Temporary noise impacts during construction; Negligible permanent impacts during operations and maintenance.	Temporary impacts associated with construction of additional road or rail lines (if necessary) to accommodate increased traffic volume. Permanent noise impacts associated with increased truck or rail traffic volume.	No Impacts.

TABLE ES-1
Comparison of Impacts of Considered Alternatives
Denbury Onshore, LLC Lake Charles, LA EIV

Resource Area	Proposed Action	Alternative Action	No Action Alternative
Floodplains and Wetlands	Temporary, localized impacts to floodplain and during construction stream and wetland crossings. Permanent conversion of forested wetlands to herbaceous wetlands within permanent 50-foot-wide ROW.	Permanent impacts associated with construction of additional roads or rail lines that may be necessary to accommodate increased traffic and access to CO_2 delivery point.	No Impacts.
Native American Tribal and Religious Practices	No impacts.	No impacts.	No Impacts.
Historic	No impacts.	No impacts.	No Impacts.
Ecological	Temporary impacts to vegetation and displacement of wildlife during construction; 50 foot wide permanent ROW will be maintained for operations and maintenance activities; Permanent impacts to wildlife are anticipated to be minimal.	Temporary impacts during construction of additional roads or rail lines (if necessary) to accommodate increased traffic volume. Permanent impacts associated with increased traffic volume and permanent conversion of land to roads and rail lines (if necessary).	No Impacts.
Socioeconomics	No impacts.	No impacts.	No Impacts.

Mitigation

A summary of potential mitigative measures associated with an 11.6-mile Pipeline Lateral is provided below. Detailed discussion of these mitigative measures can be found in Section 4 of this EIV.

- To mitigate for temporary topographical, land use, water body, wetland, ecological, and visual impacts, the Pipeline Lateral ROW will be re-contoured and re-vegetated as near to pre-construction conditions as is practicable following construction to allow for operational activities. Adjacent elevations and topography will be referenced to ensure that the ROW contours are consistent with the surrounding area.
- Temporary impacts to air quality from dust and combustion emissions during construction will be mitigated by implementing typical control techniques such as watering, chemical stabilization, use of windbreaks, and performing proper vehicle maintenance in compliance with 30 Texas Administrative Code (TAC) Chapter 114 Control of Air Pollution from Motor Vehicles. Potential construction impacts to surface water quality and quantity will be mitigated by obtaining and complying with all applicable water quality and quantity permits, such as National Pollutant Discharge Elimination System permits for Stormwater Discharges Associated with Construction Activities and for Hydrostatic Test Water Discharges and developing a project-specific Stormwater Pollution Prevention Plan, Horizontal Directional Drill Contingency Plan and a Site-Specific Crossing Plan.
- Wetland impacts will be mitigated following the General and Regional Conditions set forth by the U.S. Army Corps of Engineers (USACE) for all temporary construction impacts. Loss of forested wetland habitat will be mitigated by the purchase of wetland credits from an approved bank, as required by conditions in the Section 404/401 permit to be obtained for the Pipeline Lateral.
- Impacts to terrestrial wildlife will be mitigated by minimizing the duration of construction and scheduling construction within any critical habitat identified during ecological field surveys to avoid nesting periods to the greatest extent practicable. Migratory bird populations in the Project area would be expected to peak during the winter months. Project construction could be scheduled to avoid disturbing preferred habitats during winter months, which would minimize the potential for impacts.
- To mitigate solid waste disposal and handling impacts, all contractors associated with the Pipeline Lateral will be required to develop a project-specific Waste Management Plan, which will include specifications for handling, containment, and disposal of all wastes (non-hazardous and hazardous) generated during construction.
- Soil erosion, compaction, and top soil disturbances through agricultural and wetland areas will be mitigated through temporary erosion and sedimentation control measures, plowing or tilling severely compacted soils, and top soil segregation during construction and implementation of permanent measures, such as revegetation, following construction.

- If field reconnaissance discovers historical sites that may be culturally significant, impacts will be mitigated by localized re-routes to avoid impacts to the greatest extent practicable. If avoidance is not possible through design, Phase II archaeological evaluation will be undertaken to assess whether the site(s) qualify as historic properties as defined by 36 CFR 800.
- Transportation impacts will be limited to temporary increase in construction equipment transportation and construction worker transport. Mitigation measures will include notifying affected landowners of project schedule and potential traffic delays, implementation of safety measures and traffic controls during heavy equipment operations near roadways, and promoting carpooling and safe driving for construction staff.
- Denbury would mitigate the safety and health risks associated with construction activities through compliance with Occupational Safety and Health Administration (OSHA) standards including 29 CFR 1926, Safety and Health Standards for Construction, applicable state and local labor laws, and through good business practices.
- No mitigation measures are proposed or required for population, employment, housing, or environmental justice.

Operation and Maintenance

Denbury will operate and maintain the Pipeline Lateral components in accordance with applicable federal and state requirements. The DOT, Pipeline and Hazardous Materials Safety Administration (PHMSA) maintains the authority to regulate interstate carbon dioxide pipelines under the Hazardous Liquid Pipeline Act of 1979, and PHMSA regulates the design, construction, operation, maintenance, and spill response planning for regulated pipelines. All line pipe will be manufactured and mill tested in compliance with American Petroleum Institute (API) Specifications for Line Pipe.

Pipeline

Maintenance of the pipeline will include periodic visual inspections. Denbury will conduct routine pedestrian surveys, as necessary, in accordance with applicable regulatory requirements and Denbury's Operation and Maintenance Manual. Post-construction surveys will identify erosion areas, exposed pipe, possible leaks, damaged or non-functional permanent erosion control measures, and other concerns that could potentially affect the environment and operation of the facilities. To reduce the potential for metallurgical and corrosion of the pipeline, a project-specific plan will be developed.

Leak inspections and cathodic protection maintenance will be conducted in accordance with DOT requirements and Denbury's internal requirements. Pipeline markers and signs will be inspected and maintained or replaced, as necessary, to assure that the pipeline location at critical points is clearly identified.

Maintenance of the pipelines will include periodic vegetation mowing, as necessary and in accordance with the Denbury's policies, to allow for visual pipeline inspections. Active cropland will be allowed to revert to pre-construction use for the full width of the ROW. In non-cultivated uplands, the 50-foot-wide permanent ROW will be maintained in an

herbaceous or similar state to allow for visual inspection. In unsaturated wetlands, a 10-foot-wide corridor centered over the pipeline may be maintained in an herbaceous state, and trees within 15 feet of the pipelines that are greater than 15 feet in height may be selectively cut and removed from the ROW.

ROW maintenance activities are normally performed in late summer or early fall during the driest seasonal times of the year.

SECTION 1.0

Purpose and Need for the Proposed Action

1.1 Project Description

Leucadia Energy, LLC (Leucadia), teamed with Denbury Onshore, LLC (Denbury) will demonstrate advanced technologies that capture and sequester more than 1 million tons of carbon dioxide (CO_2) emissions at the Lake Charles cogeneration petroleum coke-to-chemicals (methanol) project (hereafter referred to as the Project) to be located near Lake Charles, Louisiana. Assuming the U.S. Department of Energy (DOE) funds the Project, compressed CO_2 will be transported through new and existing pipeline systems so that it can be used for enhanced oil recovery (EOR) in the Hastings oilfields in Texas.

As part of the Project, Denbury is proposing to construct, own, and operate an 11.6-mile CO_2 pipeline and associated ancillary equipment (hereafter Pipeline Lateral) to Denbury's and an affiliate's Green Pipeline for CO_2 transport to the Hastings oilfields in Texas (Figure 1-1). Denbury's and an affiliate's 24-inch Green Pipeline, to be completed in 2010, will be capable of transporting up to 800 million standard cubic feet per day (mmscf/d) of CO_2 between Donaldsonville, Louisiana and Alvin, Texas. The Pipeline Lateral will include a 20-inch outside diameter CO_2 pipeline (with a maximum allowable operating pressure of 2,200 pounds per square inch gauge [psig]), one valve, and one meter station (Figure 1-2). The pipeline route will parallel existing rights-of-way (ROWs) (transmission lines, roads, pipelines, railroads, and other linear features) to the extent practicable. The meter station will be located at the terminus of the Pipeline Lateral at the Green Pipeline, and the valve will be located about mid-way between the Leucadia Plant and the Green Pipeline, within the pipeline corridor.

Construction activities for the proposed Pipeline Lateral will require a temporary office and construction and pipeline storage yard of approximately 5 acres. The yard is anticipated to be located along a road strategic to the pipeline ROW. The initial scouting of potential project yards will be of previously developed commercial sites and other utilized non-residential locations.

Leucadia, teamed with Denbury, was one of the projects selected by the DOE to receive federal funding[2] under the American Recovery and Reinvestment Act for carbon capture and storage research and development. As part of Phase I of the Project, an Environmental Information Volume (EIV) must be prepared and submitted to DOE in order for DOE to fulfill its responsibilities under the National Environmental Policy Act of 1969 (NEPA). DOE is required to conform to the Council on Environmental Quality's regulations for Implementing the Procedural Provisions of the National Environmental Policy Act, 40 Code of Federal Regulations (CFR) Parts 1500 through 1508, and DOE Regulations for Implementation of NEPA (10 CFR Part 1021).

[2] The projects are cost-shared collaborations between the DOE and industry to increase investment in clean industrial technologies and sequestration projects.

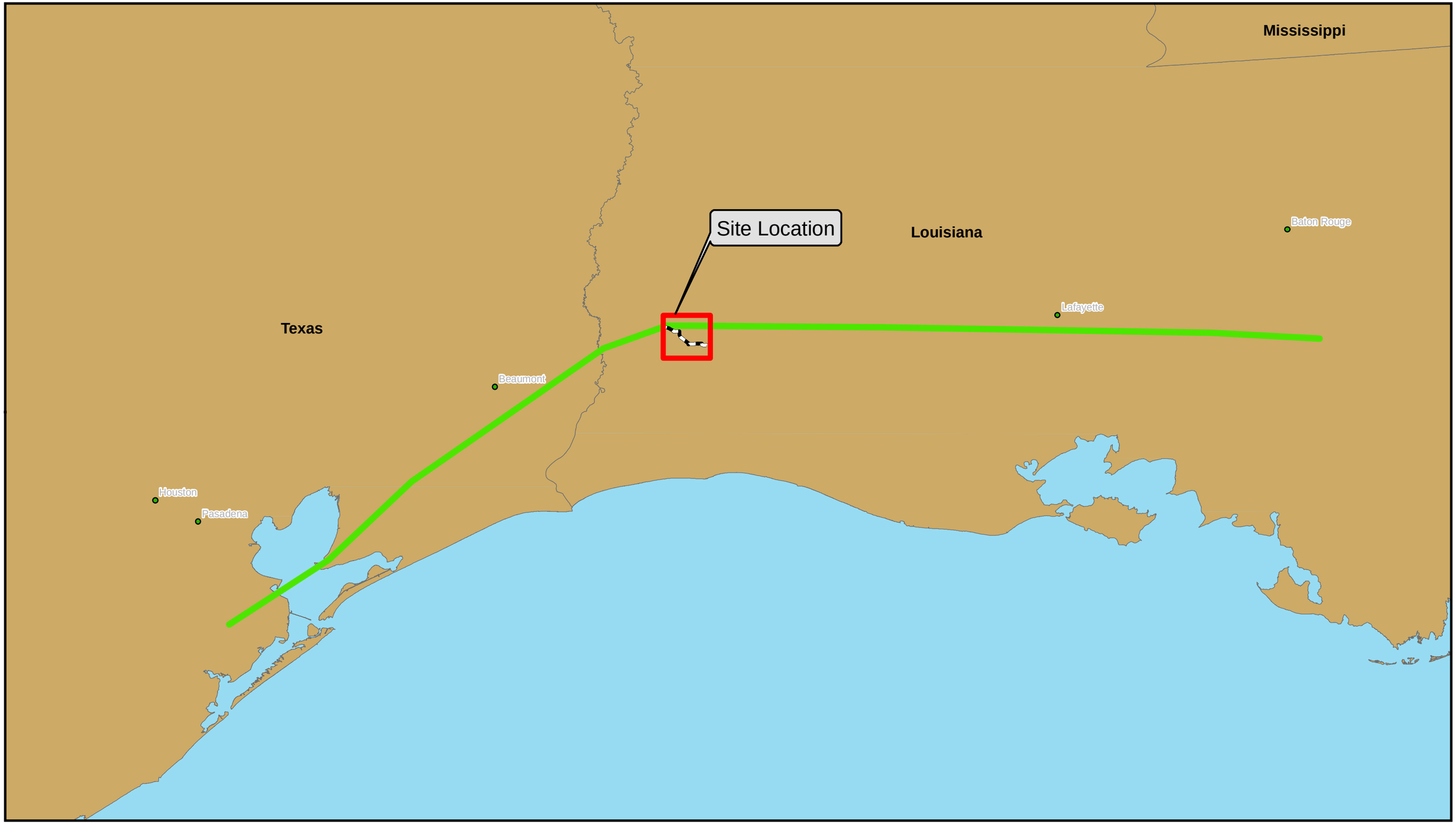
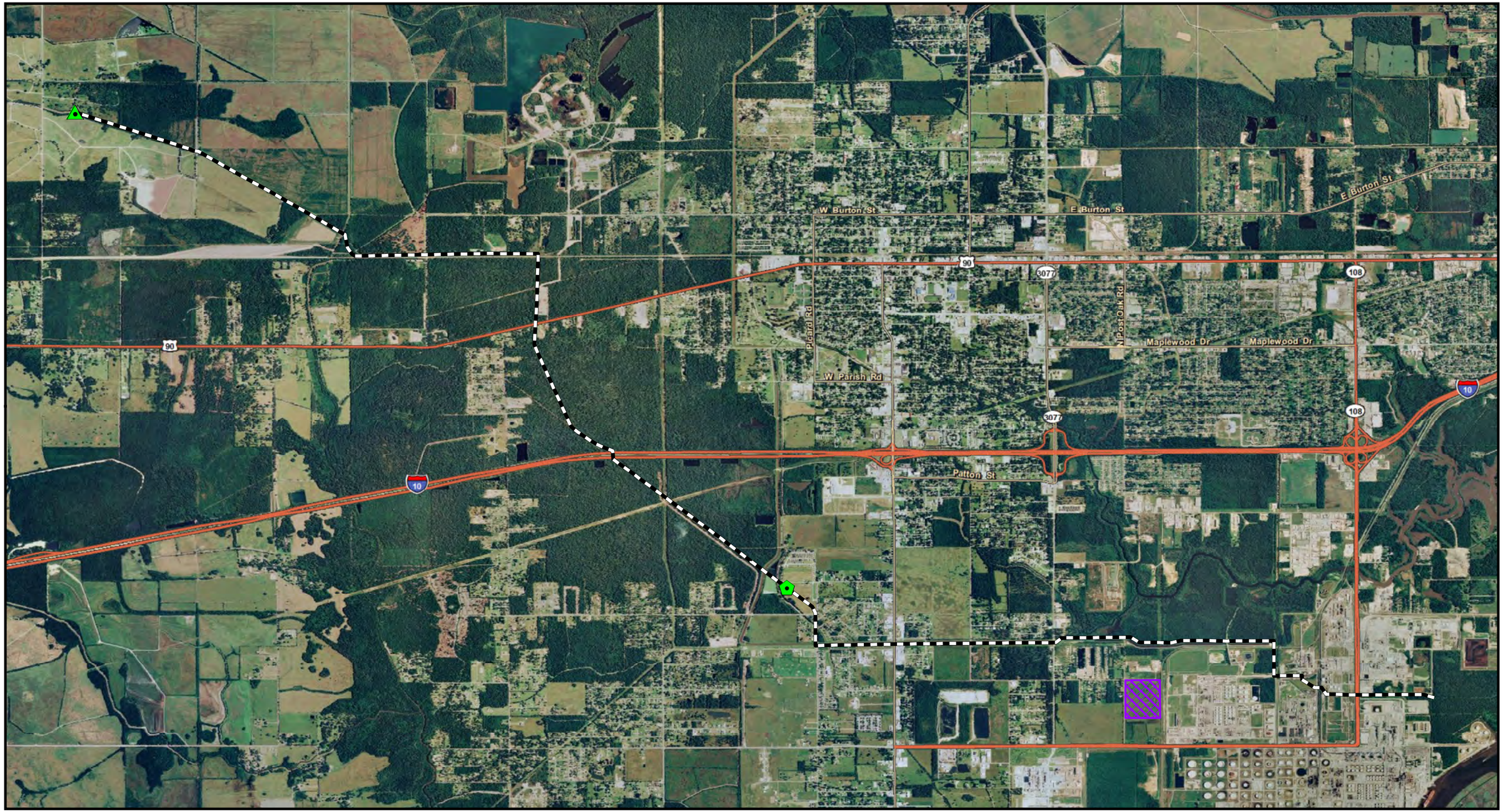


Figure 1-1
Project Location/Green Line Location
Proposed Denbury CO2 Pipeline
Calcasieu Parish, Louisiana

CH2MHILL

\\GALILEO\PROJ\DENBURY_LAKE_CHARLES\MAPFILES\SITE_LOCATION_GREENLINE.MXD EKLEIN 3/1/2010 12:12:54



Proposed Alignment
Proposed Meter Site
Proposed Valve Site
Proposed Contractor Yard
1 Mile Buffer

N

0 0.5 1 2

Miles

Figure 1-2
Valve and Meter Station Locations
Proposed Denbury CO2 Pipeline
Calcasieu Parish, Louisiana

CH2MHILL

\\GALILEO\PROJ\DENBURY_LAKE_CHARLES\MAPFILES\VALVE_METER.MXD EKLEIN 2/26/2010 15:01:31

This EIV is for the proposed Pipeline Lateral that will be constructed, owned, and operated by Denbury. This EIV is conceptual in scope with the effects and impacts of the proposed Pipeline Lateral on the environment and mitigation for those impacts. No field characterization was conducted for this effort.

1.2 Purpose and Need

The proposed Project involves an integrated carbon capture, transport, injection, and monitored sequestration program that will accelerate commercialization of large-scale CO_2 storage from industrial sources. The Project includes: 1) the capture of more than 1 million tons/year of CO_2 emissions generated at the Lake Charles cogeneration petroleum coke-to-chemicals (methanol) plant to be located near Lake Charles, Louisiana; 2) the transport of CO_2 through a new 11.6-mile CO_2 Pipeline Lateral to Denbury's and an affiliate's Green Pipeline for transport to the Hastings Field in Texas for injection into a depleted oil field for enhanced oil recovery; and 3) implementation of a comprehensive monitoring, verification, and accounting (MVA) program to confirm the sequestration of the injected CO_2 in Hastings Field south of Houston, Texas.

1.3 Project Schedule

A general schedule of the Pipeline Lateral is provided in Figure 1-3. The estimated overall project time frame for the design, permitting, and construction of the Pipeline Lateral is approximately 1.5 years. Construction of the Pipeline Lateral is expected to be completed by first quarter of 2013, with delivery of CO_2 from the Project source to commence by third quarter 2013. Once CO_2 is flowing, it will supplement and/or replace naturally occurring CO_2 taken from the Jackson Dome in Mississippi and used for CO_2 flooding.

Further evaluation of impacts to the environment, health, safety, and socioeconomics (including field studies and verifications) for the Pipeline Lateral will be evaluated in greater depth once funding is secured.

1.4 Resource Requirements and Technical Data

This section discusses the resource requirements and technical data on how the Pipeline Lateral would be constructed and operated.

1.4.1 Land Requirements

Construction of the Pipeline Lateral will affect a 62 landowners and 113 parcels of land (Appendix C) totaling approximately 192.4 acres of land, including the pipeline construction ROW, pipe and storage yards, and the metering and valve facilities (Table 1-1). (Additional temporary workspaces have not been identified at this time.) Both temporary and permanent land disturbance will occur during construction and operation of the Pipeline Lateral. Following construction, approximately 77.4 acres of land consisting of the temporary pipeline construction ROW and pipe and storage yards will be restored and allowed to revert to previous conditions and use. The temporary and permanent land requirements for the project components are described in the following sections.

FIGURE 1-3:
DENBURY ONSHORE, LLC
LAKE CHARLES CO2 PIPELINE FROM THE LEUCADIA PLANT TO THE GREEN PIPELINE

ID	ID	Task Name
1	**1**	**PHASE 1**
2	2	**1.1 Project Kickoff**
3	3	1.1.1 Establish Project Criteria
4	**4**	**PHASE 2**
5	**5**	**SUBPHASE 2a: Design**
6	**6**	**2a.1 Engineering**
7	7	2a.1.1 Route Finalization
8	8	2a.1.2 Hydraulic Calculations
9	9	2a.1.3 Prepare System PFD and P&ID's
10	10	2a.1.4 Determine Crossing permit Requirements
11	11	2a.1.5 Development Material & Equipment Specifcations
12	12	2a.1.6 Prepare Alignment Drawings
13	13	2a.1.7 Prepare Landowner Plat Maps
14	14	2a.1.8 Prepare Permit Exhibits
15	15	2a.1.9 Prepare PipelineConstruction Details
16	16	2a.1.10 Design & Drawings for Facilities
17	17	2a.1.11 Confirm/Develop Construction Specifications
18	18	2a.1.12 Cathodic Protection Design and Details
19	**19**	**2a.2 Survey**
20	20	2a.2.1 Civil and Easement Survey
21	21	2a.2.2 Pre-Construction Staking
22	**22**	**2a.3 Environmental**
23	23	2a.3.1 Update Permit Requirements
24	24	2a.3.2 Agency Meetings and Consultations
25	25	2a.3.3 Perform Ecological and Cultural Resources Field Surveys
26	26	2a.3.4 Prepare Permit Applications
27	27	2a.3.5 Mitigation Plan Development
28	28	2a.3.6 Permit Acquisition
29	**29**	**2a.4 Right of Way - Land**
30	30	2a.4.1 Update Landowner Line List
31	31	2a.4.2 Obtain Access Permission
32	32	2a.4.3 Perform Title Work
33	33	2a.4.4 Right of Way & Site Acquistion
34	34	2a.4.5 Conduct Landowner Condemnation(s)
35	35	2a.4.6 Travel
36	**36**	**2a.5 Procurement**
37	37	2a.5.1 Procure Pipe & Long Lead Material Items
38	38	2a.5.2 Procure Misc. Materials
39	39	2a.5.3 Receive Material & Equipment
40	40	2a.5.4 Cathodic Protection Materials - Subcontract
41	**41**	**2a.6 Inspection**
45	**45**	**2a.7 Construction**
46	46	2a.7.1 Develop Bid Packages
47	47	2a.7.2 Bid & Award Construction
48	**48**	**SUBPHASE 2b: Construction**
49	**49**	**2b.1 Procurement**
50	50	2b.1.1 Procure Misc. Materials, Continued from 2a.4
51	51	2b.1.2 Receive Material & Equipment, Continued from 2a.4
52	**52**	**2b.2 Survey**
53	53	2b.2.1 Complete Pipeline As-Built Survey
54	**54**	**2b.3 Inspection**
66	**66**	**2b.4 Pipeline Construction**
67	67	2b.4.1 ROW Clearing
68	68	2b.4.2 Trenching & HDDs
69	69	2b.4.3 Pipe Stringing
70	70	2b.4.4 Welding & Tie-ins
71	71	2b.4.5 Lower In
72	72	2b.4.6 X-ray and Inspection
73	73	2b.4.7 Backfill
74	74	2b.4.8 Fill and clean-up
75	75	2b.4.9 Hydrotest
76	76	2b.4.10 Cathodic Protection System Installation - Subcontract
77	**77**	**2b.5 Facility Construction**
78	78	2b.5.1 Site Clearing
79	79	2b.5.2 Civil & Foundation Work
80	80	2b.5.3 Site fence installation
81	81	2b.5.4 Fabrication, welding, installation
82	82	2b.5.5 Instrumentation & Electrical install
83	83	2b.5.6 X-ray and Inspection
84	**84**	**SUBPHASE 2c: Operation**
85	**85**	**2c.1 Inspection**
89	89	2c.1 ROW Damage Settlement
90	90	2c.2 Complete As-Built Drawings
91	91	2c.3 PPL & Equip Start Up & Commissioning
92	92	2c.4 Complete Job Books

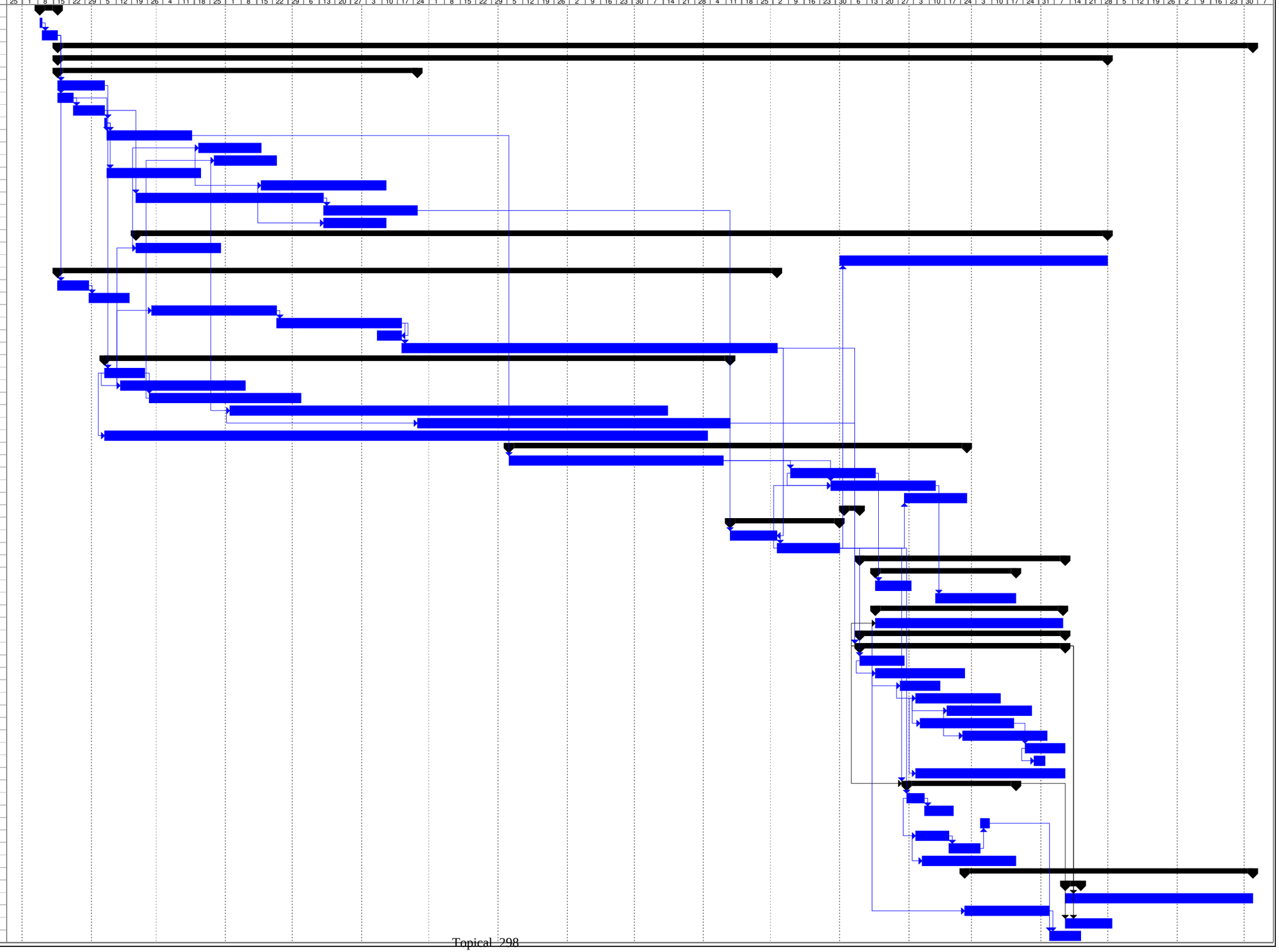


TABLE 1-1
Summary of Land Requirements for Pipeline Facilities
Denbury Lake Charles, Louisiana, EIV

Project Component	Parish, State	Length (miles)/ Number of Sites	Temporary Construction ROW and Staging Sites (acres)[a]	Permanent ROW (acres)[b]
Right-of-way for 20-inch diameter CO_2 pipeline	Calcasieu Parish, Louisiana	11.6	72.3	114.9
Additional Temporary Workspace	Calcasieu Parish, Louisiana	Not yet determined	Not yet determined	Not yet determined
Valve and Meter Station	Calcasieu Parish, Louisiana	--	0.1	0.1
Pipe Storage Yards and Contractor Yards[c]	Calcasieu Parish, Louisiana	--	5	0
TOTAL			**77.4**	**115.0**

[a] Construction ROW is based on temporary ROW width of 95 feet and includes permanent ROW.

[b] Permanent ROW is based on new permanent ROW width of 50 feet.

[c] Assumes existing previously used commercial/industrial sites.

1.4.1.1 Pipeline Facilities

The land requirements associated with the Pipeline Lateral are summarized in Table 1-1 and described in the following sections. Appendix B provides route maps for the proposed 11.6-mile lateral.

Right-of-Way

Construction of the 20-inch CO_2 Pipeline Lateral will generally require a 95-foot-wide construction ROW. Denbury proposes to parallel existing pipeline or utility corridors for over 90% of the length of the pipeline. This collocation will be adjacent to existing pipelines, transmission lines, railroads, roads, and canals (Table 1-2).

TABLE 1-2
ROW Summary
Denbury Lake Charles, Louisiana, EIV

ROW Type	Length Paralleled (feet)	Percentage of Total Route
Pipeline	11,690	19%
Power	5,950	10%
Canal	15,790	26%
RR	7,310	12%
Road	11,740	19%
Other	3,490	6%
	55,970	91%

For the portion of the Pipeline Lateral paralleling existing foreign pipelines or utility ROWs, Denbury's new permanent ROW will be 50 feet wide abutting the adjacent existing ROW. The additional 45 feet of temporary construction ROW will be located on the opposite side from the existing utility corridor. A figure presenting a typical cross section of the pipeline construction ROW for this collocated portion of the proposed pipeline route is provided in Appendix A.

For the portion of the pipeline ROW that will not be adjacent to an existing foreign pipeline or utility corridor, the temporary construction ROW will be 95 feet wide and the new permanent ROW will be 50 feet wide. A figure presenting a typical cross section of the pipeline construction ROW for the non-collocated portions of the proposed pipeline route is provided in Appendix A.

The total acreage of land that will be affected by pipeline construction (not including additional temporary workspace and off ROW contractor work sites) is 187.2 acres, of which 114.9 acres are new permanent ROW and 72.3 acres are temporary ROW.

Additional Temporary Workspace

Additional temporary workspace (ATWS) outside the 95-foot-wide temporary pipeline construction corridor will typically be required at the following locations:

- Wetland and water body crossing staging areas
- Public road crossings
- Railroad crossings
- Areas where special construction techniques (e.g., horizontal directional drill [HDD]) will be used
- Tie-ins with existing pipeline facilities
- Pipeline crossings
- Areas where storage of stripped topsoil is needed

ATWS needed for the Pipeline Lateral have not been identified at this time; however, they will be identified during the project design phase. ATWS will be restored and allowed to revert to pre-existing conditions following construction activities, so there will be no permanent impacts to these areas. The specific location of temporary workspaces will be depicted on alignment sheets once available for the Lateral Pipeline.

1.4.1.2 Pipe Storage Yards and Contractor Yards

Denbury will require additional space for pipe storage and contractor staging activities. Pipe storage and contractor yards needed for the Pipeline Lateral will total approximately 5 acres, all of which will be temporarily impacted by construction. Table 1-1 details the land requirements for the proposed pipe storage and contractor yards.

1.4.1.3 Aboveground Facilities

The land requirements associated with the Pipeline Lateral aboveground facilities are summarized in Table 1-1. Denbury will construct, own, and operate a meter station adjacent to the tie-in of the Lateral Project with Denbury's and an affiliate's Green Pipeline. The meter station will require an approximate 75-foot by 50-foot permanent site adjacent to the Lateral Project.

Denbury will construct, own and operate a valve as part of the Lateral Project. The valve will be located about mid-way along the Pipeline Lateral corridor, within the permanent ROW boundaries.

1.4.1.4 Construction Access

Access to the temporary and permanent pipeline ROW and associated facilities will be through existing public and private roads to the extent practical. Some of the existing access roads may require modifications or improvements to accommodate the weight and dimensions of construction equipment and materials. Denbury would construct new access roads for permanent access to facilities, as necessary, where an existing road does not exist; a formal Road Use Agreement will be entered into between Denbury and the affected landowner. The specific location of access roads will be determined as Denbury continues to refine the details of the Lateral Project.

1.4.1.5 Construction

Pipeline

Standard pipeline construction proceeds in the manner of an outdoor assembly line composed of specific activities that make up the linear construction sequence. These operations collectively include survey and staking of the ROW, clearing and grading, trenching, pipeline stringing and bending, welding and coating, lowering-in and backfilling, hydrostatic testing, and cleanup and restoration.

Construction of the pipeline would generally be as follows. Clearing and grading would be conducted in a single pass for the pipeline within a given spread. Next, the pipeline would be constructed from stringing through backfill and rough cleanup. Final cleanup and restoration would then occur.

Survey and Staking

Before construction, survey crews would survey and stake the centerline and exterior boundaries of the construction ROW. Drainage centerlines and elevations, highway and railroad crossings, and any temporary extra work spaces (e.g., laydown areas or at stream crossings) would also be staked. The exterior boundary stakes would define the limit of approved disturbance areas and would be maintained throughout the construction period. Utility lines would be located and marked to prevent accidental damage during pipeline construction. The Louisiana "One Call" system would be used to identify utility locations. If there is a question about utility locations, other methods, such as field instrumentation and test pits would be used to verify their locations.

Clearing and Grading

Clearing crews would clear the ROW of obstacles such as trees, brush, and logs. Trees to be saved would be marked before clearing begins. Timber would be stacked along the edges of the ROW or disposed of in accordance with landowner agreements or as specified by

Denbury's construction inspectors. Brush maybe piled at the edge of the ROW to provide filter strips or wildlife habitat. Trees and brush not used for other purposes would be disposed of in accordance with applicable state and local regulations and landowner agreements by chipping, burning, or transported to an approved landfill. Where necessary, fences would be cut and braced along the ROW and temporary gates would be installed to control livestock and limit public access. The ROW would then be graded where necessary to allow access and safe operation of construction equipment. Where applicable (e.g., residential and agricultural lands), conserved topsoil would be stockpiled along one side of the ROW, allowing the other side to be used for access, material transport, and pipe assembly. Construction crews would install temporary erosion control measures immediately after initial disturbance of the soil.

Trenching

A rotary trenching machine, track-mounted backhoe, or similar equipment would be used to excavate trenches to sufficient depths to provide a minimum 3-foot depth of cover over the pipeline. Depending on soil conditions, the top of the trenches for the pipeline would typically be 12 to 14 feet wide and the bottom of the trenches would be typically be approximately 5 to 6 feet wide. In unstable and saturated soils, the trenches could be wider. Spoil material excavated during trenching operations would be temporarily piled to one side of the ROW adjacent to the trench. In agricultural areas, where topsoil stripping is required, the topsoil and subsoil would be stored in separate windrows or piles on the construction ROW and would not be allowed to mix. Where the pipeline route is adjacent to an existing pipeline, the subsoil spoil would be placed on the same side of the trench as, but not directly over the existing pipeline, to keep working equipment off the operating pipeline. Written consent of the adjacent pipeline owner/operator will be obtained for use of its easement during construction.

Stringing and Bending

Individual joints or double joints of pipe would be strung along the ROW either prior to trenching or adjacent to the excavated trench and arranged so that they would be accessible to construction personnel. This operation typically involves specially designed stringing trucks to deliver pipe from the pipe yard to the ROW. Small portable cranes and/or side-boom tractors would be used to unload the stringing trucks and place the pipe along the trench line. A mechanical pipe-bending machine would bend individual joints of pipe to the desired angle to accommodate changes in the natural ground contour or pipeline alignment. In certain areas, prefabricated fittings would be used where field bending is not practicable.

Welding and Coating

After stringing and bending are complete, pipe sections would be placed on temporary supports and the ends would be aligned and welded together. To ensure that the assembled pipe meets or exceeds the design strength requirements, inspection crews would inspect all welds, both visually and radiographically (i.e., x-ray), and would make any necessary repairs. Pipe is typically delivered with a factory coating of fusion-bonded epoxy or similar material. Following weld inspection, the previously uncoated ends of the pipe at the welds would be epoxy coated. The coating on the completed pipe section would be inspected and any damaged areas repaired.

Lowering-in and Backfilling

After welding and coating are completed, the pipe would be lowered into the trench by side-boom tractors. Bladed equipment or a specially designed backfilling machine would be used to backfill the trench.

Hydrostatic Testing

After backfilling, construction personnel would hydrostatically test the pipelines in accordance with U.S. Department of Transportation (DOT) regulations to ensure that the system is capable of operating at the designed pressure. The testing process involves filling a segment of the pipeline with water and maintaining a prescribed pressure for a specified amount of time. If a leak or break in the line were to occur during the testing, the pipe would be repaired and retested to ensure that section of the pipe meets DOT specifications. Construction crews would also conduct hydrostatic "pre-tests" on HDD sections prior to installing them. Hydrostatic test water would be withdrawn from readily available water sources along the pipeline route or from municipal sources and would be discharged onsite in a vegetated upland area or offsite at a permitted wastewater treatment facility. Test water will be transferred for re-use between test sections whenever feasible. Hydrostatic test water withdrawals and discharges would be conducted in accordance with the applicable permit conditions and procedures.

Cleanup

After the pipeline has been installed, backfilled, and successfully tested, the ROW, temporary extra workspaces, and other disturbed areas would be re-graded and restored as nearly as practicable to the original contour of the land. Topsoil would be re-spread over areas from which it was originally removed and permanent soil stabilization (e.g., installation of permanent erosion controls) efforts begin.

Construction debris would be disposed of and fences, gates, driveways, and roads disturbed by the pipeline construction would be restored. The restored construction ROW would be revegetated in accordance with plans and procedures, other permit requirements and site-specific landowner requests.

Special Pipeline Construction Techniques

Wetland Crossings

Denbury would construct its pipelines across wetlands in accordance with plans and procedures, which would include measures designed to minimize construction-related impacts.

At certain locations, wetlands would be crossed by the HDD method in conjunction with associated water body crossings. For the remaining wetlands, Denbury proposes to use three types of wetland crossing methods as described below.

Wetland Method 1 would be used in unsaturated wetlands where soils are dry enough at the time of construction to support equipment. Construction would be similar to the upland construction method described above but would require segregation of topsoil over the trench line. Stumps would be removed only from the trench line unless additional stump removal is required to provide safe working conditions.

Wetland Method 2 is consistent with conventional wetland construction techniques used to cross wetlands with saturated soils or soils otherwise unable to support construction

equipment. In such areas, it would be necessary to stabilize the ROW or use wide-tracked/low ground weight equipment. During clearing, construction crews would stabilize the ROW using timber riprap (corduroy roads) or fabricated timber mats. Construction would attempt to use no more than two layers of timber for this purpose. Dirt, pulled tree stumps or brush riprap would not be used to stabilize the travel lane.

Wetland Method 3 would involve push-pull construction. This method would be used in large wetland areas where sufficient water is present for floating the pipeline in the trench, and grade elevations over the length of the push-pull area would not require damming to maintain adequate water levels for floatation of the pipe.

When using the push-pull construction technique, clearing within the wetlands would be limited to only that necessary to install the pipeline. Trees and brush would be cut at ground level by hand with low ground-weight equipment or with equipment supported by timber mats. Grading in inundated wetlands would be held to a minimum. Amphibious excavators (pontoon-mounted backhoes) or tracked backhoes (supported by fabricated timber work mats of floats) would be used for trenching.

Water Body Crossings

Typically, water body crossings will be made using one of the following methods:

Crossing Method 1 (Wet Crossing – typically less than 50 feet). This method is applicable to small perennial streams (less than 50 feet wide), field and roadside ditches, and intermittent streams. The stream should be small enough to enable the equipment to be worked from the banks. A backhoe will open a temporary trench within the flowing stream; the pipe will be placed and the trench will be backfilled as quickly as possible to minimize impacts.

Crossing Method 2 (Dry Crossing – typically less than 30 feet). This method is applicable to perennial streams (with flow) less than 30 feet in width with downstream water users or with listed species present in the stream. Stream flow may be channeled into one or multiple flume pipes to convey water across the trench and maintain downstream flow, or alternatively, a dam-and-pump arrangement may be used to convey the stream water around the construction area. The trench will be excavated from under the flume pipe, the pipeline will be threaded under the flume, the trench will be backfilled, and the flume pipe will be removed to restore natural downstream flow.

Crossing Method 3 (Wet Crossing – typically greater than 50 feet). This method is applicable to perennial streams greater than 50 feet in width that have not been designated to be directionally drilled. The trench will be opened within the flowing stream using a backhoe or dragline, and the pipe will be pulled or floated into place. Flow in these streams will most likely be sufficient to inundate the trench and allow for a natural downstream flow. Sufficient downstream flow should be maintained during construction. Following installation of the pipe, the trench will be backfilled.

Crossing Method 4 (HDD). HDD methodology will be used in specially designated stream crossings. HDD involves using specialized equipment to install pipelines beneath wetlands or waterways, which potentially minimizes environmental impacts. However, a potential exists for environmental impacts, such as turbidity and deposition of dredged material, which can occur from the discharge of drilling muds in the unlikely event of a drilling failure or interruption in construction. These potential risks are typically mitigated fully

with an HDD failure contingency plan and/or drilling mud disposal plan. The applicability of this method is subject to a variety of site-specific physical and engineering factors. Therefore, this method is applicable to water bodies with conditions determined to be suitable and after extensive assessment for both environmental and engineering considerations. The potential risks are significantly minimized when compared to the benefits associated with a successful HDD. These benefits are discussed in Section 4.

Horizontal Directional Drill

Denbury proposes to install the pipeline at selected water bodies using the HDD method. All stages of HDD involve circulating drilling fluid (bentonite slurry, or drilling muds) from equipment on the surface, through a drill pipe to a downhole bit or reamer, and back to the surface through the annular space between the pipe and the wall of the hole. Drilling fluid returns collected at the entry and exit points are stored in a steel tank and processed through a solids control system that removes spoil from the drilling fluid, allowing the fluid to be reused. The basic method used by the solids control system is mechanical separation using shakers, desanders, and desilters. Excess spoil and drilling fluid are transported to, and disposed of, at an approved disposal site.

Under ideal circumstances, drilling fluid exhausted at the bit or reamer will flow back to the entry or exit point through the drilled annulus. Under actual conditions, this happens inconsistently. Drilling fluid expended downhole will flow in the path of least resistance. In the drilled annulus, this path may be an existing fracture or fissure in the soil. This can result in dispersal of drilling fluid into the surrounding soils (lost circulation) or discharge to the surface at some random location (inadvertent returns). Lost circulation and inadvertent returns are common occurrences in pipeline installation by HDD and do not prevent completion. However, if drilling fluid inadvertently returns to the surface at a location on a waterway's banks or within a waterway, adverse environmental impacts would occur. Drilling parameters may be adjusted to maximize circulation and minimize the risk of inadvertent returns. However, the possibility of lost circulation and inadvertent returns cannot be eliminated.

The major component of drilling fluid used in HDD pipeline installation is fresh water obtained at the crossing location. In order for water to perform the required functions, it is generally necessary to modify its properties by adding a viscosifier. The viscosifier used almost exclusively in HDD drilling fluids is naturally occurring bentonite clay typically mined by "open pit" methods from locations in Wyoming and South Dakota. Bentonite is soft clay, formed by the weathering of volcanic ash, with the unique characteristic of swelling to several times its original volume when in contact with water. It is not a hazardous material as defined by the U.S. Environmental Protection Agency's (EPA) characteristics of ignitability, corrosivity, reactivity, or commercial chemicals. It is also used to seal earth structures such as ponds or dams and as a suspending component in livestock feeds.

Environmental impacts associated with HDD can often be minimized most effectively by completing HDD operations in the shortest possible amount of time. Specific steps may be taken by the contractor to maintain or restore circulation of drilling fluids; specifically, by maintaining the size of the hole and utilizing the correct pressure and drill rates, along with keeping the drill path clean and unobstructed.

If inadvertent surface returns occur on dry land, it will be the responsibility of the HDD contractor to contain, collect, and restore the disturbed area in accordance with the

requirements of Denbury's construction specifications. Should inadvertent returns occur within a waterway, Denbury will notify appropriate parties and evaluate the potential impact of the release on a site-specific basis in order to determine an appropriate course of action. In general, Denbury does not believe that it is environmentally beneficial to try to contain and collect drilling fluid returns in a waterway. HDD drilling fluids are nontoxic and discharge of the amounts normally associated with inadvertent returns does not pose a threat to public health and safety. Placement of containment structures and attempts to collect drilling fluid within a waterway often result in greater environmental impact than simply allowing the drilling fluid returns to dissipate naturally.

Roads and Railroads

Road and railroad crossings would be constructed in accordance with applicable state and local regulations and permits, which will be obtained from the appropriate entities, or in the case of private land, approval of the landowner. Denbury would use construction techniques designed to minimize disruptions to traffic flow patterns, and construction across existing highways and railroads would not significantly disrupt traffic flow.

With the exception of road crossings that would occur within the HDD paths for water body crossings, Denbury would install the pipeline under paved roads and some unpaved roads by boring beneath them. The bore method requires the excavation of a bore pit on either side of the road or railroad to accommodate the boring equipment and the pipe to be installed. A large-diameter auger would be used to excavate a hole between the two bore pits. Once the hole is complete, a section of the pipe would be pulled back to complete the crossing. Subject to agency/landowner approval, the majority of unpaved roads would be crossed using the traditional open-cut method. Steel plates would be available onsite to cover the open area to allow passage by emergency vehicles. Access would be maintained except for the limited periods required for installing the pipeline. Open-cut road crossings would be construction in one day. Steel plates would be used until fill is properly compacted.

Foreign Pipeline and Electric Transmission Line Crossings

In addition to excavation and boring equipment, crossing other pipelines would require some hand digging beneath the foreign pipeline(s) to ensure no damage to the pipe. Additional temporary workspaces would be used at these crossings to accommodate storage of the increased amounts of spoil resulting from the need to excavate a deeper trench, and to prevent spoil and construction equipment from being placed over the existing pipelines. The general practice would be to install the new pipeline under the existing foreign pipeline(s) with an agreed upon separation distance that would meet or exceed applicable DOT requirements.

Where the proposed pipelines would cross electric transmission lines, Denbury would adhere to specific criteria regarding minimum clearances between the transmission line and pipeline construction equipment. Also, pipelines being constructed parallel to, crossing, or in proximity of electric power transmission lines would be subject to electrostatic and electromagnetic induced voltages and currents. Therefore, additional protection would need to be used to prevent damage due to fault currents and induced voltages. Accordingly, all equipment operating near transmission lines would be properly grounded and insulated.

Agricultural Areas

In actively cultivated agricultural areas, up to 12 inches of topsoil would be stripped from the trench line and spoil storage area, or as based on landowner agreements. The topsoil would be temporarily stockpiled separate from the excavated subsoil within the construction ROW. Denbury would work with landowners prior to construction to identify irrigation pipelines or drain tiles within the construction ROW and would develop irrigation crossing standards that are satisfactory to the affected landowners. Any irrigation pipeline systems or drain tiles damaged during construction would be repaired to the landowner's specifications or to pre-construction conditions.

Residential and Commercial Areas

Denbury would implement the measures described below when working in residential areas and would coordinate with the appropriate landowners for the required site-specific mitigation measures.

Homeowners or business owners would be notified in advance of construction activities and any scheduled disruptions of utilities. To minimize impacts on residences, residential areas, and commercial properties, Denbury may use specialized construction methods such as stovepipe and/or drag section construction.

Disruptions would be minimized to the extent practicable. If project-related work activity in a residential or commercial area would disrupt ingress and egress to the affected property, Denbury would attempt to provide alternative access to the property. Attempts would be made to leave any mature trees and landscaping intact within the construction work areas unless the trees and landscaping interfere with installation techniques or present unsafe working conditions. Topsoil segregation would be performed over the trench line only.

Cleanup would occur quickly following construction activities. Sidewalks, driveways, and roads would be restored as soon as practicable, and fences, mailboxes, and other structures that were removed would be restored. After cleanup, a Denbury representative would contact landowners to ensure that conditions of all landowner agreements have been met.

1.4.1.6 Aboveground Facilities

During installation of aboveground facilities, construction activities and storage of construction materials and equipment would be confined to the pipeline construction ROW or approved temporary workspace areas. Denbury would implement plans and procedures and would construct the aboveground facilities in accordance with applicable permit conditions, regulations, and landowner agreements.

Workforce

Construction of the new facilities will be accomplished using one pipeline spread with a work force of approximately 450 to 500 people. The prime contractor may select secondary contractors for specialty installation of the pipeline, such as boring and directional drilling.

Once construction of the proposed components is completed, Denbury anticipates that it may hire one new employee who would be responsible for operation and maintenance of the new facilities. Additional information regarding construction and permanent workforce requirements is included in Section 3.10 Socioeconomics.

Operation and Maintenance

Denbury will operate and maintain the Pipeline Lateral components in accordance with applicable federal and state requirements. The DOT, Pipeline and Hazardous Materials Safety Administration (PHMSA) maintains the authority to regulate interstate carbon dioxide pipelines under the Hazardous Liquid Pipeline Act of 1979, and PHMSA regulates the design, construction, operation, maintenance, and spill response planning for regulated pipelines. All line pipe will be manufactured and mill tested in compliance with American Petroleum Institute (API) Specifications for Line Pipe.

Pipeline

Maintenance of the pipeline will include periodic visual inspections. Denbury will conduct routine pedestrian surveys, as necessary, in accordance with applicable regulatory requirements and Denbury's Operation and Maintenance Manual. Post-construction surveys will identify erosion areas, exposed pipe, possible leaks, damaged or non-functional permanent erosion control measures, and other concerns that could potentially affect the environment and operation of the facilities.

Leak inspections and cathodic protection maintenance will be conducted in accordance with DOT requirements and Denbury's internal requirements. Pipeline markers and signs will be inspected and maintained or replaced, as necessary, to assure that the pipeline location at critical points is clearly identified.

Maintenance of the pipelines will include periodic vegetation mowing, as necessary and in accordance with the Denbury's policies, to allow for visual pipeline inspections. Active cropland will be allowed to revert to pre-construction use for the full width of the ROW. In non-cultivated uplands, the 50-foot-wide permanent ROW will be maintained in an herbaceous or similar state to allow for visual inspection. In unsaturated wetlands, a 10-foot-wide corridor centered over the pipeline may be maintained in an herbaceous state, and trees within 15 feet of the pipelines that are greater than 15 feet in height may be selectively cut and removed from the ROW.

ROW maintenance activities are normally performed in late summer or early fall during the driest seasonal times of the year.

Aboveground Facilities

Denbury will perform operation and maintenance activities (including calibration, inspection, and scheduled and routine maintenance) on the new meter station and scraper/receiver equipment regularly. Operational testing will be performed on safety equipment to ensure proper function, and problems will be corrected immediately.

1.4.1.7 Construction Environmental Inspection and Compliance

Denbury is committed to constructing and operating the proposed Pipeline Lateral in a manner that will minimize environmental impacts in compliance with applicable permits and approvals. Denbury will develop project specific environmental plans and procedures that describe the environmental requirements and/or permit conditions that will be incorporated into specifications and drawings issued with the construction bid documents. This will assist prospective contractors in being aware of the environmental requirements that apply to the Pipeline Lateral. The construction contractor will be provided with copies of each of these environmental plans, procedures, permits and documents.

Prior to construction, Denbury will conduct environmental training for company and contractor supervisory personnel to familiarize them with the environmental requirements pertaining to the Pipeline Lateral. The training will cover environmental documents such as the Pipeline Lateral Plan and Procedures, Storm Water Pollution Prevention Plan (SWPPP)/ Spill Prevention, Control, and Countermeasures (SPCC) Plan, Unanticipated Discoveries Plan, Contaminated Sediments Plan, other project-specific conditions contained in applicable federal, state, and local permits and approvals, and any other project-specific mitigation plans, if applicable. In addition, Denbury will also provide group training to all construction personnel prior to beginning construction activities to make them aware of environmental requirements. Once construction is underway, Denbury's Environmental Inspectors (see below) will provide periodic follow-up training as necessary and for all newly-assigned personnel.

Denbury will assign full-time Environmental Inspectors to the project to monitor environmental compliance. The Environmental Inspector will have peer status with other inspectors and will report directly to Denbury's Environmental Project Manager. The Environmental Inspectors will be present throughout construction and restoration of pipeline and aboveground facilities and will have the authority to enforce permit conditions. The Environmental Inspector's roles and responsibilities will be described in Denbury's Implementation Plan. Briefly, he or she will be responsible for monitoring and documenting compliance with the Project plans and mitigation measures required by permits, certificates, and other environmental approvals as outlined above. The Environmental Inspectors will be authorized to issue stop-activity orders and to require corrective actions to maintain environmental compliance. In addition, the Environmental Inspectors will act as a liaison between Denbury and field representatives of environmental regulatory agencies that may visit the project during construction.

Denbury will be responsible for the implementation of environmental requirements during construction of the proposed facilities. If, notwithstanding Denbury's best intentions and efforts, a contractor does not comply with environmental requirements during construction, Denbury will, upon discovery, direct the contractor to comply. If necessary, Denbury will issue a stop-work order for that activity until the non-compliance is corrected. Where applicable, permitting agencies will be notified as required and remedial measures implemented. Where warranted, Denbury will take appropriate disciplinary action.

1.5 Interagency Cooperation

All interagency cooperation will be conducted with DOE acting as the lead agency. Scoping letters will be mailed to federal, state, and local agencies; tribal organizations; and residents in the immediate vicinity of the proposed pipeline lateral. The scoping letters will describe the Proposed Action and requested assistance in identifying potential issues that should be a part of the NEPA review. Comments received as part of the interagency cooperation will be incorporated into future NEPA review documentation.

SECTION 2.0

Alternatives Including the Proposed Action

This section discusses the proposed action and the alternatives to the proposed action that may be considered for the transport and sequestration of CO_2 in the Lake Charles, Louisiana area. This EIV is conceptual in scope in determining the effects and impacts of the proposed action on the environment and mitigation of those impacts. No field characterization was conducted for this effort.

Further evaluation of impacts to the environment, health, safety, and socioeconomics (including field studies and verifications) for the Pipeline Lateral will be evaluated in greater depth once funding is secured.

2.1 Proposed Action (assuming DOE funding)

Leucadia, teamed with Denbury will demonstrate advanced technologies that capture more than 1 million tons/year of CO_2 emissions at the Lake Charles cogeneration petroleum coke-to-chemicals (methanol) project (hereafter Project) to be located near Lake Charles, Louisiana. Assuming DOE funds the Project, compressed CO_2 will be transported through new and existing pipeline systems so that it can be used for EOR in the Hastings oilfields in Texas.

As part of the Project, Denbury is proposing to construct, own, and operate an 11.6-mile CO_2 pipeline and associated ancillary equipment that will transport the CO_2 from Leucadia's Plant to Denbury's and an affiliate's Green Pipeline for transport to the Hastings Field in Texas (Figure 2-1). The Pipeline Lateral will include a 20-inch outside diameter CO_2 pipeline, one valve, and one meter station. The Pipeline Lateral would be located in Calcasieu Parish, Louisiana, near the city of Lake Charles.

The proposed action would include approximately 11.6miles of 50-foot wide permanent pipeline ROW. In addition, up to 45 feet of temporary or construction ROW would be required for pipeline installation. Temporary access roads and ATWS would be constructed along the proposed pipeline ROW as required. Construction of the Pipeline Lateral is expected to be completed by September 2012, with delivery of CO_2 from the Lake Charles carbon capture and sequestration (CCS) project industrial source to commence by third quarter 2013.

Much of the Pipeline Lateral route will follow established utility corridors and other linear easements. Assuming the proposed action is the preferred alternative, Sections 3 and 4 of this EIV present the current environmental conditions and environmental consequences of the proposed action as determined through a conceptual design desktop study.

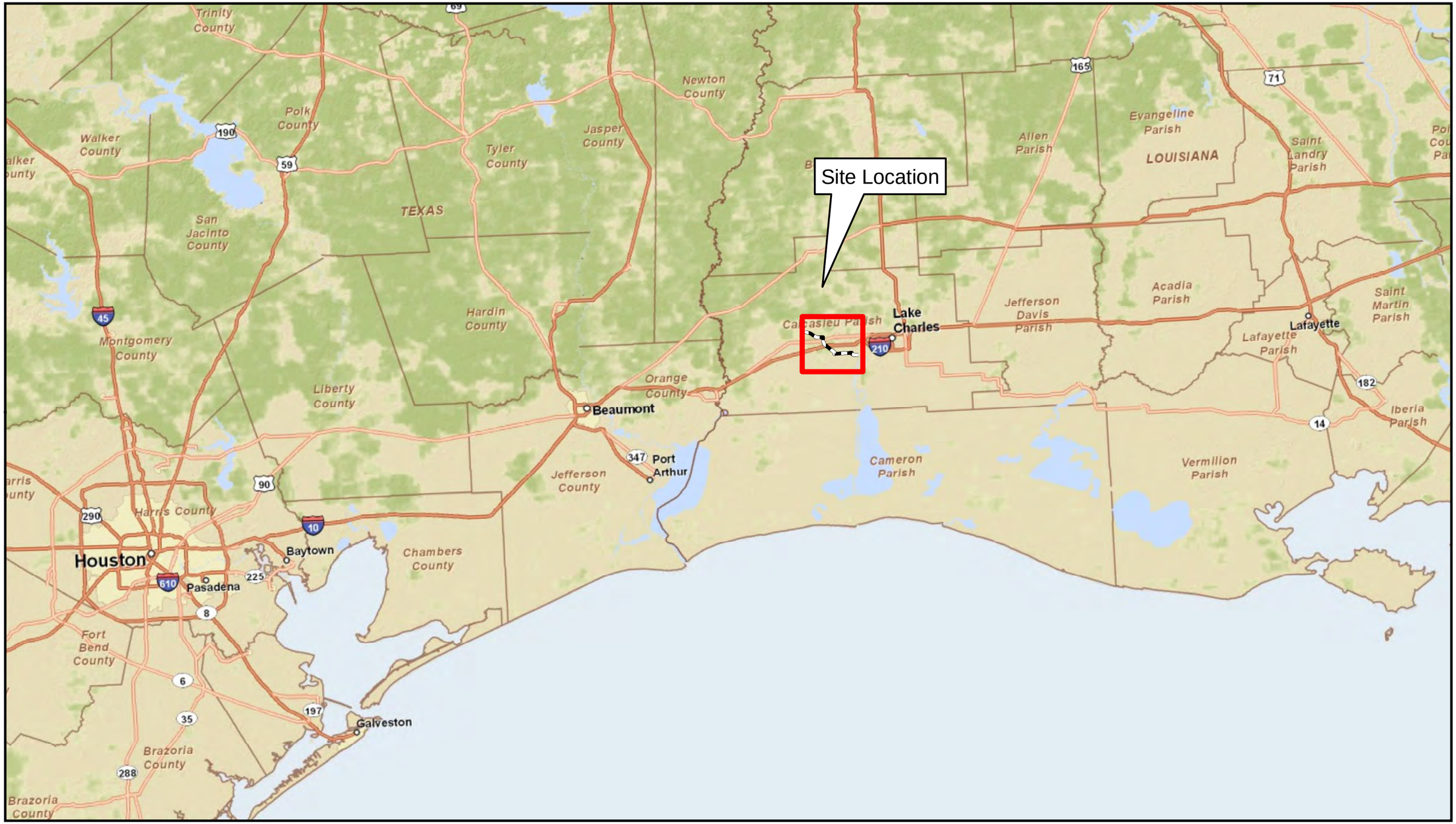


Figure 2-1
Site Location Map
Proposed Denbury CO2 Pipeline
Calcasieu Parish, Louisiana

CH2MHILL

\\GALILEO\PROJ\DENBURY_LAKE_CHARLES\MAPFILES\SITE_LOCATION.MXD JMINIX 2/15/2010 10:53:52

2.2 Alternative Action (assuming no DOE funding)

It may be economically feasible and environmentally beneficial for Leucadia and Denbury to continue with the proposed Project without DOE providing funding. Alternative actions to the pipeline mode of CO_2 transport could potentially include "CO_2 road transport" and "CO_2 rail transport" scenarios.

In the CO_2 road transport alternative, a truck could hold 20 tons of CO_2 (0.349 MMSCF) each run, making it possible to have 135 trucks ship CO_2 from the point of origin to the terminus daily. In the rail transport alternative, a rail car holds approximately 60 tons (1.048 MMSCF) of CO_2 each run and would require 45 rail cars per day to carry CO_2 to Hastings Field. While removed from the environment at a lower rate, CO_2 would still be sequestered. CO_2, regardless of the mode (pipeline, road, or rail) by which it arrives at Hastings Field, could still be sequestered and used for EOR at that field, or transferred to other fields via Denbury's and an affiliate's Green Pipeline, a 24-inch CO_2 pipeline capable of transporting up to 800 million standard cubic feet of CO_2 per day between Donaldson, Louisiana and Hastings, Texas. A more detailed, quantitative analysis of these sequestration options and the associated impacts would need to be conducted should DOE funding become unavailable and Denbury still wishes to pursue sequestration.

2.3 No Action Alternative

Without DOE cost-sharing funding for the Project, it is unlikely that the Project would be implemented. Consequently, with the No Action Alternative, the lack of sequestration would increase the CO_2 in the environment and oil production would decrease in Hastings Field.

SECTION 3.0

Affected Environment

3.1 Project Area and Topography

The proposed Pipeline Lateral is located entirely within Calcasieu Parish in the southwestern portion of Louisiana. Specifically, the Pipeline Lateral lies southwest of Sulphur City, extending from the Calcasieu River Shipping Channel generally north-northeast across Interstate 10 to the interconnect with Denbury's and an affiliate's Green Pipeline north of the intersection of WPA Road and State Highway 90. The Pipeline Lateral begins (MP 0.0) approximately 4.4 miles southwest of Lake Charles; 8.0 miles north of Lake Calcasieu; and approximately 30 miles north of the Louisiana Gulf of Mexico coast. An overview map of the Project area is provided as Figure 2-1.

The Pipeline Lateral's permanent ROW encompasses 72.32 contiguous acres of land collocated primarily along existing ROW corridors (e.g., pipeline, railroad, and transmission line) for most of the route. Surrounding land use is primarily comprised of developed industrial and residential areas, forested upland and wetlands, and pasture or agriculture.

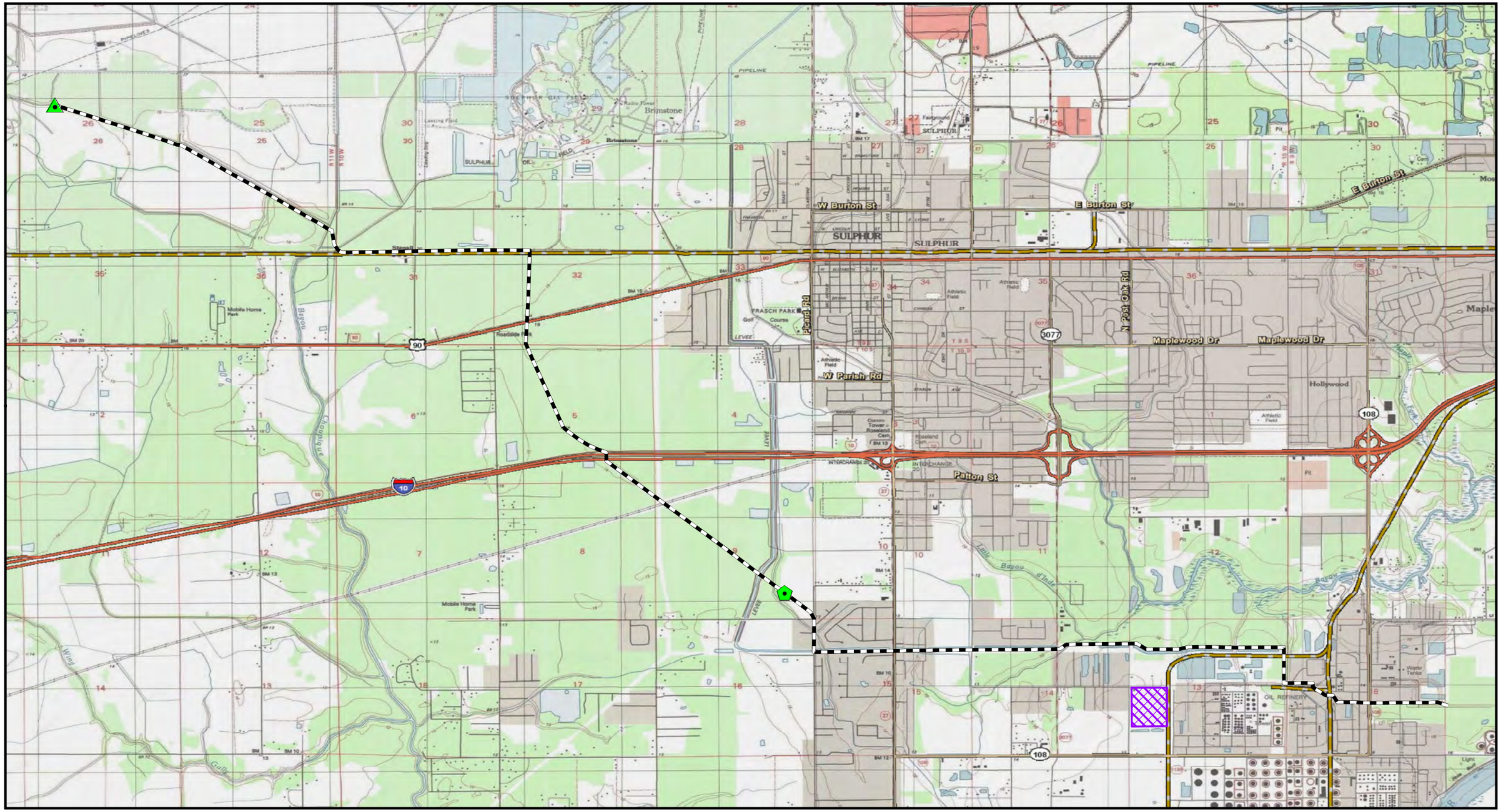
Topography along the Pipeline Lateral is generally flat with low relief and elevations generally ranging from sea level to approximately 15 feet above mean sea level (AMSL). Low circular mounds and occasional low coastal ridges and indistinct relict fluvial channels are present throughout the area of the Pipeline Lateral. A Site Location Map with U.S. Geological Survey (USGS) topographic map background is provided as Figure 3-1.

3.2 Climate, Meteorology, and Air Quality

The climate, meteorology, ambient air quality, in the vicinity of Lake Charles, Louisiana, and surrounding areas are presented below.

3.2.1 Climate

Annual maximum and arithmetic mean weather information for Jefferson County, Texas, which is located near the Lake Charles project site, was obtained from the EPA AirData monitoring station. Data are based on year 2009 information and is provided in Table 3-1.



Proposed Alignment
Proposed Meter Site
Proposed Valve Site
Proposed Contractor Yard

N

0 0.25 0.5 1

Miles

Figure 3-1
Project topographic Map
Proposed Denbury CO2 Pipeline
Calcasieu Parish, Louisiana

CH2MHILL

\\GALILEO\PROJ\DENBURY_LAKE_CHARLES\MAPFILES\TOPO.MXD EKLEIN 2/26/2010 15:13:00

TABLE 3-1
2009 Annual Weather Information for Jefferson County, Texas
Denbury Lake Charles, Louisiana, EIV

Weather Parameter	Maximum	Average
Barometric Pressure, mbar	1041	1017.5
Dew Point, F	79	60.9
Temperature, F	105	71
Relative Humidity, %	99	73.7
Peak Wind Gust, Knots	43	11.76
Wind Speed, Knots	22.4	6.23
Resultant Direction, degrees compass	NA	172
Resultant Speed, Knots	21.9	5.89
Solar Radiation, Langleys/minute	1.5	0.27
UV Radiation, Langleys/minute	0.05	0.012

Source: http://oaspub.epa.gov/aqspub1/AQS_Annsum.AnnualSummary

The Beaumont, Texas, wind rose (Figure 3-2) indicates the wind most frequently comes from the south.

Between 1974 through 2003, the highest temperature recorded was 105 degrees Fahrenheit in August 2000 and the lowest temperature recorded was 12 degrees Fahrenheit in December 1989. Additional annual average data for Jefferson County for a 30-year period, between 1974 through 2003, can be found in Table 3-2.

TABLE 3-2
30-Year Annual Average Weather Information for Jefferson County, Texas
Denbury Lake Charles, Louisiana, EIV

Weather Parameter	Annual
Rainfall, inches	59.89
Normal Annual Snowfall, inches	0.2

Source: (TCEQ, 2010a)

3.2.1.1 Severe Weather

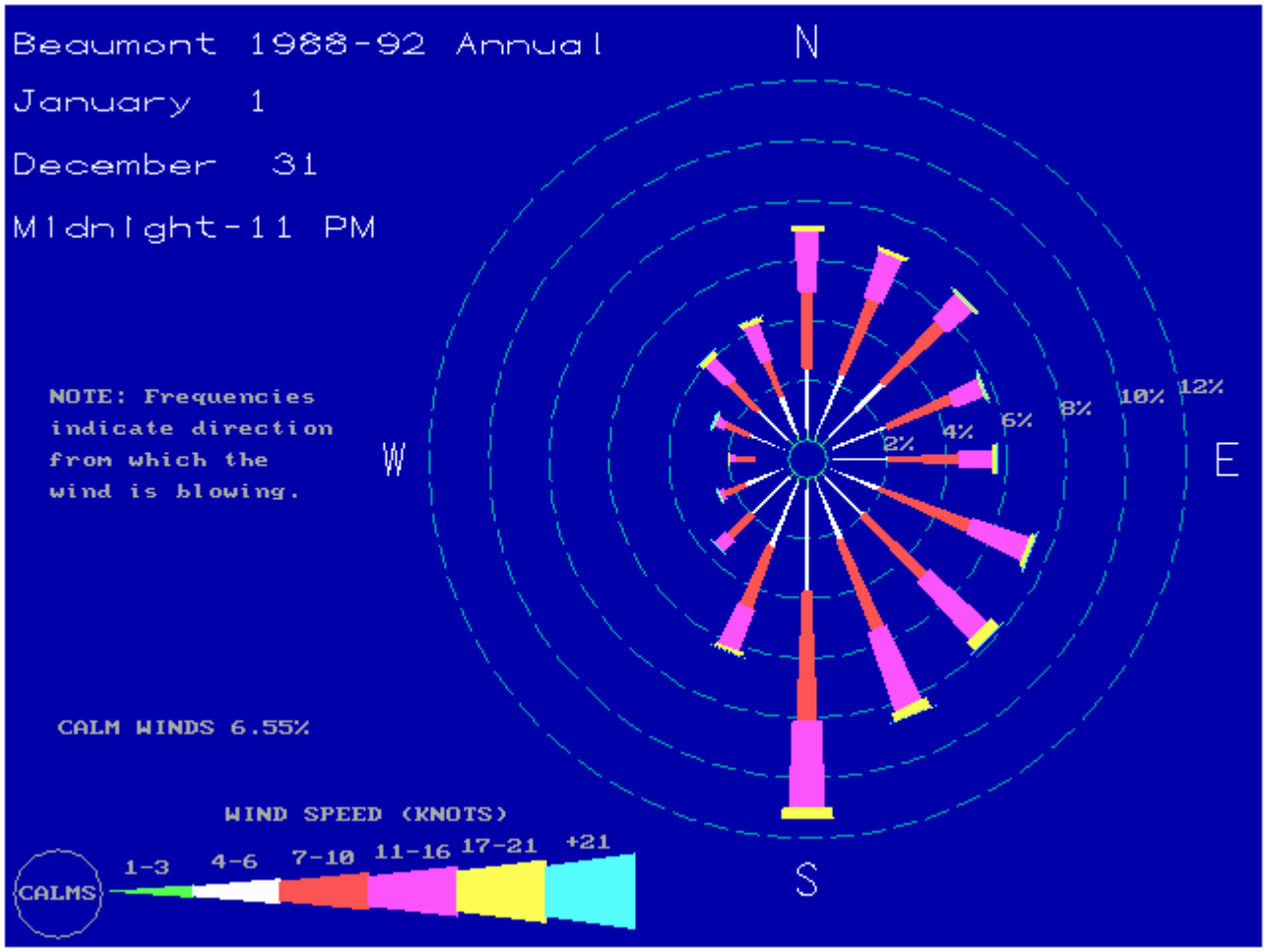
The Lake Charles National Weather Service Office reviewed documented storms from 1886 through 1997 for a 150-mile radius around Lake Charles and provided findings in a 1998 report. The report included Houston and Beaumont, Texas and Lake Charles, Lafayette, Alexandria, Baton Rouge, and Shreveport, Louisiana. During the 112 seasons studied, 71 tropical storms passed within the area, 34 of which were hurricanes. Of the 34 hurricanes, eight were considered major (Category 3 to 5 on the Saffir-Simpson Scale). This gives a frequency of one tropical storm through the area every 1.6 years and one hurricane every 3.3 years with a major hurricane every 14 years.

- According to National Climactic Data Center data (NCDC, 2010), there were 635 severe weather events in Calcasieu Parish, Louisiana, between January 1, 1950 and November 30, 2009. These events include the following: Drought – 7 events
- Hail –144 events
- Ice Storm – 3 events
- Storm Surge/Tide – 1 event
- Hurricanes – 4 hurricanes including Hurricane Earl (9/1/1998), Hurricane Lila (10/3/2002), Hurricane Rita (9/23/2005), and Hurricane Humberto (9/13/2007)
- Tropical Storm – 4 events including Hurricane Ike (9/12/2008) that caused tropical storm conditions in the area
- Tornadoes – 76 events. On February 12, 1971, a Category 3 (maximum wind speeds of 158 to 206 mph) tornado occurred 0.6 mile from the city center and caused approximately $2.5 million dollars in damages. On April 17, 1973, a Category 3 tornado occurred 3.4 miles from the city center and caused between $5,000 and $50,000 in damages
- Flood – 57 events
- Winds – 19 events greater than 60 knots
- Lightning Strike –5 events causing personal injury or death

Lake Charles-area historical tornado activity is slightly above the state average and it is 117 percent greater than the overall U.S. average (City-Data.com, 2010).

Figure 3-2 is a wind rose chart for Beaumont, Texas, from 1988 to 1992, found on the TCEQ Web site (2010b).

FIGURE 3-2
Beaumont Wind Rose



Source: TCEQ, 2010b

3.2.2 Meteorology

Detailed 2008 meteorology data for the State of Louisiana can be found in Appendix E.

3.2.2.1 Class I Areas

The term visibility, when used in the context of scenic vistas at mandatory Federal Class I areas, refers to the clarity with which distant objects are perceived. Visibility is affected by pollutant concentrations, the viewing angle, relative humidity, cloud characteristics, and other physical factors such as color contrast between objects. Without the effects of manmade air pollution, a natural visual range would be nearly 140 miles (225 kilometers [km]) in western areas and 90 miles (145 km) in eastern areas.

Five key contributors to manmade visibility impairment are:

- Sulfates, predominately from utility and industrial boilers
- Nitrate, predominantly from automobiles and utility and industrial boilers
- Organic carbon, from sources such as automobiles, trucks, and other industrial processes
- Elemental carbon (i.e., soot) from diesel, wood, and other combustion

- Crustal material (soil dust) from roads, construction, and agricultural activities

The concentration of these five species are measured regularly in many mandatory Federal Class I areas, and the light extinction coefficients and deciview visibility indices are calculated from these concentrations and are used as metrics to describe visibility.

There are no Federal Class I areas within a 200 mile radius of the Pipeline Lateral. The nearest Federal Class I area is the Breton National Wildlife Refuge (BRET1 Site), which is more than 220 miles from the Pipeline Lateral near Plaquemine Parish in southeast Louisiana. Caney Creek Wilderness Area in Arkansas (CACR1 Site) is located more than 380 miles from the Pipeline Lateral, and Wichita Mountains Wilderness Area in Oklahoma (WIMO Site) is more than 570 miles from the Pipeline Lateral. These sites are shown in Figure 3-3 below.

The Interagency Monitoring of Protected Visual Environments (IMPROVE) program was initiated in 1985 to monitor visibility conditions. Figure 3-4 shows monitoring sites, some of which are Federal Class I areas. Table 3-3 provides monitoring data from 2000 to 2004 for the three Federal Class I areas nearest to the Pipeline Lateral, as well as a Houston urban monitor.

FIGURE 3-3
IMPROVE Aerosol Network Location Map

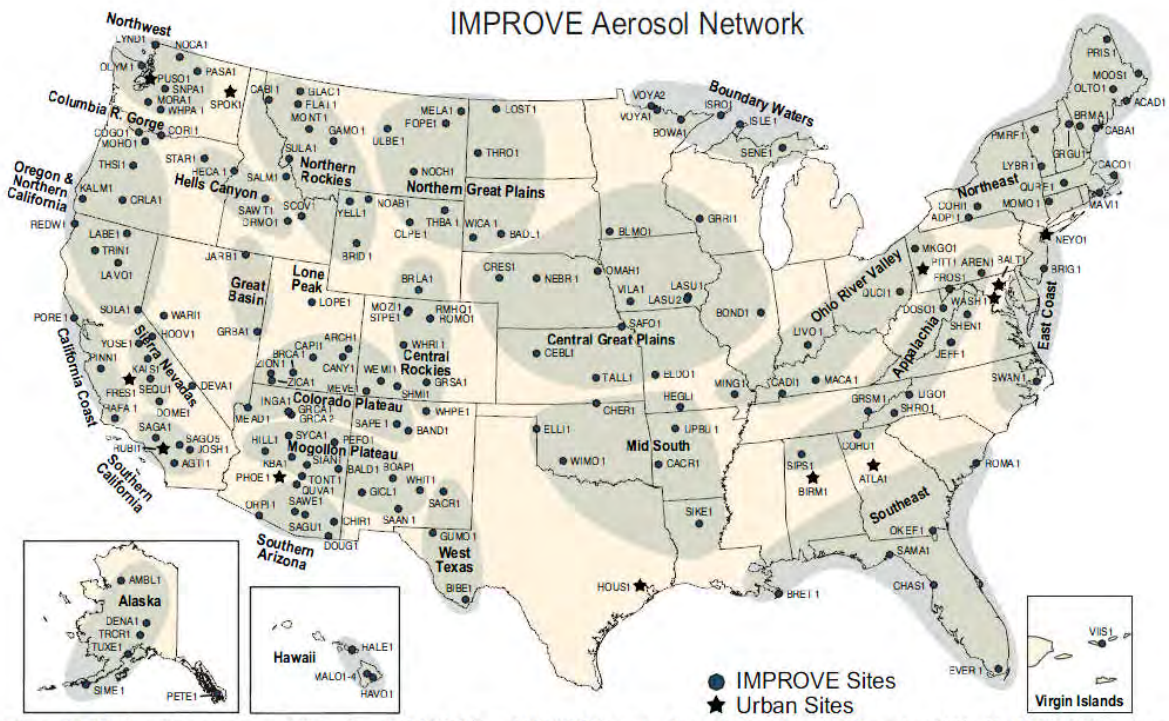


Figure S.1. The locations current and discontinued IMPROVE and IMPROVE protocol monitoring sites as of December 2004. The IMPROVE regions used for grouping the sites in some analyses in this report are indicated by green shading and bold text. Urban sites included in the IMPROVE network for quality assurance purposes are identified by stars.

TABLE 3-3
Pollutants Contributing to Reduced Visibility in Class I Areas
Denbury Lake Charles, Louisiana, EIV

Location	IMPROVE Monitor	Class I Area	Distance to Project Site	Sulfates	Nitrates	Organic Carbon Particles	Elemental Carbon	Crustal Material	Aerosol Extinction Coefficient	Annual Visibility
		Yes/No	miles	%	%	%	%	%	Mm-1	Deciview
Breton Wildlife Refuge Monitor, Louisiana	BRET1	Yes	>220	48-54%	4-8%	4-8%	30-36%	4-8%	54.9-64.0	18.5-20.9
Caney Creek Wilderness Area, Arkansas	CACR1	Yes	>380	42-48%	8-12%	0-4%	30-36%	8-12%	64.0-73.1	18.5-20.9
Wichita Mountains Wilderness Area, Oklahoma	WIMO1	Yes	>570	36-42%	12-16%	0-4%	30-36%	8-12%	45.7-54.9	16.2-18.5
Houston Monitor, Texas	HOUS1	No	>140	42-48%	8-12%	0-4%	30-36%	8-12%	45.4-54.9	16.2-18.5

Data from 2000 – 2004

Source: IMPROVE Spatial and Seasonal Patterns and Temporal Variability of Haze and its Constituents in the United States, Report IV; ISSN:0737-5352-74, Colorado State University CIRA Cooperative Institute for Research in the Atmosphere, November 2006.

3.2.3 Air Quality

The proposed project area is located in Calcasieu Parish, Louisiana. Large population areas within the 50-mile (80- km) region of influence (ROI) include the cities of Lake Charles and Lafayette, Louisiana, and Beaumont and Port Arthur, Texas. Smaller cities immediately surrounding the project site include Sulphur, Prien, and Iowa, Louisiana.

3.2.3.1 General Air Quality and Classification

Several air monitoring sites are located near the proposed Pipeline Lateral. Table 3-4 provides information on the nearest monitoring sites located in Lake Charles.

TABLE 3-4
Active Ambient Air Quality Monitors Nearest the Project Site
Denbury Lake Charles, Louisiana, EIV

Monitor	Site Location	Coordinates	Pollutants Monitored
Carlyss 22-019-0002	Hwy 28 & Hwy 108	Latitude: 30.14 Longitude: -93.37	O_3
Lake Charles McNeese University 22-019-0010	Common & E. McNeese	Lat = 30.18 Long = -93.21	PM2.5
Vinton 22-019-0009	2284 Paul Bellow Rd.	Lat = 30.2383 Long = -93.58	PM2.5, O_3

TABLE 3-4
Active Ambient Air Quality Monitors Nearest the Project Site
Denbury Lake Charles, Louisiana, EIV

Monitor	Site Location	Coordinates	Pollutants Monitored
Westlake 22-019-0008	2646 John Stine Rd.	Lat = 30.26 Long = -93.28	PM2.5, O_3, SO_2, NO_x, VOC
Lake Charles Lighthouse Lane SPECIAL3	Lighthouse Lane & Bayou D'Inde Pass	Lat = 30.22 Long = -93.31	VOC

Source: 2009 Louisiana Annual Network Assessment, LDEQ AQ Assessment Division, May 30, 2009

Detailed ambient air quality data within the ROI can be found on the EPA Web site for the monitoring network data, provided in the EPA AirData database. Data for CO, PM_{10}, and HAPs was not available for Calcasieu Parish. Data from the next closest monitor was used. All pollutant concentrations are within the standard limit with the exception of the eight-hour ozone value.

TABLE 3-5
2009 Ambient Air Quality Data for Calcasieu Parish
Denbury Lake Charles, Louisiana, EIV

Pollutants	2009 Maximum Concentration	NAAQS Standard Limit
CO (8-hour)	1.2 ppm	9 ppm (10 mg/m^3)
CO (1-hour)	2.03 ppm	35 ppm (40 mg/m^3)
NO_2 (Annual)	0.0065 ppm (Arithmetic Mean)	0.053 ppm (100 µg/m^3)
NO_2 (1-hour)	0.051 ppm	0.100 ppm
Ozone (1-hr)	0.114 ppm	0.12 ppm
Ozone (8-hr)	0.096 ppm 0.0427 ppm (Arithmetic Mean)	0.075 ppm
SO_2 (Annual)	0.0026 ppm (Arithmetic Mean)	0.03 ppm
SO_2 (24-hr)	0.019 ppm	0.14 ppm
PM_{10} (24-hr)	89 µg /m^3	150 ug/m^3
$PM_{2.5}$ (Annual)	8.6296 ug/m3 (Arithmetic Mean)	15 ug/m^3
$PM_{2.5}$ (24-hr)	23 µg /m^3	35 ug/m^3
HAPs (1)	0.0769 ppm 0.0011481 ppm (Arithmetic Mean)	—

Source: EPA, 2010a

Data for CO, PM10, and HAPs not available for Calcasieu Parish. The next closest monitor location was used (East Baton Rouge County for CO, West Baton Rouge County for PM10, and city of Lafayette for HAPs).

According to the Louisiana Department of Environmental Quality (LDEQ), Louisiana is in attainment for all federal National Ambient Air Quality Standards (NAAQS) pollutants, with the exception of ozone, in the five parish area that includes the city of Baton Rouge.

3.3 Water

3.3.1 Surface Water

The Pipeline Lateral is located in southwest Louisiana within the Coastal Marsh region of the Coastal Plain physiographic province. The Pipeline Lateral area is characterized by relatively flat topography transected by slow-moving bayous within an estuarine aquatic environment. The Project lies within the Lower Calcasieu River Basin, USGS Hydrologic Unit Code (HUC) 08080206 (EPA, 2010b), approximately 30 aerial miles from the Gulf of Mexico.

Topographic quadrangle maps and the National Hydrography Dataset (NHD) from the USGS were reviewed to identify surface water bodies crossed by the proposed Pipeline Lateral route. Fifteen mapped USGS streams will be crossed by the Pipeline Lateral as illustrated in Table 3-6 and Figure 3-4. Wetland and water body delineation surveys will be undertaken during project implementation to confirm the locations of jurisdictional waters of the United States. Crossings of surface water bodies would be permitted under Sections 401 and 404 of the Clean Water Act (CWA) and Section 10 of the Rivers and Harbors Act, as applicable.

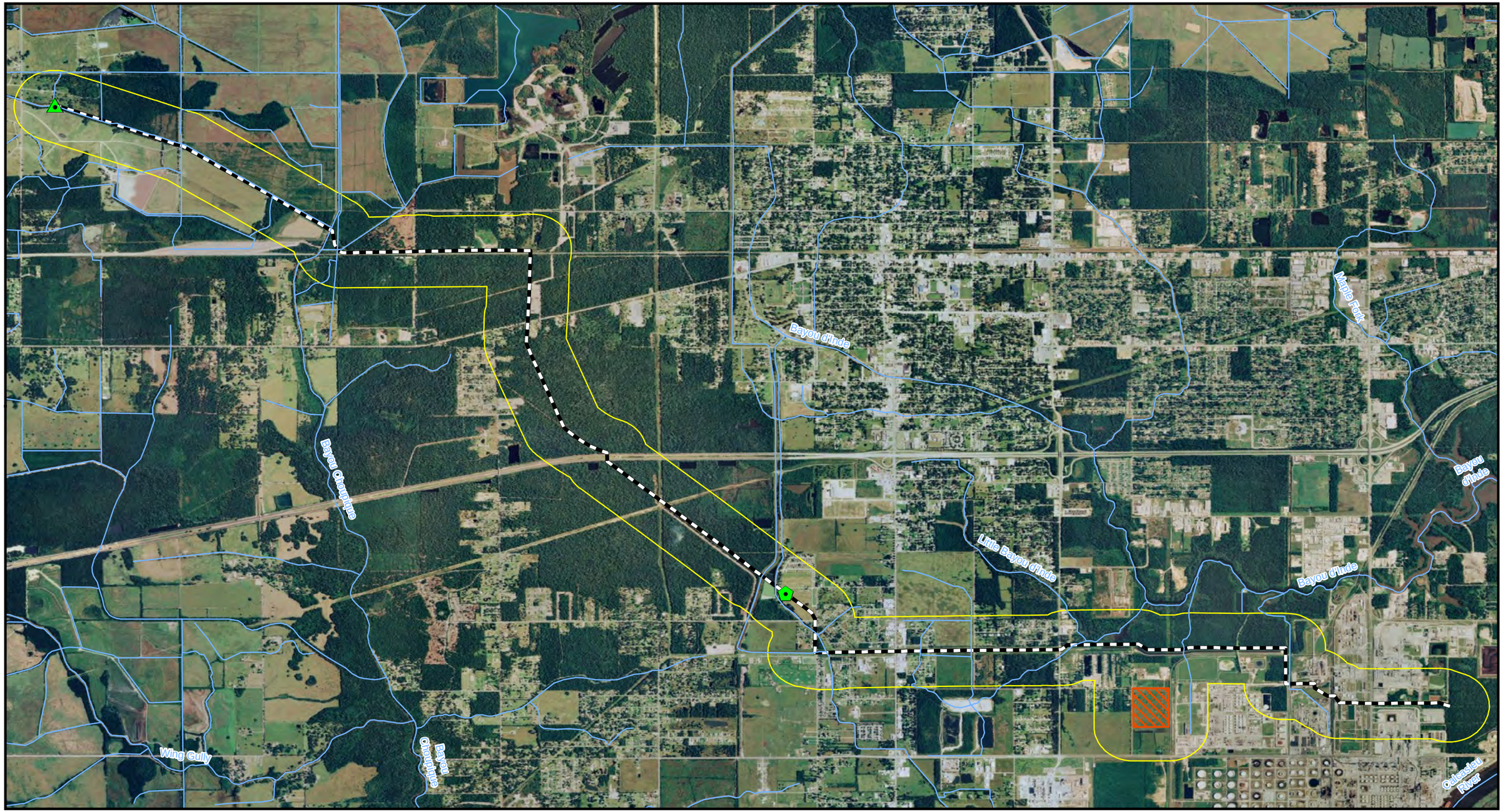
There are no designated or proposed federal or state Wild and Scenic Rivers crossed by the Pipeline Lateral.

TABLE 3-6
USGS-Mapped Waterways Crossed by the Proposed Project
Denbury Lake Charles, Louisiana, EIV

County	Name of Water Body	Possible HDD Crossing
Calcasieu	Bayou Choupique	No
	Unnamed Man-Made Canal	Yes
	Little Bayou D'Inde	Yes
	Unnamed Tributary to Little Bayou D'Inde	No
	Multiple (11) Unnamed Tributaries to Bayou D'Inde	No

Source: USGS, 2010

LDEQ manages the state's surface water quality assessment program under CWA Sections 303(d) and 305(b) (LDEQ, 2010). CWA Section 303(d) requires all states to submit a list reporting all impaired waters in or bordering the state that have not met water quality standards and those with pollutants that can be measured with maximum daily load metrics. All states also report a water quality inventory of state waters to the EPA based on CWA Section 305(b) requirements.



- Proposed Alignment
- Proposed Meter Site
- Proposed Valve Site
- 1/4 Mile Buffer of Disturbance Limits
- Proposed Contractor Yard
- USGS Mapped Stream

Source:
National Hydrography Dataset Wetlands - USGS, 2010

N

0 0.25 0.5 1

Miles

Figure 3-44
NHD Stream Map
Proposed Denbury CO2 Pipeline
Calcasieu Parish, Louisiana

CH2MHILL

\\GALILEO\PROJ\DENBURY_LAKE_CHARLES\MAPFILES\STREAMS.MXD EKLEIN 2/18/2010 14:45:08

Two LDEQ-assessed stream segments would be crossed by the Pipeline Lateral. These segments include Bayou D'Inde (Stream Subsegment Number LA031001_00) and Bayou Choupique (Stream Subsegment Number LA031001_00) (LDEQ, 2008). As shown in Table 3-7, Bayou D'Inde is fully attaining the designated use for secondary contact recreation but is not supporting the designated use for primary contact recreation or fish and wildlife propagation. Bayou Choupique is fully attaining its designated use for primary and secondary contact recreation and fish and wildlife propagation.

Field surveys will be performed during project implementation to delineate jurisdictional water bodies, in accordance with U.S. Army Corps of Engineers (USACE) guidelines and standard practice. Permitting activities would be based on data gathered by these environmental professionals.

3.3.2 Groundwater

The Pipeline Lateral area is situated within the Chicot aquifer system. The Chicot Aquifer is designated by the EPA as a Sole Source Aquifer. A sole source aquifer is one that supplies at least 50 percent of the drinking water consumed in the area overlying the aquifer (EPA, 2010b). These areas may have no alternative drinking water source(s) that could physically, legally, and economically supply all those who depend on the aquifer for drinking water. The Chicot aquifer system consists of Pleistocene deposits with fining upward sequences of materials from clay to gravel. In the Lake Charles area, the Chicot is divided into the shallow alluvial sands, the "200-foot" sand, the "500-foot" sand, and the "700-foot" sand (LDEQ, 2005).

Aquifer recharge occurs primarily through direct infiltration from rainfall, and recharge potential in the area is low (LDEQ, 1988). The range of thickness of fresh water in the Chicot Aquifer is 50 to 1,050 feet, and maximum depths of occurrence of freshwater range from 100 feet above sea level to 1,000 feet below sea level. In 2005, LDEQ's Baseline Monitoring Program performed analysis on Chicot Aquifer wells that ranged in depth from 66 feet to 697 feet, and results demonstrate that no maximum contaminant level (MCL) of the federal Primary Drinking Water Standards was exceeded. However, three Secondary Drinking Water Standards that serve as non-enforceable guidelines were exceeded; these secondary MCLs include color, pH, and total dissolved solids.

Approximately 112 registered water wells are situated within 0.25-mile of the Pipeline Lateral (Figure 3-5).

3.3.3 Floodplains

Floodplains are the normally dry land areas adjoining surface waters that are inundated during flood events (Mays, 2001). The 100-year floodplain includes that area subject to a one percent chance of flooding in any given year. The 500-year floodplain is that area subject to a 0.2 percent chance of flooding in any given year. Areas within the designated floodplains may be subject to more frequent flooding.

The National Flood Insurance Program (NFIP), administered by the Federal Emergency Management Agency (FEMA), is a program that provides federally-backed flood insurance to property owners. Minimum floodplain management requirements for participation in the NFIP are presented in the Code of Federal Regulations (CFR) 44 CFR 60.3 (FEMA, 2010).

TABLE 3-7
305(b) Water Quality Assessment of Project Area Waterways
Denbury Lake Charles, Louisiana, EIV

Subsegment Number	Subsegment Description	Type[1]	Size (River Miles)	PCR	SCR	FWP	Suspected Cause(s) of Impairment	Suspected Source(s) of Impairment
LA030901_00	Bayou D'Inde – From Headwaters to Calcasieu River (Estuarine)	R	12	N	F	N	Bromoform, hexachlorobenzene, nitrate/nitrite, dissolved oxygen, total phosphorus, polychlorinated biphenyls	Industrial Point Source Discharge, Discharges from Municipal Separate Storm Sewer Systems, Municipal Point Source Discharges
LA031001_00	Bayou Choupique – From Headwaters to Intercoastal Waterway (Estuarine)	R	20	F	F	F	None	None

1 R = River

2 PCR = Primary Contact Recreation; SCR = Secondary Contact Recreation; FWP = Fish and Wildlife Propagation; N = Non-supporting; and F = Fully Supporting

Proposed Alignment
Proposed Meter Site
Proposed Valve Site
DOTD Listed Water Wells
Proposed Contractor Yard
1/4 Mile Buffer of Disturbance Limits

Source:
Well Locations - Louisiana Department of Transportation and Development, 2010

0 0.25 0.5 1
Miles

N

Figure 3-5
Publicly Listed Water Wells
Proposed Denbury CO2 Pipeline
Calcasieu Parish, Louisiana

CH2MHILL

\\GALILEO\PROJ\DENBURY_LAKE_CHARLES\MAPFILES\WATER_WELLS.MXD EKLEIN 2/18/2010 14:06:32

Regulations pertaining to floodplains are typically enacted at the local government level when a community enters the NFIP. In Louisiana, the Louisiana Department of Transportation and Development (LA DOTD) is the State Coordinating Agency for the NFIP; in this role, the agency assists the local floodplain administrators in maintaining compliance with the NFIP.

To determine whether the proposed Pipeline Lateral is potentially located with FEMA-designated floodplains, Digital Q3 Flood Data maps, a digital representation of certain features of the Flood Insurance Rate Maps (FIRM), were obtained. Figure 3-6 presents the FEMA designations for the area of the Pipeline Lateral as indicated in the Digital Q3 Flood Data maps. While Q3 data provide a simplified and straightforward view of floodplain boundaries, more detailed, accurate, and up-to-date floodplain information is presented in FEMA's Flood Insurance Rate Maps.

The Pipeline Lateral crosses approximately 3.5 miles of 100-year floodplain.

3.3.4 Wetlands

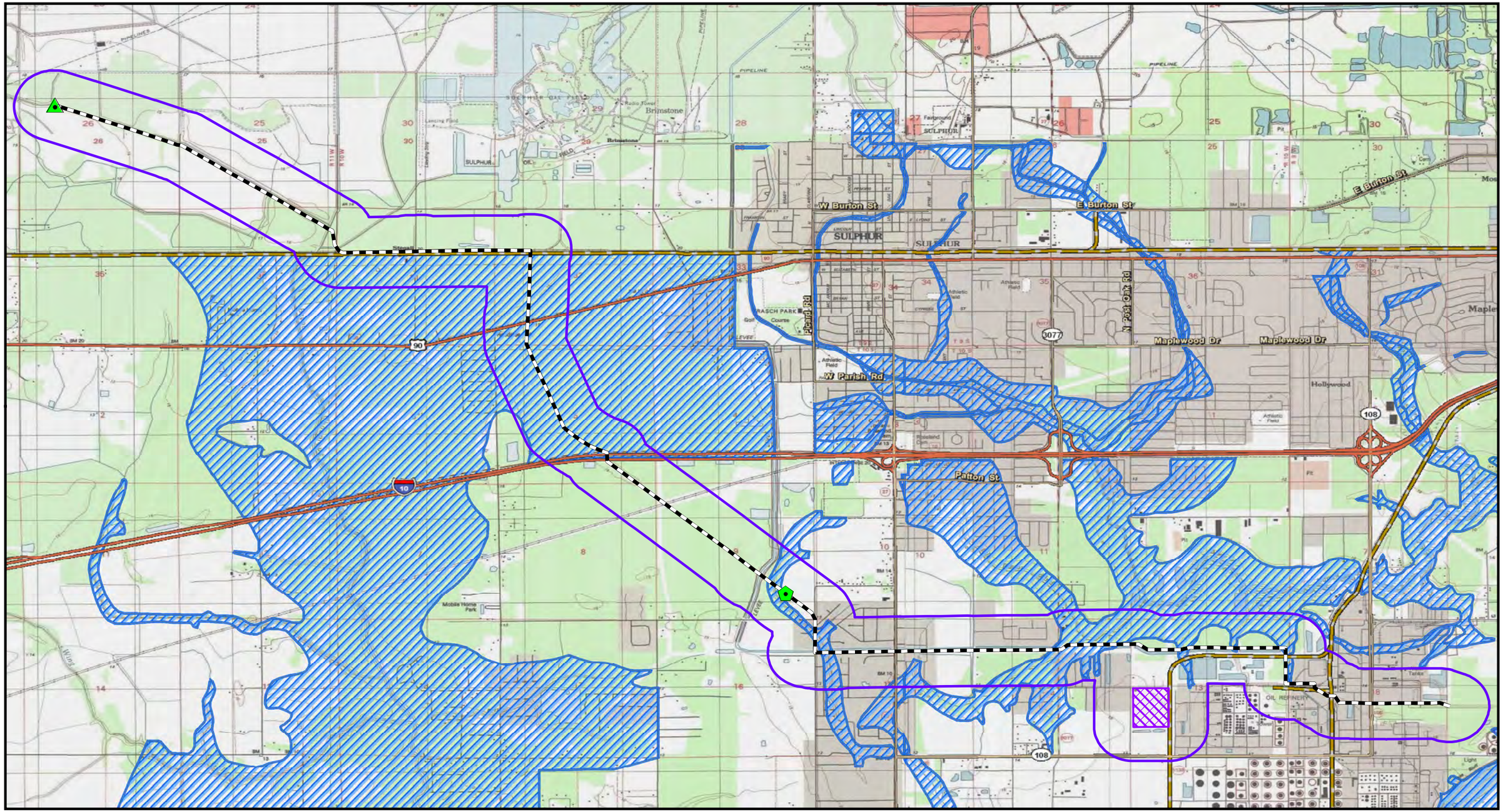
The National Wetlands Inventory (NWI) program is administered by the U.S. Fish and Wildlife Service (USFWS) and was established in the mid-1970s to inventory wetlands within the United States and report on the status of these resources (USFWS, 2010). Electronic NWI map coverage is not available for the area of the Pipeline Lateral.

The NHD consists of a comprehensive set of digital spatial data representing surface water features of the United States (USGS, 2010a). The NHD is maintained by the USGS and is intended to be used by scientists in general mapping and in the analysis of surface-water systems using Geographic Information Systems (GIS). The dataset can be used in modeling applications to assess the downstream effects of an upstream action. The NHD is more conservative in predicting the presence of wetlands than the NWI program.

NHD mapping was referenced for the area traversed by the Pipeline Lateral, but data was insufficient to reflect wetland information indicated by other sources. Land use mapping for the Pipeline Lateral area indicates significant wetland areas within the proposed pipeline corridor. Soils information for the Pipeline Lateral area supports this assumption.

Hydric and partially hydric soils are present within the area of the Pipeline Lateral; detailed information on soils within the Pipeline Lateral area can be found in Section 3.7. Additionally, Section 3.6 discusses land use attributes present within the area of the Pipeline Lateral. Characterization of land use in the area was based on Multi Resolution Land Characteristics Consortium (2001) data. According to these data, woody wetlands occur within the area of the Pipeline Lateral boundaries.

Field surveys will be performed during project implementation to delineate jurisdictional wetlands, in accordance with USACE guidelines and standard practice. Permitting activities would be based on data gathered by these environmental professionals.



Proposed Alignment
Proposed Meter Site
Proposed Valve Site
Proposed Contractor Yard
1/4 Mile Buffer of Disturbance Limits
100 Year Floodplain

Source:
Q3 Floodplain Boundaries - FEMA, 1996

N

0 0.25 0.5 1
Miles

Figure 3-6
FEMA 100-Year Floodplain Map
Proposed Denbury CO2 Pipeline
Calcasieu Parish, Louisiana

CH2MHILL

\\GALILEO\PROJ\DENBURY_LAKE_CHARLES\MAPFILES\FLOODPLAIN.MXD JMINIX 2/15/2010 13:28:33

3.4 Ecology

Terrestrial and aquatic ecologies of the proposed Pipeline Lateral, as well as information regarding threatened and endangered species are presented within this section.

3.4.1 Terrestrial Ecology

The proposed Pipeline Lateral is located within the Western Gulf Coastal Plain (Level III) and Northern Humid Gulf Coastal Prairies (Level IV) ecoregion (Daigle, et al. 2006). The distinguishing characteristic of this ecoregion is the relatively flat topography and historic presence of expansive coastal grasslands. Clay soils and frequent fire historically excluded woody vegetation from becoming established in most areas except along stream floodplains (TNC, 2010). Common historic grassland vegetation likely included little bluestem (*Andropogon scoparius*), big bluestem (*Andropogon gerardii*), yellow Indiangrass (*Sorghastrum nutans*), and brownseed paspalum (*Paspalum plicatulum*) among other herbaceous species.

Much of the natural grasslands that historically characterized the ecoregion have been converted to rice and soybean cropland due primarily to the flat topography and presence of relatively fertile soils. Woody shrub and tree coverage has increased with the exclusion of naturally occurring fire regimes in many areas. Specific ecological field surveys will be conducted to determine the species composition in the area of the Pipeline Lateral.

Common flora in the Northern Humid Gulf Coastal Prairies ecoregion are summarized in Table 3-8 based on general habitat descriptions provided in Daigle, et al. (2006).

TABLE 3-8
Common Flora in the Northern Humid Gulf Coastal Prairies Ecoregion
Denbury Lake Charles, Louisiana, EIV

Common Name	Scientific Name	Strata
Red maple	*Acer rubrum*	Tree / Canopy
Black hickory	*Cayra texana*	Tree / Canopy
Southern hackberry	*Celtis* sp.	Tree / Canopy
Persimmon	*Diospyros virginiana*	Tree / Canopy
Sweetgum	*Liquidambar styraciflua*	Tree / Canopy
Short-leafed pine	*Pinus echinata*	Tree / Canopy
Loblolly pine	*Pinus taeda*	Tree / Canopy
Southern red oak	*Quercus falcata*	Tree / Canopy
Post oak	*Quercus stellata*	Tree / Canopy
Sumac	*Rhus* sp.	Shrub
Blackberry	*Rubus* sp.	Shrub
Longleaf uniola	*Uniola* sp.	Herbaceous
Broomsedge	*Andropogon virginicus*	Herbaceous

Many of the most common fauna occurring in the Northern Humid Gulf Coastal Prairies ecoregion are opportunistic and are capable of survival in a variety of habitats. The primary habitat types crossed by the proposed Pipeline Lateral are pasture or agriculture, forested upland and wetland areas, low-density residential, and industrial. Table 3-9 provides a summary of the fauna in the ecoregion that may utilize these habitat types.

TABLE 3-9
Common Fauna in the Northern Humid Gulf Coastal Prairies Ecoregion
Denbury Lake Charles, Louisiana, EIV

Common Name	Scientific Name	Group
White-tailed deer	*Odicoileus virginianus*	Mammal
Gray squirrel	*Sciurus carolinensis*	Mammal
Raccoon	*Procyon lotor*	Mammal
Bobcat	*Lynx rufus*	Mammal
Skunk	*Spilogale* sp. and *Mephitis* sp.	Mammal
Armadillo	*Dasypus novemcinctus*	Mammal
Mourning dove	*Zenaida macroura*	Avian
Wild turkey	*Meleagris gallopavo*	Avian
Bobwhite quail	*Colinus virginianus*	Avian
Red-tailed hawk	*Buteo jamaicensis*	Avian
Eastern bluebird	*Sialia sialis*	Avian
Green heron	*Butorides virescens*	Avian
Copperhead snake	*Agkistrodon* sp.	Reptile
Diamondback rattlesnake	*Crotalus* sp.	Reptile
Box turtle	*Terrapene* sp.	Reptile
Texas salamander	*Eurycea neotenes*	Amphibian
Great plains narrow-mouthed toad	*Gastrophryne olivacea*	Amphibian
Bullfrog	*Rana catesbeiana*	Amphibian

3.4.2 Aquatic Ecology

The primary aquatic features crossed by the proposed Pipeline Lateral are an unnamed tributary to Choupique Bayou and Little Bayou d'Inde. The unnamed tributary to Choupique Bayou is channelized through a pasture/agricultural area and likely provides limited habitat value to aquatic species. Little Bayou d'Inde is a headwater of Bayou d'Inde that originates west of Sulphur City near the Interstate 10 bridge. Little Bayou d'Inde flows primarily east-northeast to Bayou d'Inde, then east to the Calcasieu River Ship Channel southwest of Coon Island (LDEQ, 2010a). The Calcasieu River Ship Channel flows generally south to Calcasieu Lake, which flows through a series of levees and ultimately into the Gulf of Mexico.

Common fish species that are likely to occur in reservoirs, streams, and ponds within the Northern Humid Gulf Coastal Prairies ecoregion are summarized in Table 3-10.

TABLE 3-10
Fish Species Potentially Occurring in the Northern Humid Gulf Coastal Prairies Ecoregion
Denbury Lake Charles, Louisiana, EIV

Common Name	Scientific Name
Largemouth bass	*Micropterus salmoides*
Black crappie	*Pomoxis nigromaculatus*
Bluegill	*Lepomis macrochirus*
Spotted sucker	*Minytrema melanops*
Red-eared sunfish	*Lepomis microlophus*

3.4.3 Threatened and Endangered Species

Four species listed as endangered or threatened by the USFWS are shown by the Louisiana Natural Heritage Program (LNHP) as potentially occurring in Calcasieu Parish (LNHP, 2008; NatureServe, 2010). The four species, current listing status, preferred habitat requirements, and potential for impacts to the species during construction and operation are summarized in Table 3-11.

TABLE 3-11
Federal and State Listed Species Potentially Occurring in Calcasieu Parish
Denbury Lake Charles, Louisiana, EIV

Common Name	Scientific Name	State Status (1)	Federal Status (1)	Preferred Habitat	Potential Project Impacts
Red wolf	*Canis rufus*	--	Endangered (Presumed Extirpated in Louisiana)	Upland and lowland forests, shrublands, and coastal prairies and marshes; areas with heavy vegetative cover.	Suitable habitat is likely not present along the Pipeline Lateral ROW.
Crested caracara	*Caracara cheriway*	--	Threatened	Open country, including pastureland, and cultivated areas.	Negligible to minor impacts. Field verification of pasture and cultivated lands along ROW needed to determine suitability.
Bald eagle	*Haliaeetus leucocephalus*	Endangered	--	Nests and winters near rivers, lakes and along coasts; nests in tall trees or on cliffs near large bodies of water.	Suitable habitat is likely not present along the Pipeline Lateral ROW.
Red-cockaded woodpecker	*Picoides borealis*	Endangered	Endangered	Prefers old-growth, fire-maintained pine woodlands with little to no mid-story. Ground cover typically contains grasses and shrubs.	Suitable habitat is likely not present along the Pipeline Lateral ROW.

Source: LNHP, 2008 and NatureServe, 2010

3.5 Solid Waste Disposal

A description of existing general waste as well as existing solid and hazardous waste sites in the vicinity of the proposed Pipeline Lateral are presented below.

3.5.1 General Waste

Denbury is not aware of any solid waste or other debris along the Pipeline Lateral that would require removal prior to construction activities. The construction of the proposed Pipeline Lateral is anticipated to generate waste primarily consisting of non-hazardous solids such as timber cleared from the ROW, construction mats and scrap, packaging materials, and general refuse (e.g., trailer office materials and debris from employees).

3.5.2 Known Hazardous Waste Sites

A review of the LDEQ database was conducted to identify known hazardous waste sites within a two mile area of the Pipeline Lateral. LDEQ regulates and manages solid waste facilities, federal and state-listed superfund sites, and remediation sites in Louisiana (LDEQ, 2010b).

No municipal solid waste facilities are located within two miles of the proposed Denbury Lake Charles Project area.

LDEQ documents sites in Louisiana that have been designated as state or federal Superfund sites, including sites that have been removed from the cleanup list since designation. Four EPA regulated sites are located within 2 miles of the Pipeline Lateral, all of which are Toxics Release Inventory (TRI) sites. The TRI Program is administered by the EPA Emergency Planning and Community Right-to-Know Act (EPCRA) under Section 313 of EPCRA, which requires EPA and individual states to annually collect data on releases and transfers of certain toxic chemicals from industrial facilities, and make these data available to the public in the TRI program (EPA, 2010c). The four regulated sites are: Basell USA Inc. Lake Charles Plant, Equistar Chemicals Lake Charles Plant, and two separate sites within Millennium Power facilities. All four sites are located in the Calcasieu River Ship Channel industrial area.

3.6 Land Use

Characterization of land use in the area of the Pipeline Lateral was based on Multi Resolution Land Characteristics Consortium (2001) data. The Pipeline Lateral extends along existing ROW corridors for most of the route. Surrounding land use is primarily comprised of developed industrial and residential areas (approximate MP 0.0 to MP 5.7), forested upland and wetland areas (approximate MP 5.7 to MP 9.6), and pasture/agriculture areas (approximate MP 9.6 to MP 12.2). No significant landforms (e.g., waterfalls or runoff areas), public lands, or other protected natural areas are crossed by the Pipeline Lateral. Figure 3-7 depicts the areal extent of the land uses near the Pipeline Lateral.

Pipeline and energy infrastructure are abundant throughout the area of the Pipeline Lateral, with crude oil, natural gas, refined products, and petrochemical pipelines traversing the Lake Charles industrial area near the beginning of the proposed Pipeline Lateral. Existing utility corridors in the vicinity of the Project are depicted as Figure 3-8.

Proposed Alignment
1/4 Mile Buffer of Disturbance Limits
Proposed Contractor Yard
Proposed Valve Site
Proposed Meter Site
NHD Wetland

Land Use

Open Water
Developed, Open Space
Developed, Low Intensity
Developed, Medium Intensity
Developed, High Intensity
Barren Land (Rock/Sand/Clay)
Deciduous Forest
Evergreen Forest
Mixed Forest
Shrub/Scrub
Grassland/Herbaceous
Pasture/Hay
Cultivated Crops
Woody Wetlands
Emergent Herbaceous Wetlands

N

0 0.25 0.5 1

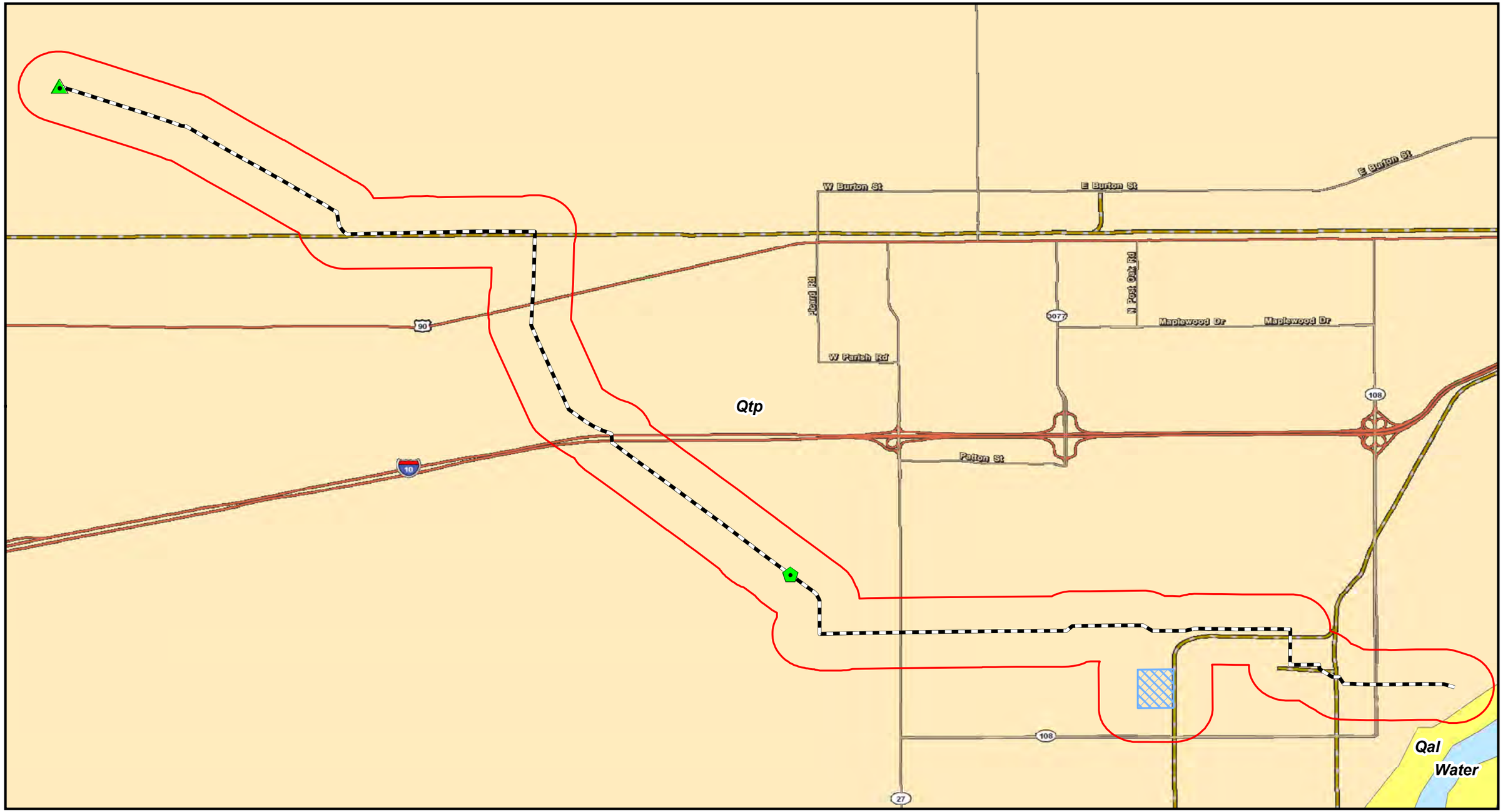
Miles

Source:
Land Use - Multi Resolution Land Characteristics Consortium, 2001

Figure 3-7
Existing Land Use Map
Proposed denbury CO2 Pipeline
Calcaseiu Parish, Louisiana

CH2MHILL

\\GALILEO\PROJ\DENBURY_LAKE_CHARLES\MAPFILES\LANDUSE.MXD EKLEIN 2/25/2010 16:17:58



Proposed Alignment
Proposed Meter Site
Proposed Valve Site
1/4 Mile Buffer of Disturbance Limits
Proposed Contractor Yard

Rock Unit Name
Qal - Alluvium
Qtp - Prairie Terraces
Wa - Water

N

0 0.25 0.5 1
Miles

Source:
General Geology - Louisiana Geological Survey, 1998

Figure 3-8
General Geology Map
Proposed Denbury CO2 Pipeline
Calcasieu Parish, Louisiana

CH2MHILL

\\GALILEO\PROJ\DENBURY_LAKE_CHARLES\MAPFILES\GEOLOGY.MXD EKLEIN 2/18/2010 13:43:44

The Coushatta Reservation is the nearest of the four federally recognized Native American tribes in Louisiana, located approximately 30 miles northeast of the Pipeline Lateral. No historically significant resources have been previously documented within the area of potential effect (APE) (National Register of Historic Places, 2010; Louisiana Cultural Resources Map, 2010). A description of tribal lands and historical resources in the vicinity of the Pipeline Lateral is provided in Section 3.8.

Four EPA listed hazardous waste sites are located within 0.25 mile of the Pipeline Lateral. None of these four sites are crossed by the proposed Pipeline Lateral ROW. Section 3.5 provides a description of the EPA listed sites in the vicinity of the Pipeline Lateral (EPA, 2010b).

3.7 Geology and Soils

This section discusses the geology, seismology, and soils (including problem soils) located in the area of the Pipeline Lateral.

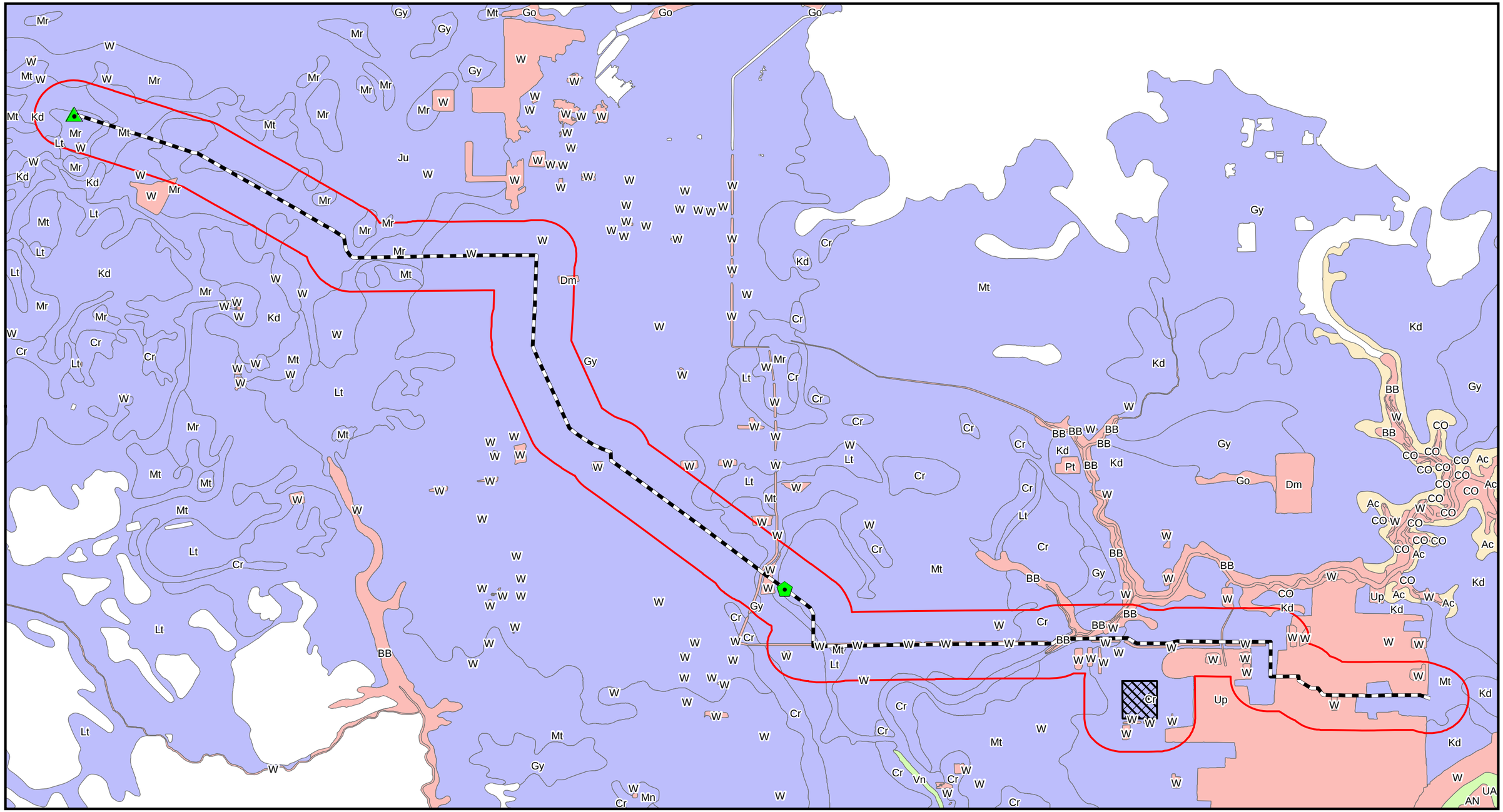
3.7.1 Geology

The proposed Pipeline Lateral is located within the West Gulf Coastal Plain Section of the Coastal Plain Physiographic Province (LGS, 2010). This region is comprised of a thin strip of land along the Gulf of Mexico that developed through alluvial deposits over the last two million years with a cap of mixed loess and alluvium derived from the flood plain along the Mississippi River (USGS, 2010a).

The majority of the Pipeline Lateral is within the Prairie Terraces (Qtp) unit, which is the youngest terrace in Southeast Louisiana and the first Pleistocene formation beneath the Holocene deltaic plain (Autin et al., 1991). The Prairie Terrace unit has low relief with elevations generally ranging from sea level to approximately 15 feet AMSL in the area of the Pipeline Lateral. The eastern-most portion of the Pipeline Lateral is within the Alluvium (Qal) unit associated with the Calcasieu River. Geologic mapping depicting the near-surface geology in the area is included as Figure 3-9.

The Pipeline Lateral area is underlain by Quaternary (late Pleistocene) alluvial and deltaic sand, silt, clay, and gravel that are generally not susceptible to dissolution associated with karst development. The USGS Earthquake Hazards Program classifies seismic hazard levels based on historical earthquake locations and recurrence rates of ground ruptures. The area is located within a Seismic Zone 0, which is the least likely classification for seismic activity. Calcasieu Parish is rated by the USGS as having a 1.483 percent peak acceleration (%g) with a 10 percent probability of exceedance in 50 years (USGS, 2010b).

No rare geologic formations or protected aquifers are located in the vicinity of the Pipeline Lateral.



Source:
Soils -USDA/NRCS Soil Survey Geographic (SSURGO)

Figure 3-9
Soils Map
Proposed Denbury CO2 Pipeline
Calcaseiu Parish, Louisiana

\\GALILEO\PROJ\DENBURY_LAKE_CHARLES\MAPFILES\SOILS.MXD DDICKMA1 2/18/2010

CH2MHILL

3.7.2 Soils

The Pipeline Lateral is located within the Gulf Coast Prairies Major Land Resource Area (MLRA), as classified by the Natural Resources Conservation Service (NRCS, 2009). Dominant soil orders in this MLRA are Alfisols, Entisols, and Ultisols formed in alluvium on flood plains, in depressions, and on terraces. They dominantly have a thermic soil temperature regime, an aquic or udic soil moisture regime, and siliceous, mixed, or smectitic mineralogy. A summary of soil series characteristics within the Pipeline Lateral construction boundaries is provided in Table 3-12. Soil mapping depicting soil map units is provided as Figure 3-10.

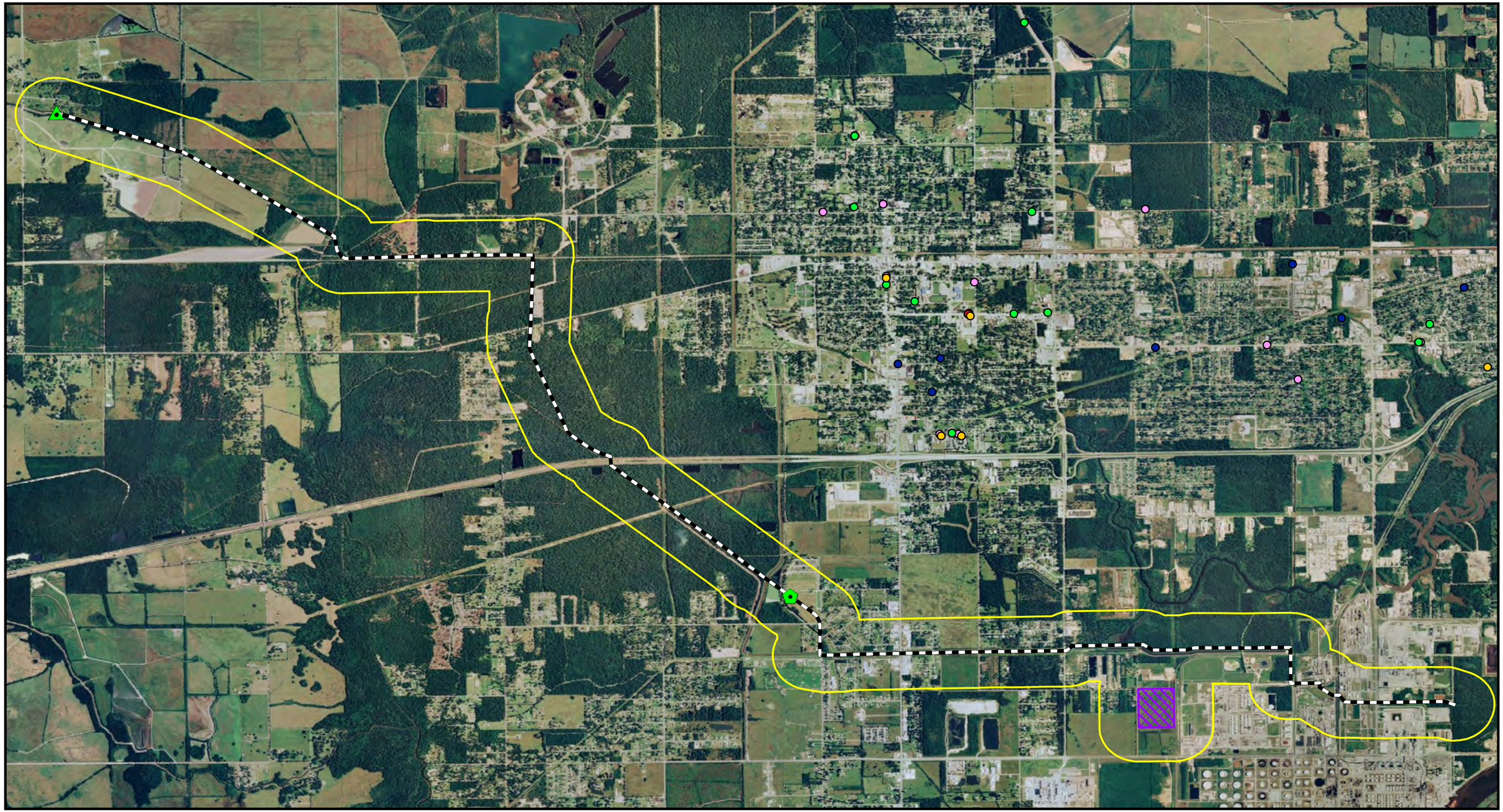
Approximately 176.6 acres within the boundaries of the Pipeline Lateral construction area are classified as prime farmland soils by the U.S. Department of Agriculture (USDA). Soils classified as prime farmland have a combination of physical and chemical characteristics that are highly suitable for producing food, feed, forage, fiber, and oilseed crops (7 CFR § 657.5(a)). Soils classified as unique farmland by the USDA are those lands other than prime farmland that are used for the production of specific high value food and fiber crops (7 CFR § 657.5(b)). No soils within the Pipeline Lateral construction boundaries are classified by the USDA as unique farmland. Soils of statewide importance, as classified by the USDA, are those that are nearly prime farmland and economically produce high yields of crops when treated and managed according to acceptable farming methods (7 CFR § 657.5(c)). No soils within the Pipeline Lateral construction boundaries are classified by the USDA as soils of statewide importance.

All of the soils within the Pipeline Lateral construction boundaries are rated as not highly erodible by the NRCS following the Universal Soil Loss Equation (USLE). A USLE rating for a given soil is calculated based on average rainfall, general soil characteristics, and length and steepness of slope for a given area (7 CFR § 610). The USLE is calculated without consideration of conservation practices, which can significantly decrease the actual erosion potential. Soils generally have increased erosion potential when exposed, excavated, or stockpiled.

NRCS hydric soils lists are intended to identify soil series that have the potential to include hydric soils based on estimated properties (e.g., permeability and estimated water table depth). Field assessments, such as the documentation of contemporary soil redoximorphic features or *in situ* oxidation-reduction monitoring, are necessary to verify the hydric status of soils. Most of the soils within the Pipeline Lateral construction boundaries are classified as having hydric or partial hydric soils. Hydric soil assessments would be conducted during field surveys to confirm the presence or absence of hydric soils.

TABLE 3-12
Soil Series Properties
Denbury Lake Charles, Louisiana, EIV

Soil Series	Taxonomic Class	Drainage	Hydric Listing	Prime Farmland	Erosion Potential	Impact Acres		
						Construction	Permanent	TOTAL
Basile and Guyton silt loams, frequently flooded	Typic Glossaqualfs	Poorly Drained / Very Poorly Drained	Partially Hydric	No	Not Highly Erodible	0.9	0.9	1.8
Crowley-Vidrine silt loams	Typic Albaqualfs / Aquic Glossudalfs	Somewhat Poorly Drained / Moderately Well Drained	Not Hydric	Yes	Not Highly Erodible	9.2	50.5	59.6
Guyton-Messer silt loams	Haplic Glossudalfs	Moderately Well Drained	Partially Hydric	Yes	Not Highly Erodible	26.0	24.3	50.3
Judice silty clay loam	Typic Epiaquerts	Poorly Drained	Hydric	Yes	Not Highly Erodible	8.4	8.6	16.9
Kinder-Messer silt loams	Typic Glossaqualfs / Haplic Glossudalfs	Poorly Drained / Moderately Well Drained	Partially Hydric	Yes	Not Highly Erodible	1.9	2.4	4.3
Morey loam	Oxyaquic Argiudolls	Somewhat Poorly Drained	Not Hydric	Yes	Not Highly Erodible	6.4	5.7	12.1
Mowata-Vidrine silt loams	Typic Glossaqualfs / Aquic Glossudalfs	Poorly Drained / Moderately Well Drained	Partially Hydric	Yes	Not Highly Erodible	15.1	18.2	33.4
Urban land	--	--	--	--	--	4.2	4.1	8.4
(Water)	--	--	--	--	--	0.3	0.2	0.5
		TOTAL				**72.3**	**114.9**	**187.2**



- Proposed Alignment
- Proposed Meter Site
- Proposed Valve Site
- 1/4 Mile Buffer of Disturbance Limits
- Proposed Contractor Yard
- Day Care Facility
- School
- Hospital
- Adult Care Facility
- Child Care Facilities
- Church

Source:
Day Care Facilities - LA Department of Social Services, 2006
Child and Adult Care Facilities and Hospitals - LA Department of Health and Hospitals, 2006 and 2007
Schools - LA Department of Education, 2007
Churches - US Census Bureau, 2000

N

0 0.5 1 2

Miles

Figure 3-10
Public Resources
Proposed Denbury CO2 Pipeline
Calcasieu Parish, Louisiana

CH2MHILL

\\GALILEO\PROJ\DENBURY_LAKE_CHARLES\MAPFILES\RECEPTORS.MXD EKLEIN 2/15/2010 12:20:39

3.8 Cultural and Archaeological Resources

Cultural resources are structures, buildings, archaeological sites, districts (a collection of related structures, buildings, and/or archaeological sites), cemeteries, objects, or religious sites of importance to Native American cultures. Both federal and state laws require consideration of cultural resources during project planning. At the federal level, the NEPA of 1969, and the National Historic Preservation Act (NHPA) of 1966, among others, requires federal agencies to consult with the Louisiana State Historic Preservation Office (SHPO) and interested Tribal Historic Preservation Offices (THPO) in order to identify potential significant cultural resources.

Within this section, the terms "significant" and "significance" are used in the context of NEPA and NHPA. When referring to structures, objects, or artifacts, the terms are used as defined in 36 CFR Part 800 for NHPA. When referring to impacts, the terms are applied relative to their meaning under NEPA.

Regulations implementing Section 106 of NHPA, 36 CFR Part 800.8, encourage the coordination of two processes: (1) review of possible impacts to the environment under NEPA and (2) assessment of effects of undertakings required under NHPA. It is the intent of Denbury that this EIV support both of these independent reviews.

3.8.1 Native American Tribal and Religious Practices

The four federally recognized Native American tribes in Louisiana are the Chitimacha Tribe of Louisiana, Coushatta Tribe of Louisiana, Jena Band of Choctaw Indians, and Tunica-Biloxi Indian Tribe of Louisiana (National Conference of State Legislatures [NCSL], 2010). Based upon readily available information, the Coushatta Reservation, approximately 30 miles northeast of the Pipeline Lateral, is the location of the nearest tribe. . Formal consultation with the THPO will be required to determine if any tribal lands, religious or ceremonial grounds exist near or adjacent to the Pipeline Lateral.

3.8.2 Historic Areas

Cultural resources that would be potentially impacted by the proposed action include historical properties and archaeological resources. In order to determine potential effects, an APE is delineated for purposes of compliance with Section 106 of NHPA and includes the area of disturbance and all adjacent areas where direct effects of the construction might affect archaeological resources. The APE also includes adjacent areas where the setting of existing historic structures may be visually and structurally affected as a result of construction. Consultation with the SHPO will be required to determine the APE for the Pipeline Lateral; however, it is anticipated that the APE would cover the area to be affected by construction which would be a 95-foot ROW width (50-foot permanent ROW and 45-foot construction ROW) that would extend along the entire length of the proposed pipeline corridor. Formal consultation with the SHPO will be required to determine if any cultural resources exist near or adjacent to the Pipeline Lateral.

3.9 Noise

3.9.1 Affected Environment

For determination of impacts to human receptors, noise measurements are weighted to increase the contribution of noises within the normal range of human hearing and decrease the contribution of noises outside that range. Human hearing is best approximated by using an A-weighted decibel scale (dBA). When sound pressure doubles, the dBA level increases by 3 (The Engineering Toolbox, 2007). Psychologically, most humans perceive a doubling of sound as an increase of 10 dBA (USEPA, 1974). Sound pressure decreases with distance from the source. Typically, the sound measured from a point source decreases at a rate of 6 dBA per doubling of distance from the source and sound from a continuous source decreases at a rate of 3 dBA per doubling of distance from the source. However, factors such as the ground type, atmospheric conditions, and shielding by vegetation and structures further affect the amount of decrease in sound over distance (Federal Highway Administration [FHWA], 2007). Construction areas typically act as continuous sources of noise.

Noise levels are often expressed as Ldn, which is the dBA sound level over a 24-hour day and night period. The Ldn also applies a 10-dBA penalty to nighttime sounds occurring between 10 PM and 7 AM to account for the desirability of a quieter night than day in order to avoid sleep interruption. A noise level considered low is less than 45 dBA, a moderate noise level is 45 to 60 dBA, and a high noise level is above 60 dBA. In busy urban areas, noise levels are typically near 75 dBA, and can reach 85 dBA near airports and major freeways (California State Lands Commission, 2005). Sound levels in rural residential areas typically average 40 dBA. In business and commercial areas, sound levels typically range from 50 dBA to 60 dBA (The Engineering Toolbox, 2007).

Existing noise levels along the proposed route would be expected to range from approximately 45 dBA in the undeveloped and agricultural portions of the route to approximately 75 dBA when passing through heavily industrialized areas. The areas that contain potential residential receptors would be expected to have existing noise levels of approximately 60 dBA due to proximity to the industrial areas.

3.10 Socioeconomics

The proposed Pipeline Lateral is located in Calcasieu Parish, Louisiana, which had an estimated population of 184,431 in 2008 (United States Census Bureau [USCB], 2000a). The urban areas within two miles of the proposed Pipeline Lateral corridor include Sulphur to the northeast and Carlyss to the southeast. Both cities fall within the Lake Charles metropolitan statistical area (MSA). An MSA is a core-based statistical area associated with at least one urban cluster that has a population of more than 50,000 (BEA, 2010). The direct ROI is defined as the Lake Charles MSA and Calcasieu Parish since those areas have the potential to be directly impacted by construction. Louisiana and the United States are the reference areas and are used as the basis of comparison. The socioeconomic indicators summarized in this section of the EIV include population and race, employment, housing, and environmental justice. The project from a construction, surveying and inspection point of view, will infuse approximately $3,800,000 into the local economy.

3.10.1 Population and Race

The estimated population for Lake Charles and the State of Louisiana has decreased between 2000 and 2008, while the estimated population of Calcasieu Parish and the United States has increased. Construction personnel may become temporary residents in the ROI and the reference areas. Table 3-13 summarizes recent and estimated populations for the ROI (where available), State of Louisiana, and the United States.

TABLE 3-13
Population Statistics in the ROI and Reference Areas
Denbury Lake Charles, Louisiana, EIV

Geographical Area	2000 Population	Estimated 2008 Population
Lake Charles MSA	71,757	67,631
Calcasieu Parish	183,577	185,618
State of Louisiana	4,468,968	4,410,796
United States	281,424,602	304,059,724

Source: USCB 2000a, USCB 2000b, USCB 2008a, USCB 2008b, USCB 2008c, USCB 2008d, USCB 2000c

Table 3-14 summarizes the population by race for the ROI, state of Louisiana, and the United States. Within the Lake Charles MSA, the majority of the population is of a "White alone" race (73 percent), followed by "Black/African American alone" (23 percent). Other races comprise the remaining population (4 percent).

TABLE 3-14
Population by Race in the ROI and Referenced Areas (2008)
Denbury Lake Charles, Louisiana, EIV

Race	Calcasieu Parish	Louisiana	United States
White alone	133,677	2,794,194	223,965,009
Black/African American alone	44,631	1,366,990	37,131,771
American Indian and Alaska Native	783	24,951	2,419,985
Asian alone	1,399	62,295	13,164,169
Native Hawaiian and Other Pacific Islander alone	22	1,139	446,164
Some other race alone	1,311	42,925	17,538,990
Two or more races	2,608	50,088	6,571,705
Of Hispanic/Latino Origin	3,711	140,640	45,432,158
Total Population	**185,618**	**4,410,796**	**304,059,724**

USBC 2008a, USBC 2008b, USBC 2008c, USBC 2008d

3.10.2 Employment

Total employment for the Lake Charles MSA and reference areas are show in Table 3-15. Employment numbers are based on estimates of the number of jobs, full-time plus part-time,

and by place of work. Full-time and part-time jobs are counted as equal weight. Unpaid family workers and volunteers are not included in these totals. Total employment remained the same between 2008 and 2009 in the MSA, but decreased in both the state of Louisiana and the United States over that period of time.

TABLE 3-15
Total Employment in the ROI and Reference Areas
Denbury Lake Charles, Louisiana, EIV

Geographic Area	2008 Employment	Dec 2009 Employment
Lake Charles MSA	87,005	87,700
Calcasieu Parish	83,564	N/A
Louisiana	1,908,974	1,889,600
United States	143,195,793	130,912,000

Notes:
Source: USC 2008a, USCB 200b, USCB 2008c, USCB 2008d, BLS 2010

The labor force for the area consists of individuals 16 years of age or older who are either employed or available for employment. The labor force is used to calculate the unemployment rate or percentage of unemployment members of the labor force. From 2008 to December 2009, the labor force increased in the Lake Charles MSA as well as the nation, but decreased in the state (Table 3-16). In December 2009, Lake Charles had an unemployment rate of 6.9 percent, 7.5 percent for the state of Louisiana, and 10 percent for the nation.

TABLE 3-16
Unemployment Status for the ROI and Reference Areas
Denbury Lake Charles, Louisiana, EIV

Geographic Area	2000 Labor Force	Dec. 2009 Labor Force	Dec. 2009 Unemployment Rate
Lake Charles MSA	89,910	94,100	6.9%
Calcasieu Parish	N/A	N/A	N/A
Louisiana	9,937,1250	2,049,800	7.5%
United States	138,820,935	153,989,802	10.0%

Source: USCB 2000a; USCB 2000b, USCB 2000d, BLS 2010.

Per capita income represents the total earnings of a given labor force divided by its number of individuals over a year and can be used to compare areas economically. The Lake Charles MSA, Calcasieu Parish and the State of Louisiana have lower per capita income than the United States, but income in Lake Charles and Calcasieu Parish is slightly higher than per capita income in the state of Louisiana (Table 3-17).

TABLE 3-17
Per Capital Income for ROI and Reference Areas
Denbury Lake Charles, Louisiana, EIV

Geographical Area	2000 Per Capita Income ($)	2008 Per Capita Income ($)
Lake Charles MSA	17,922	23,970
Calcasieu Parish	17,710	23,777
Louisiana	16,912	22,488
United States	21,587	39,582

USCB 2000a, USCB 2000b, USCB 2000c, USCB 2000d, USCB 2008a, USCB 2008b, USCB 2008c, USCB 2008d

3.10.3 Housing

The city of Lake Charles is the nearest urban areas within a five-mile radius of the proposed area of the Pipeline Lateral. The 2000 Census data was used for comparison of housing data for the ROI (Table 3-18). There is a total vacancy rate of 16.4% in Lake Charles, compared to 11.6% in Calcasieu Parish.

TABLE 3-18
Housing for the ROI and References Areas
Denbury Lake Charles, Louisiana, EIV

Geographical Area	Total Housing Units	Total Housing Units Available	Total Vacancy Rate (%)
Lake Charles	33,296	5,448	16.4
Calcasieu Parish	82,032	9,541	11.6

Source: USCB 2008c, USCB 2008d

3.10.4 Environmental Justice

Environmental Justice (EJ) is the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulation, and policies (Council on Environmental Quality [CEQ], 1997). "Fair treatment" means that no group, including racial, ethnic, or socioeconomic groups, should bear a disproportionate share of the adverse environmental consequences resulting from industrial, municipal, or commercial operations or the execution of federal, state, local, and tribal programs and policies.

In 1994, Executive Order 12898 was issued to focus on environmental and human health conditions in minority and low-income communities. This Order requires federal agencies to achieve environmental justice "to the greatest extent practicable" by identifying and addressing "disproportionately high adverse human health or environmental effects of….activities on minority populations and low-income populations." The CEQ has issued guidance to federal agencies to assist them with their NEPA procedures so that EJ concerns are effectively identified and addressed (CEQ, 1997).

For the purpose of this analysis, the Environmental Justice Study Area is defined as the proposed Project area and its immediate vicinity including the Lake Charles MSA and

Calcasieu Parish. The state of Louisiana and the United States are the reference populations and are used as the basis of comparison.

The percentage of the population living below the poverty level within the Pipeline Lateral area ranges between 15.8 percent in the Lake Charles MSA and 15.9 percent in Calcasieu Parish (Table 3-19). The percent of the population living in poverty in the State of Louisiana and the United States is 18.5 percent and 13.2 percent, respectively.

TABLE 3-19
Populations Living Below the Poverty Level by Race within the Referenced Areas
Denbury Lake Charles, Louisiana, EIV

Race	Lake Charles MSA	Calcasieu Parish	Louisiana	United States
White alone	139,939	133,677	2,794,194	223,965,009
Black/African American alone	44,677	44,631	1,366,990	37,131,771
American Indian and Alaska Native	798	783	24,951	2,419,985
Asian alone	1,420	1,399	62,295	13,164,169
Native Hawaiian and Other Pacific Islander alone	22	22	1,139	446,164
Some other race alone	1,311	1,311	42,925	17,538,990
Two or more races	2,654	2,608	50,088	6,571,705
Of Hispanic/Latino Origin[a]	3,764	3,711	140,640	45,432,158
Total Population	**190,821**	**184,431**	**4,342,582**	**301,237,703**
Percent Minority Population	26.9%	27.8%	35.8%	26.1%
Percent Hispanic Population	2%	2.0%	3.2%	15.1%
Income Below Poverty Level				
Percent of population below poverty level	15.8%	15.9%	18.5%	13.2%

Source: USCB 2008a, USCB 2008b, USCB 2008c, USCB 2008d

Executive Order 13045, Protection of Children from Environmental Health Risks and Safety Risks, which requires federal agencies to make it a high priority to identify and assess environmental health risks and safety risks that may disproportionately affect children and ensure that policies, programs, and standards address disproportionate risks to children that result from environmental health and safety risks.

Within the Pipeline Lateral area, the percent of the population below 18 years of age is between 25.2 and 25.7 percent. This percentage is comparable with the state of Louisiana and the United States (Table 3-20).

TABLE 3-20
Percentage of Population Under age 18 in Referenced Area
Denbury Lake Charles, Louisiana, EIV

Geographic Area	Lake Charles MSA	Calcasieu Parish	Louisiana	United States
Total Population	67,361	185,618	4,410,796	304,059,724
Percent of population under the age of 18	25.2%	25.7%	25.1%	24.3%

Source: USCB 2008a, USCB 2008b, USCB 2008c, USCB 2008d

3.11 Public Resources

Figure 3-11 depicts the locations of public resources, including fire, police, schools, and emergency services in the vicinity of the Pipeline Lateral.

The Sulphur Fire Department and Sulphur Police Department are located approximately 1.5 miles northeast of the Pipeline Lateral. The nearest emergency services provider is the West Calcasieu Cameron Hospital, located approximately 1.9 miles east of the Pipeline Lateral. Several schools, including W. T. Henning Elementary School, Frasch Elementary School, W.W. Lewis Middle School, Sulphur High School, and Richard W. Vincent Elementary School, are located between 1.5 and 2.0 miles from the proposed Pipeline Lateral.

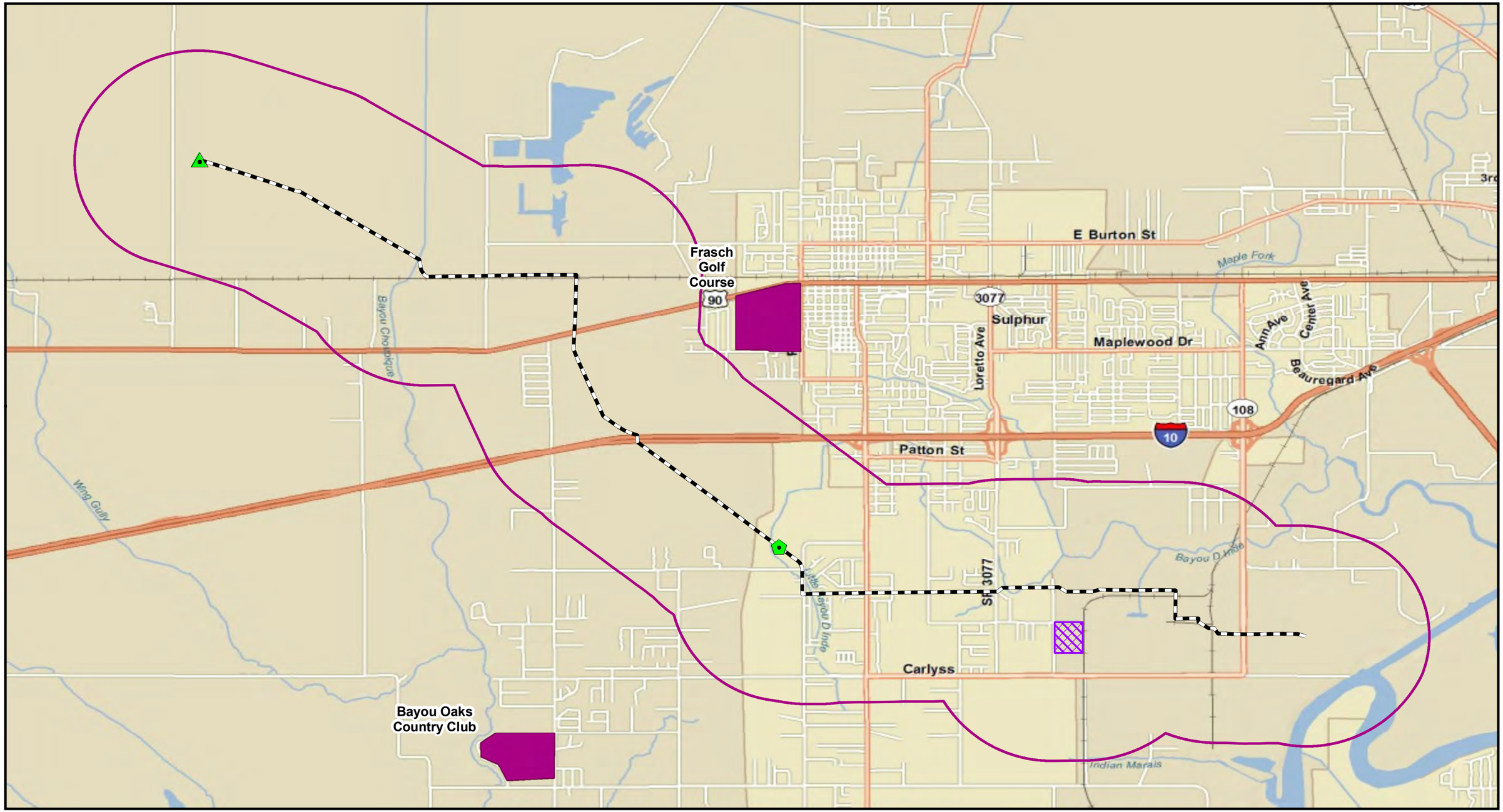
3.12 Transportation

The proposed Pipeline Lateral will be accessed primarily through the use of interstate, state, county, and local roads, and existing ROW corridor access roads. Interstate 10, Highway 90, State Road 27, and State Road 108 provide access to the area of the Pipeline Lateral. Local roads and existing ROW access roads provide construction and operation access throughout the length of the pipeline corridor. A tabular summary of the major roadways in the vicinity of the Pipeline Lateral and annual average daily traffic (AADT) count stations maintained by the LA DOTD is provided in Table 3-21. The AADT for the remaining roads in the area are not available but are considered to be significantly less than the AADT for the major roadways.

TABLE 3-21
Major Roadways and Average Daily Traffic in the Vicinity of the Pipeline Lateral
Denbury Lake Charles, Louisiana, EIV

Road Name	Average Daily Traffic	LDOTD Station ID / Count Year
Interstate 10	37,860 (Road Milepost 20.11)	240220 / 2007
Highway 90 West	6,744 (Road Milepost 20.73)	240320 / 2007
State Road 27	15,960 (Road Milepost 1.75)	240160 / 2007
State Road 108	12,981 (Road Milepost 28.22)	240200 / 2007

Source: LA DOTD, 2010



Proposed Alignment
Proposed Meter Site
Proposed Valve Site
Proposed Contractor Yard
1 Mile Buffer
Recreation Areas

Source:
recreation Facilities - US Census Bureau, 2000
Basemap - ArcGIS Online, 2010

N

0 0.5 1 2
Miles

Figure 3-11
Recreation Areas Map
Proposed Denbury CO2 Pipeline
Calcasieu Parish, Louisiana

CH2MHILL

\\GALILEO\PROJ\DENBURY_LAKE_CHARLES\MAPFILES\RECREATION.MXD JMINIX 2/15/2010 14:58:23

The proposed Pipeline Lateral crosses, then parallels Union Pacific railroad corridors from approximate MP 1.7 to MP 2.7 and from approximate MP 8.1 to MP 10.2. Two additional crossings of Union Pacific spurs through the Calcasieu River Ship Channel industrial area occur at approximate MP 1.4 and MP 1.7.

The Pipeline Lateral is proposed to begin near the Calcasieu River Ship Channel. The ship channel is approximately 40 feet deep by 400 feet wide (USACE, 2010), providing potential barge access to the area as needed.

3.13 Visual

Land use in the area of the Pipeline Lateral consists primarily of industry, low density development, agricultural/pasture lands, wooded lots and open spaces. The area is traversed by several pipelines, transmission lines, canals, roadways, and rail lines. The majority of the Pipeline Lateral route will be adjacent to existing linear ROW such as railroads, canals, roadways, transmission lines and other pipelines.

There are no National Parks, National Wildlife Refuges, publicly owned lands, recreational areas, schools, hospitals, or churches are located within 1 mile of the proposed Pipeline Lateral (LDSS, 2006; LDHH, 2006 and 2007; LDOE, 2007).

Major roads in the vicinity of the Pipeline Lateral include Interstate 10, Highway 90, County Road 27, and County Road 108 - none of which are considered scenic highways in Calcasieu Parish according to the National Scenic Byways Program (2010).

Of the 15 water bodies crossed by the proposed Pipeline Lateral, none are designated by the Wild and Scenic Rivers Council (WSRC) as being a National Wild and Scenic River (WSRC, 2010).

3.14 Occupational Safety and Health

Denbury implements a company-wide Health, Safety and Environmental (HSE) Management Program. These initiatives are communicated to employees through new employee orientations, formal training programs, regularly scheduled safety meetings and field visits by HSE staff. Routine audits are conducted to document compliance with federal, state and local regulations and with company policies and procedures. Details of the HSE program are provided in the following section.

3.14.1 Construction

Construction sites are classified as high-risk environments due to the health and safety risks that are present onsite, including noise hazards; biological hazards; slip, trip, and fall hazards; electrocution; construction equipment hazards; and potential exposure to hazardous materials or extreme weather conditions. The construction activities of the proposed Pipeline Lateral include, but are not limited to: clearing and grading, trenching, welding, backfilling, hydrostatic testing, and cleanup. Equipment that may pose hazards include: track hoes/back hoes, trench safety equipment, forklifts, dump trucks, water tankers, compaction equipment, electrical equipment dozers, cranes, welding equipment, and graders. Denbury would mitigate these risks through compliance with Occupational Safety and Health Administration (OSHA) standards including Title 29 of the Code of

Federal Regulations (29 CFR 1926, Safety and Health Standards for Construction), applicable state and local labor laws, and through good business practices (OSHA, 2010).

3.14.2 Operations

The DOT, PHMSA maintains the authority to regulate interstate carbon dioxide pipelines under the Hazardous Liquid Pipeline Act of 1979, and PHMSA regulates the design, construction, operation, maintenance, and spill response planning for regulated pipelines.

Denbury's operational goals, as outlined below, include a strong commitment to health, safety and environmental performance:

- Comply with all pertinent environmental and safety regulations and requirements;.
- Set HSE targets and goals annually to measure our performance, to achieve superior results and continually improve.
- Monitor, revise and re-employ safety systems and environmental assessments on a regular basis.
- Provide education and training to our employees in order for them to have the knowledge, skills, and understanding to perform their responsibilities and duties at the highest level.

Denbury measures and regularly communicates its progress towards these goals by tracking four "Key Performance Indicators" (KPI)—safety, spill prevention, training, and regulatory compliance. Performance towards these targets is also assessed annually as part of its employee compensation package.

3.14.2.1 Safety

Safety is the first metric against which Denbury measures its operational HSE goals. Through June 30, 2009, Denbury had a Total Recordable Incident Rate (TRIR) of 1.43, the lowest rate measured in the company's last three years (Figure 3-12). The TRIR is the rate at which the total number of OSHA recordable incidents occurs for every 200,000 hours worked. The Bureau of Labor Statistics (BLS) has provided the most recent data for occupational injuries and illnesses in 2007. The oil and gas extraction sector had an average TRIR of 1.7 in 2007 (BLS, 2007). Denbury exceeded this rate in 2007 but has lowered its TRIR each year.

Of these incidents, there are cases that resulted in days away from work, restricted duty, or job transfer. According to BLS, the oil and gas extraction sector had a rate of 1.2 for such occupational injuries and illnesses (BLS, 2007). Denbury was significantly below this rate in 2007 with a rate of 0.28; furthermore, Denbury has maintained a rate lower than this industry average through 2009.

FIGURE 3-12
Denbury's Total Recordable Incident Rate as Compared to Oil and Gas Extraction Sector Industry Average

Source: Denbury, 2010

3.14.2.2 Spill Prevention

Spill prevention is the second metric against which Denbury measures its operational HSE goals. Denbury strives to reduce and prevent spills and releases in the fields in which they operate. The spill prevention program incorporates employee training, management supervision, improvements in operating procedures, and new investments in technology and equipment. The implementation of this program has seen marked achievement in reducing and preventing spills and releases from 2007. From 2007 to 2008 alone, Denbury improved 84 percent in its release volume (barrels) to million barrels produced ratio. Excluding two large well control events at Eucutta and Smithdale Fields, Denbury still maintained an improvement of 32 percent. Denbury's response to the well control event at Smithdale Field has been utilized by both the EPA and the Mississippi Department of Environmental Quality (MDEQ) as a case study in lessons learned on effective response procedures. Denbury briefed federal on-scene coordinators and emergency response officials.

Denbury maintains a company-wide Emergency Response Plan to cover various emergency events such as spill response, well control events, natural disasters, fire, and pandemics. Field locations also maintain site-specific emergency response procedures for these events such as Facility Response Plans. Additionally, SPCC Plans are prepared and updated at the field locations as applicable.

3.14.2.3 Employee Training

Employee training is the third metric against which Denbury measures its operational HSE goals. Denbury implements a company-wide comprehensive training program covering HSE matters, including job-specific and productivity training. The HSE training comprises

computer-based, classroom and field training exercises. Some examples of required training for field personnel are listed below:

- Accident Prevention
- Asbestos Awareness
- Confined Space Entry
- Electrical Safety
- Fire
- Forklift Safety
- Hazard Communications
- Hazwoper Awareness
- Hearing Conservation
- Lockout/Tagout Authorization
- Personal Protective
- Respiratory Protection
- Safety Overview
- Small Spills
- Workplace Emergencies
- Workplace Violence

3.14.2.4 Regulatory Compliance

Regulatory compliance is the fourth metric against which Denbury measures its operational HSE goals. Denbury strives to achieve full regulatory compliance with applicable federal, state, and local HSE regulations and to minimize its operational footprint on the environment. A key component of success with this KPI is conducting routine audits to identify and generate corrective actions. Denbury often acquires older properties during expansion of operations, and therefore, is often in the situation of correcting existing adverse environmental issues while also striving to minimize potential future impacts.

SECTION 4.0

Environmental Consequences

4.1 Project Area and Topography

The proposed Pipeline Lateral is located entirely within Calcasieu Parish in the southwestern portion of Louisiana. Specifically, the Pipeline Lateral lies southwest of Sulphur City, extending from the Calcasieu River Shipping Channel generally north-northeast across Interstate 10 to the interconnect with Denbury's and an affiliate's Green Pipeline north of the intersection of WPA Road and State Highway 90. The Pipeline Lateral begins (MP 0.0) approximately 4.4 miles southwest of Lake Charles; 8.0 miles north of Lake Calcasieu; and approximately 30 miles north of the Louisiana Gulf of Mexico coast. An overview map of the Project area is provided as Figure 2-1.

The Pipeline Lateral's permanent ROW encompasses 72.32 contiguous acres of land collocated primarily along existing ROW corridors (e.g., pipeline, railroad, and transmission line) for most of the route. Surrounding land use is primarily comprised of developed industrial and residential areas, forested upland and wetlands, and pasture or agriculture.

Topography along the Pipeline Lateral is generally flat with low relief and elevations generally ranging from sea level to approximately 15 feet AMSL. Low circular mounds and occasional low coastal ridges and indistinct relict fluvial channels are present throughout the area of the Pipeline Lateral. A Site Location Map with USGS topographic map background is provided as Figure 3-1.

4.1.1 Impacts

Potential impacts to topography may occur during construction of the proposed Pipeline Lateral as a result of land clearing activities and pipeline trenching and installation activities. Prior to the commencement of pipeline and trenching activities, existing trees and woody vegetation within the ROW corridor would be removed to facilitate construction access and safe construction operations. Removal of woody vegetation and root masses is likely to result in minor and localized temporary disturbances to the land surface. Pipeline trenching activities will have a direct temporary impact on the surrounding topography as a trench, approximately five-feet deep, is excavated in preparation for pipeline installation. Spoil removed from the trench will be stockpiled immediately adjacent to the trench within the construction ROW then replaced into the trench following pipeline installation.

4.1.2 Mitigative Measures

The Pipeline Lateral ROW will be re-contoured and re-vegetated as near to pre-construction conditions as is practicable following construction to allow for operational activities. Adjacent elevations and topography will be referenced to ensure that the ROW contours are consistent with the surrounding area. Site restoration activities are further discussed in Section 4.3.1.2. Soil mitigation measures including top soil segregation and erosion and sedimentation control are discussed in Section 4.6.2.

4.2 Climate, Meteorology, and Air Quality

4.2.1 Existing Source Emissions

Past air point source emissions from Calcasieu Parish are reported from information provided by LDEQ. With the exception of ammonia, HAPs, and Urban HAPs which are reported for 2002, the remaining pollutants in Table 4-1 are reported for 2008.

TABLE 4-1
2008 Calcasieu Parich Point Source Facility Emissions
Denbury Lake Charles, Louisiana, EIV

Pollutants	Total Facility Emissions, tons
CO	9,306
NOx	24,281
Lead (Pb)	0.22
VOC	9,485
SO2	45,530
PM2.5	2,326
PM10	3,137
NH3	94
HAPs	6,763
Urban HAPs	727

Source: EPA, 2010d (from 79 Facilities for NH_3, HAPs, and Urban HAPS for 2002)

Remaining pollutant emissions from LDEQ Emission Inventory Data Sets for 2008 from 42 unique facilities (LEDC, 2010)

4.2.2 Future Air Emission Sources

A search of the TCEQ Web site (TCEQ, 2010c) for pending New Source Review (NSR) construction permits in Jefferson County identified 10 unique projects at 10 separate facilities. These projects have the potential to impact future emissions.

4.2.3 Air Permitting and Compliance

The site is located in an ozone attainment area but may become an ozone non-attainment area with marginal classification in the near future. Most air emissions occur during the construction phase of the project with only a very small amount, if any, of fugitive emissions occurring during operation. The construction emissions will have short term, direct impacts on air quality during periods of construction but are temporary and would cease after construction ceases. The State of Louisiana has addressed temporary and minor emissions in its State Implementation Plan (SIP).

The project will not generate routine emissions of air contaminants.

Preliminary analysis suggests there are no operating permit requirements for this project. The project is expected to be exempt from permitting requirements through one of the following:

- Facilities with potential emissions less than 5 tons per year (tpy) of any regulated air pollutant as defined by the Federal Clean Air Act, less than 15 tpy of all such defined pollutants combined, and less than the minimum emission rate (MER) for each toxic air pollutant. See "Act 547" below for more information on this exclusion.

- **Small Source Exemptions**
  If not exempt as described above, a source may still qualify for a small source exemption under Louisiana Administrative Code (LAC) 33:III.501.B.4.

  The owner or operator of any source which is not a major source may apply for an exemption from permitting requirements provided each of the following criteria is met:

  1. The source emits or has the potential to emit no more than 5 tpy of any regulated pollutant.
  2. The source emits or has the potential to emit less than the MER listed in LAC 33:III.5112, table 51.1, for each Louisiana toxic air pollutant.
  3. No enforceable permit conditions are necessary to ensure compliance with any applicable requirement.
  4. No public notice is required for any permitting or other activity at the source.

- **Insignificant Activities**
  The LDEQ has also developed a list of insignificant activities (by size, type of pollutant, and activity) which are exempt from permitting (LAC 33:III.501.B.5). Note: In order to claim an activity is exempt pursuant to LAC 33:III.501.B.5.D, see Case By Case Insignificant Activities. Some examples that could apply to this project:

  – Surface-coating of equipment during miscellaneous maintenance and construction activities, including spray painting, roll-coating and painting with aerosol spray cans, provided no paint or coating exceeds a maximum 3.5 lb/gal organic toxic air pollutant listed in LAC 33:III.5112, Table 51.1 or 51.3, and no paint or coating exceeds any limitations listed in LAC 33:III.2123. This activity specifically does not include any facility whose primary business activity is surface-coating or includes surface-coating of products;

  – Miscellaneous equipment maintenance or construction unless otherwise regulated by state or federal regulation, which may include, but is not limited to, such activities as: welding, steam cleaning, equipment used for hydraulic or hydrostatic testing, miscellaneous solvent use 1, miscellaneous sandblasting, sweeping, non-asbestos insulation removal, acid washing, caustic washing, water blasting, application of refractory and insulation, brazing, soldering, the use of adhesives, grinding, and cutting

  – Exhaust emissions or vehicle refueling emissions from cars, trucks, forklifts, courier vehicles, front-loaders, graders, cranes, carts, maintenance trucks, locomotives, helicopters, marine vessels, and other self-propelled on-road and non-road mobile sources unless required to obtain a permit under Title V of the Clean Air Act. This

exemption does not include any transportable emissions units such as temporary compressors or boilers, unless regulated by Title II of the Clean Air Act. This exemption does not cover loading racks or fueling operations covered by LAC 33:III.Chapter 21

- Miscellaneous additions or upgrades of instrumentation or control systems
- Emissions from *oil and gas well and pipeline* as defined in accordance with LAC 33:III.502

Since the project will not generate routine emissions of air contaminants, preliminary analysis suggests there are no additional regulatory requirements. Some regulations to review to verify non-applicability are the following:

- The Highly Reactive Volatile Organic Compound (HRVOC, 30 TAC Chapter 115) Rules apply to HRVOC emitting sources located in the Houston-Galveston-Brazoria (HGB) area.
- The CAA Title V Operation Permit (CAA, Title V, 40 CFR Part 70 and 30 TAC Chapter 122) applies to facilities that fall within 40 CFR 70.3 designations.
- Acid Rain Permits (CAA, Title VI, 40 CFR Part 72 and 30 TAC Chapter 122) are submitted, issued, and monitored by the Title V permitting authority and apply to combustion units generating SO_2 emissions.
- The Clean Air Interstate Rule (CAIR) caps emissions of SO_2 and NO_x in the eastern United States (including Louisiana). This rule will be replaced but remains active in the interim.
- National Emission Standards for Hazardous Air Pollutants (NESHAPs, 40 CFR Part 61, 30 TAC Chapter 113).
- Maximum Achievable Control Technology (MACT, 40 CFR Part 63, 30 TAC Chapter 113).
- New Source Performance Standards (NSPS, 40 CFR Part 60, 30 TAC Chapter 116).

These regulations should be reviewed for applicability.

4.2.4 Impacts

4.2.4.1 Project Air Emissions

The bulk of project air emissions will occur during the construction phase and will mostly comprise PM emissions from dust and combustion emissions from heavy equipment usage. PM emissions from dust during the construction phase can be estimated using EPA AP-42 emission factors for heavy construction operations (EPA AP-42 Chapter 13.2.3) and are shown below assuming three months of construction activity across 187 acres (11.6 miles of pipeline by 95 feet wide).

PM Emissions = (1.2 tons/acre/month) x (3 months activity) x (187 acres) = 673 tons PM

This estimate is conservatively high because it uses a total suspended particulate (TSP) emission factor and therefore assumes all TSP is PM_{10}, does not account for dust control

measures (which are typically used or implemented during construction), and assumes construction activity occurs for the three entire months.

Emissions from combustion equipment were estimated using equipment ratings, quantity and type of equipment, duration of usage, and are shown in Table 4-2.

An operation phase air emissions for the 11.6-mile pipeline will not be applicable because all of the pipeline is expected to be underground. It is assumed that the pipeline does not include flow pumps or compressors along the ROW because the CO_2 source would provide the pressure and flow rates necessary to deliver the CO_2 from the source to the Green Pipeline interconnect. For aboveground facilities (valve site and meter station), the associated equipment may emit fugitive emissions, which would be the primary source of greenhouse gas emissions. These emissions will be the same speciation as the content of the pipeline and mostly CO_2 (estimated 99.32 percent CO_2, 0.67 percent CH_4, and 0.01 percent CO).

TABLE 4-2
Uncontrolled Estimated Project Air Emissions
Denbury Lake Charles, Louisiana, EIV

Activity	Pollutant Emissions, Tons									
	PM	Pb	SOx	NOx	VOC	CO	CO2	CH4	N2O	HAPs
Construction Phase Combustion	6.75	0.0004687	1.575	112.17	7.485	24.33	8,518	0.346	0.069	0.197
Construction Phase Dust	522									
Alternative Emissions, Railcar Transit						21	211,126	1,424		
Alternative Emissions, Truck Transit						21	211,126	1,424		

Criteria pollutant emissions for construction phase combustion provided by Denbury.

PM Emissions from Construction Phase Dust were estimated using AP-42 Chapter 13.2.4

GHG emissions estimated using methodologies provided in API Compendium of Greenhouse Gas Emissions Methodologies for the Oil and Natural Gas Industry, August 2009.

HAP Emissions from Construction equipment combustion were Estimated using EPA AP-42 Chapter 3 For Internal Combustion, Table 3.3-1 For Diesel Fuel

Lead (Pb) Emissions were estimated using emission factors from AP-42 Chapter 1 Table 1.3-10

Alternative Emissions were estimated using Rail/Truck Transit TOC emission factors from AP-42 Chapter 5.2.2.1.3 For gasoline and overestimated emissions assuming all of the TOC was CO2 product (99.32% CO2, 0.67%CH4, and 0.01%CO)

The project emissions for criteria pollutants (without consideration of dust from construction activities) will be less than 1 percent of the total existing inventory for each pollutant (e.g., NO_x will be less than 0.8 percent of the total existing inventory and the project emissions of CO will be less than 0.4 percent of the total existing inventory). Therefore, any emissions associated with the pipeline operations will be minimal.

Overall, Greenhouse gas emissions will be greatly decreased as a result of this entire project. The CO_2 (with trace amounts of CO and CH_4) that is proposed to be captured is currently

being directly released to the atmosphere. This point source will be captured and any emissions from this source will be limited to pipeline fugitives.

4.2.5 Mitigative Measures

For dust emissions from construction activities, typical control techniques such as watering, chemical stabilization, or reduction of surface wind speed with windbreaks or source enclosures will be used. Additionally, preventative techniques such as elimination of mud/dirt carryout on paved roads and mitigation measures such as cleanup of spillage on paved and unpaved travel surfaces and clean-up of material spillage at transfer points will also be employed.

For combustion emissions from construction equipment, proper maintenance of the combustion equipment is the most effective method of preventing blue smoke emission from all types of internal combustion (IC) engines. Reducing equipment idle run time and use of lower emission fleet vehicles can also reduce emissions. The motor vehicles used for the project will comply with 30 TAC Chapter 114 Control of Air Pollution from Motor Vehicles which includes requirements for vehicle inspection and maintenance, accelerated vehicle retirement, mobile emission reduction credits, low emission fuels, non-road large spark-ignited engine emission specifications, operational controls, and mobile source incentive programs.

For assessing pipeline fugitive emissions along a pipeline, if the pipeline is constructed above ground an industry tool used is a vehicle-mounted CO_2 monitoring system that travels along the pipeline detecting CO_2 leaks to the atmosphere. For this project the pipeline will be buried and therefore, any monitoring and leak detection would be associated with the Operations monitoring and compliance programs.

4.3 Water Quality

4.3.1 Surface Water

4.3.1.1 Impacts

Stream crossings by pipeline projects can have significant short-term effects on downstream water quality and habitat. However, pipeline construction impacts on aquatic habitats have been shown to be localized in extent and short term in duration. While environmental effects of stream crossing activities are a primary factor in selecting a particular crossing method, other factors, such as constructability, success, contractor safety, and cost, also are considered when determining what stream crossing method to employ.

Construction and mitigation for water body crossings by the Pipeline Lateral will follow procedures outlined in an Environmental Construction Plan (ECP). Typically, water body crossings will be made using one of the following methods:

- **Crossing Method 1** (Wet Crossing less than 50 feet). This method is applicable to small perennial streams (less than 50 feet wide), field and roadside ditches, and intermittent streams. The stream should be small enough to enable the equipment to work from the banks. A backhoe will open a temporary trench within the flowing stream, the pipe will be placed and the trench will be backfilled as quickly as possible to minimize impacts.

- **Crossing Method 2** (Dry Crossing less than 30 feet). This method is applicable to perennial streams (with flow) less than 30 feet in width with downstream water users, or listed species present in the stream. Stream flow may be channeled into one or multiple flume pipes to convey water across the trench and maintain downstream flow, or alternatively, a dam-and-pump arrangement may be employed to convey the stream water around the construction area. The trench will be excavated from under the flume pipe, the pipeline will be threaded under the flume, the trench will be backfilled, and the flume pipe will be removed to restore natural downstream flow.
- **Crossing Method 3** (Wet Crossing greater than 50 feet). This method is applicable to perennial streams greater than 50 feet in width that have not been designated to be directionally drilled. The trench will be opened within the flowing stream using a backhoe or dragline, and the pipe will be pulled or floated into place. Flow in these streams will most likely be sufficient to inundate the trench and allow for a natural downstream flow. Denbury will ensure that sufficient downstream flow is maintained during construction. Following installation of the pipe, the trench will be backfilled.
- **Crossing Method 4** (Horizontal Directional Drill). HDD involves using specialized equipment to install pipelines beneath wetlands or waterways, which potentially minimizes environmental impacts. However, environmental impacts such as turbidity and deposition of dredged material can occur from the discharge of drilling muds. The applicability of this method is subject to variety of site specific physical factors. Therefore, this method is applicable to those water bodies with conditions determined to be suitable.

HDD involves using specialized equipment to install pipelines beneath wetlands or waterways, which potentially minimizes environmental impacts. However, environmental impacts such as turbidity and deposition of dredged material can occur from the discharge of drilling mud. The applicability of this method is subject to a variety of site-specific physical factors that are investigated for each potential HDD crossing to determine if a potential HDD would be feasible. Denbury is currently evaluating an HDD crossing of the Bayou D'Inde and Unnamed Man-Made Canal to the west of Little Bayou D'Inde. The HDD would minimize in-stream construction activities and potential short-term turbidity impacts associated with the other crossing methods. Section 1.4.1.5 describes the HDD method in more detail.

Prior to operation, the integrity of the pipeline is evaluated through hydrostatic testing. Pipeline integrity is tested by capping pipeline segments with test manifolds, filling a capped segment with water, subjecting the water to pressure, and monitoring the pressure. Hydrostatic testing of the pipe would be performed in multiple segments and would address the entire pipeline. Hydrostatic test water would be withdrawn from readily available water sources along the pipeline route or from municipal sources and would be discharged onsite in a vegetated upland area or offsite at a permitted wastewater treatment facility. The volume of water required for hydrostatically testing the pipeline is approximately 14,000 barrels or 588,000 gallons. This is the quantity of water required to test the longest segment of the pipeline that extends from the proposed intermediate block valve to the connection to Denbury's and an affiliate's Green Pipeline.

4.3.1.2 Mitigative Measures

Denbury would mitigate potential impacts to surface water quality and quantity by obtaining and complying with all applicable water quality and quantity permits, such as National Pollutant Discharge Elimination System permits for Stormwater Discharges Associated with Construction Activities and for Hydrostatic Test Water Discharges.

Denbury has collocated the proposed Pipeline Lateral with existing ROW corridors and cleared areas to the greatest extent practicable. This design technique minimizes new crossings of water bodies and maintains intact riparian corridors, to the extent possible. Intact riparian corridors minimize sedimentation and turbidity impacts in water bodies. During restoration of the workspace, stream banks would be restored to pre-construction contours, reducing or eliminating potential long-term effects of the pipeline crossing, such as erosion or modification of stream flow conditions.

To the extent practical, Denbury would plan its construction window for major water bodies during the time of year when low water flows are normally encountered. Construction would be prioritized in major watersheds that are prone to longer term flood events, provided that low water levels are present and normal construction methods can be utilized. For localized, short duration flood events, construction would stop until the water subsides. If flood conditions persist during this time, Denbury would wait until conditions improve at least to a point where special techniques for saturated conditions can be employed.

During project design, efforts would be made before, during, and after pipeline construction to minimize the extent and duration of project-related disturbance to water resources. Denbury would develop a Horizontal Directional Drill Contingency Plan and a Site-Specific Crossing Plan. The Horizontal Directional Drill Contingency Plan provides specific procedures and steps to contain inadvertent releases of drilling mud during the construction of various water bodies (and other type crossings, i.e., highways, etc.) using HDD techniques. Elements of the plan include: Monitoring and Sampling Procedures, Notification Procedures, Corrective Action and Cleanup, and Abandonment.

Appropriate construction techniques would be used to prevent turbidity resulting from erosion of adjacent areas during and after construction, and erosion control measures would be implemented to minimize siltation, sedimentation, and other impacts that may temporarily affect surface water bodies in the construction area. Denbury would avoid and minimize potential adverse impacts to streams by implementing the following:

- Expediting construction and limiting the amount of equipment and activities in water bodies
- Reducing the disturbance to water body banks, bed, and vegetation to the extent practical, and minimal clearing of trees and other plants in the temporary workspace to enable leaving in place as much vegetation as possible on stream banks within the temporary workspace
- Constructing water body crossings as perpendicular to the axis of the water body channel as engineering, safety, and routing conditions allow
- Maintaining ambient downstream flow rates

- Removing all construction material and structures from the water body immediately after construction
- Restoring stream channels and bottoms to their preconstruction contours or better
- Permanently stabilizing stream banks and adjacent upland areas after construction
- Inspecting ROWs periodically during and after construction and repairing any erosion controls and/or performing restoration, as needed, in a timely manner
- Padding with blasting mats if any explosives are required within the water body; no spoil material would be used for padding

Denbury would evaluate stream crossing methodologies based on field and engineering studies and in response to agency and landowner concerns. Actual field conditions at the time of construction would also affect the appropriate crossing method for a particular stream. Denbury would employ project environmental inspectors, in consultation with Denbury's project manager and the construction contractor, to identify or approve the appropriate crossing method for each location, based on site-specific conditions prior to and at the time of construction. Selected crossing methods for water bodies would be in compliance with applicable state and federal regulations and restrictions.

To minimize potential impacts to water bodies crossed by the proposed Pipeline Lateral, equipment will be parked, maintained, or fueled away from any water body and the contractor will implement procedures as described in its SWPPP to prevent spills and provide prompt cleanup in the event of a spill. If there is no reasonable alternative to maintaining the required buffer from water bodies during refueling, the contractor will have secondary containment and other spill prevention and cleanup measures in place, and will receive approval from the Environmental Inspector before proceeding.

Disposal of construction waste materials will follow local, state, and federal regulations and will be properly transported to approved public or private waste disposal sites. In addition, hazardous waste materials, chemicals, fuels, and lubricating oils will not be stored within close proximity of any water body, wetland, or designated watershed area if possible.

During water intake for hydrostatic testing, Denbury would monitor intake to minimize in-stream effects, such as entrainment of fish or aquatic species, and to ensure adequate water flow for aquatic organisms and downstream users. Denbury would also reuse water to test separate portions of the pipeline to reduce water withdrawals, to the greatest extent practicable. Hydrostatic test water discharges would have a negligible effect on water resources due to the high quality of the effluent and the energy dissipation and filtration devices used during the discharge process. These techniques would capture the small amount of solids released during discharge as well as decrease the impacts from erosion. Return of the test water to the surrounding tributaries and streams would have negligible impacts to downstream users because the discharge point would be within a well vegetated upland area adjacent to the construction corridor and would avoid or minimize direct surface runoff to water bodies. Because of the low volume of discharge, no change in flood frequency or duration is expected.

Environmental impacts from the withdrawal and discharge of test water would be minimized by utilizing the measures outlined in Denbury's ECP, including:

- Locating hydrostatic test manifolds outside of wetlands and riparian areas as practical
- Withdrawing from and discharging to water sources in compliance with appropriate agency requirements that consider the protection of fisheries and other resources on a case-by-case basis
- Complying with all appropriate permit requirements
- Screening the water intake manifold to avoid entrainment of fish
- Suspending the water intake hose with a float to reduce the uptake of sediment from the water body floor
- Maintaining adequate flow rates to protect aquatic life and provide for all water body uses and downstream withdrawals of water by existing users
- Anchoring the discharge pipe for safety
- Discharging test water to a suitable receiving body of water, across a well-vegetated upland area, or filtered through a filter bag or into erosion control barriers
- Discharging test water against a splash plate or other energy dissipating device
- Controlling the rate of discharge in order to prevent flooding or erosion

Following construction, water body crossings will be restored to preconstruction contours and elevations; all construction material and structures will immediately be removed from the water body; stream channels and bottoms will be restored to their preconstruction contours or better; and stream banks and adjacent upland areas will be permanently stabilized. Existing erosive conditions that may affect the operation of the proposed pipeline facilities will be corrected.

4.3.2 Groundwater

4.3.2.1 Impacts

There are currently no plans to withdraw from or discharge directly to groundwater for the construction of the proposed Pipeline Lateral. Of the 112 registered wells within 0.25 mile of the Project, one may be situated within the limits of disturbance; however, this well appears to be located on a dirt road. During civil surveys of the pipeline route, Denbury would document water wells within the study corridor, particularly within the limits of disturbance. Denbury would assess the status of these wells (active or abandoned), and, if active and if the well cannot safely remain in operation during and/or after construction, Denbury would coordinate with the well owner to plug and abandon the well in accordance with the Water Well Rules, Regulations and Standards as administered by the LA DOTD (2010). Denbury would coordinate with the well user to relocate the water well outside of the limits of disturbance or secure an alternate water source.

Because construction would be limited to surface ground layers and because the presence of hazardous materials would be limited and, where present, would be restricted to certain areas with appropriate secondary containment, impacts to groundwater are not anticipated.

4.3.2.2 Mitigative Measures

Impacts on groundwater resources would be minimized by implementing the construction techniques detailed in Denbury's ECP. The ECP would include guidance on such processes as blasting, trench breakers, trench dewatering, equipment refueling, and hazardous materials storage. As excavation depth typically would not exceed approximately six feet, installation of the proposed pipeline would involve construction within only the surface layers of soil.

If, during construction, areas are identified where blasting will be required, water wells, springs, and wetlands in the blasting area will be identified. A blasting plan would be developed to identify and address applicable regulatory requirements as well as outline safe construction blasting techniques and safeguards to be employed. Wells within the blasting area may be tested for water quality prior to blasting, and then again upon completion of construction. In the unlikely event that construction activities temporarily impair well water, alternative sources of water will be identified or Denbury will otherwise compensate the owner. If permanent well damage is substantiated, Denbury will either compensate the well owner for damages or arrange for a new well to be drilled.

Springs and wetlands within the proposed pipeline corridor will be documented and characterized during environmental and civil surveys of the pipeline route. Upon completion of pipeline construction, the pipeline corridor will be restored to its pre-construction contours and hydrological patterns. In the unlikely event that it is unable to restore a spring or wetland to its pre-existing condition, Denbury will work with the landowner and appropriate regulatory agencies to provide compensatory mitigation for the loss of the affected feature.

4.3.3 Floodplains

4.3.3.1 Impacts

Efforts would be made before, during, and after pipeline construction to minimize the extent and duration of project-related disturbance to floodplains.

A floodplain would be impacted by any activity that modifies the available flood storage within the designated area. The proposed pipeline installation is expected to have minor, short-term, direct impacts but no long-term, direct impacts to designated floodplains.

Short-term impacts may result from construction, underground installation, and open cutting within a floodplain. These impacts may be adverse or beneficial depending on whether they increase or decrease available flood storage. However, all disturbed areas would be returned to pre-construction contours and grades, such that long-term flood storage loss would not occur. Project design and construction will ensure that the flood-carrying capacity of each stream crossing is maintained and preserved as appropriate. Construction at the site will comply with 28 CFR Part 63 and FEMA review procedures by minimizing the amount of fill that would be placed in the flood hazard areas. No indirect impacts to floodplains are anticipated.

Rules and regulations related to floodplain management and flood damage prevention will be considered during the proposed pipeline installation. Approximately 3.5 miles of the proposed pipeline alignment traverses areas designated as within the 100-year floodplain.

Approximately 16.7 acres of 100-year floodplain occur within the proposed permanent ROW, and approximately 17.3 acres of 100-year floodplain occur within the temporary ROW. If the proposed Pipeline Lateral will require the construction of permanent access roads, Denbury will locate these roads outside of the 100-year floodplain, to the extent practicable. Denbury will consult with appropriate local floodplain management agencies prior to construction to verify compliance with requirements of NFIP regulations.

4.3.3.2 Mitigative Measures

Denbury intends to avoid, minimize, and if necessary, compensate for disturbances to floodplains and wetlands associated with the construction and operation of the proposed pipeline. All impacts to floodplains and wetlands are anticipated to be temporary, with no net loss of wetlands from the Pipeline Lateral activities. Some forested wetland areas will undergo a change in habitat type as a result of construction and operation. Mitigation will occur onsite through restoration of the disturbed areas as emergent wetland habitat in compliance with the General and Regional Conditions set forth by the USACE for all temporary construction impacts. Loss of forested wetland habitat will be mitigated by the purchase of wetland credits from an approved bank, as required by conditions in the Section 404/401 permit to be obtained for the Pipeline Lateral.

Any approach to compensatory mitigation would follow the EPA and USACE Wetland Compensatory Mitigation Rule (March, 2008) emphasizing a watershed-level approach to compensation. Previous EPA and USACE guidance favored mitigation in proximity of impacts, but the new Wetland Compensatory Mitigation Rule (March, 2008) lists this hierarchy of mitigation preferences: 1) mitigation banks, 2) in-lieu fee programs, and 3) permittee-responsible mitigation, in the event neither of the previous two options are practicable.

Denbury would mitigate for unavoidable impacts following USACE rules and guidance, with the goal of no net loss of wetland functions and values. This approach follows USACE mitigation sequencing and, where compensation is required, uses a watershed approach to select available resource replacement sites that offer the greatest functional benefits as outlined in the compensatory mitigation guidelines.

Denbury proposes a two-pronged approach to compensatory mitigation for impacts: 1) rehabilitation of wetlands temporarily impacted by construction in-situ; and 2) purchase of mitigation credits from approved wetland mitigation banks or in-lieu fee programs. To compensate for permanent conversions of forested wetlands or permanent impacts from associated facilities due to construction of the Pipeline Lateral, Denbury proposes to purchase credits from wetland mitigation banks in the affected watershed areas. Compensatory mitigation requirements for the Pipeline Lateral will be satisfied prior to construction.

4.3.4 Wetlands

4.3.4.1 Impacts

Wetland information for the Pipeline Lateral area was derived from readily available public sources, which indicate that the proposed corridor would traverse several wetland areas. Prior to construction, Denbury will conduct field surveys to delineate jurisdictional wetlands, in accordance with USACE guidelines and standard practice. Denbury would

utilize these data during project design to avoid and minimize impacts to wetland resources, to the extent practicable. Where avoidance is not achievable, Denbury would compensate as necessary for disturbances to wetlands associated with the construction and operation of the Pipeline Lateral. All impacts to wetlands are anticipated to be temporary, with no net loss of wetlands from Pipeline Lateral activities. However, some wetland areas would potentially undergo a change in habitat type as a result of construction and operation, such as from forested wetland to herbaceous wetland.

Denbury would coordinate with the appropriate local, state, and federal agencies prior to initiating construction to ensure that all applicable permits and approvals have been obtained. Denbury would reduce its construction ROW to 75 feet within wetland areas.

4.3.4.2 Mitigative Measures

Denbury will consult with the USACE and other applicable regulatory agencies in developing appropriate wetland crossing methodologies, and will comply with permit terms and conditions. Four general construction procedures typically will be used to minimize impacts associated with construction of the proposed pipeline on wetlands, as described below. Efforts will be made before, during, and after pipeline construction to minimize the extent and duration of project-related disturbance to wetland resources.

- **Crossing Method I-Standard Pipeline Construction.** This method will be used in seasonal wetlands that are sufficiently dry such that soils are stable enough to support equipment without sinking (e.g., mineral hydric soils), or in wetlands that have already been disturbed to provide sufficient traffic stability. A reduced construction ROW of 75 feet will be maintained and overland construction techniques will be used, unless exceptions are required by site conditions. Vegetation will be cut just above ground level, leaving the existing root systems in place. Grubbing will occur only at the ditch line. All cut vegetation will be removed from the wetland and disposed of by an approved method. Topsoil will be segregated, and no matting will be used if conditions are dry. The length of time that topsoil is segregated and the trench left open will be minimized to maintain seedbank viability.
- **Crossing Method 2-Conventional Wetland Construction.** This method will be utilized in wetlands where the soils are too wet (e.g., permanently or semi-permanently saturated and/or histic epipedon) to support mainline construction equipment. Timber mats will be used as necessary to support the construction equipment. A reduced construction ROW of 75 feet will be maintained. Vegetation will be cut just above ground level, leaving the existing root systems in place. Grubbing will occur only at the ditch line. All cut vegetation will be removed from the wetland and disposed of by an approved method. Topsoil will not be segregated due to saturated conditions.
- **Crossing Method 3- Push/Pull Wetland Construction.** This method will be used in wetlands with standing water (permanently or semi-permanently flooded) where it is necessary to use push/pull construction techniques. A construction corridor wide enough for only a single tractor to work on timber mats will be used. The trench will be dug and the pipe will be positioned in the trench. There will be no passing or working lanes, only room for spoil on each side of the trench with the digging/pulling tractor in the middle. A reduced construction ROW of 75 feet will be maintained. Vegetation will be cut just above ground level, leaving the existing root systems in place. Grubbing will

occur only at the ditch line. All cut vegetation will be removed from the wetland and disposed of by an approved method. Topsoil will not be segregated due to saturated conditions.

- **Crossing Method 4- HDD - Horizontal Directional Drill**. Directional-drilling methods will be used for specialized crossings of large and/or sensitive water bodies and wetland areas. In general, because an open-cut trench is not required, directional drilling results in less adverse impacts and less turbidity than conventional excavation methods. Directional drilling is limited in application and is dependent on critical wetland characteristics, including subsurface lithology, crossing length, burial depth, sediment composition, bank conditions, and access. Adverse environmental impacts that may result from drilling operations on waterway crossings would be related to discharge and transportation of drilling fluid; however, aside from turbidity effects, drilling fluid is a relatively environmentally benign substance. Mitigation of any adverse impact from drilling fluid would be by collection and cleanup of spilled material.

In general, Denbury will protect and minimize potential adverse impacts to wetlands by:

- Expediting construction in and around wetlands, and, to reduce disturbances of wetland soils, limiting the amount of equipment and mainline construction activities within wetlands
- Restoring wetlands to the original contours and flow regimes to the greatest extent practical
- Segregating wetland topsoil and its associated seedbank and returning it to the top when backfilling, where applicable
- Utilizing matting to protect the underlying soil and root stock, where applicable
- Removing stumps and root stock only along the trenchline; stumps and rootstock will be left in place for the remainder of the construction ROW to facilitate regeneration of natural revegetation
- Locating ATWS away from wetlands, where practical
- Reducing construction of ROW to 75 feet through wetland resources
- Permanently stabilizing upland areas near wetlands as soon as possible after backfilling
- Implementing appropriate erosion control procedures in and adjacent to wetlands during construction
- Inspecting the ROW periodically during and after construction, and repairing any erosion control or restoration features until permanent revegetation is successful

Restoration of wetland areas will occur by natural revegetation. Studies have shown that natural revegetation of wetlands in the Southeast has a higher success rate than planting wetlands due to inherent, regenerative capacities of seedbank and vegetative reproduction. To facilitate periodic surveys for maintenance activities, the area centered over the pipeline will be maintained in an herbaceous state. Wetland areas may be seeded with an annual rye directly after the completion of construction to ensure protection of the wetland soil from

erosion until natural vegetation is successful. No fertilizers or mulch materials will be introduced into wetland areas. Denbury will revegetate and restore adjacent upland areas utilizing seed mix and fertilizer/lime applications specified in compliance with NRCS standards for critical area plantings for Louisiana.

Denbury will mitigate for unavoidable impacts to wetlands in accordance with USACE rules and guidance, with the goal of no net loss of wetland functions and values. This approach follows USACE mitigation sequencing and, where compensation is required, uses a watershed approach (8-digit HUC code) to select available resource replacement sites that offer the greatest functional benefits as outlined in the compensatory mitigation guidelines.

Denbury proposes a two-pronged approach to compensatory mitigation for impacts to wetlands: 1) rehabilitation in-situ of wetlands temporarily impacted by construction; and 2) purchase of mitigation credits from approved wetland mitigation banks or in-lieu fee programs. To compensate for permanent conversions of forested wetlands or permanent impacts from associated facilities due to construction of the project, Denbury intends to purchase mitigation credits, participate in an in-lieu fee program, or provide onsite or offsite compensatory mitigation as required by the USACE permit conditions. Compensatory mitigation requirements for the Pipeline Lateral will be satisfied prior to construction.

4.4 Ecology

Impacts to terrestrial and aquatic wildlife, including threatened and endangered species, and mitigation of those impacts are discussed below.

4.4.1 Terrestrial Ecology

4.4.1.1 Impacts

Potential ecological impacts may occur during construction of the proposed Pipeline Lateral as a result of land clearing activities, utilization of access roads by project vehicles and equipment, pipeline trenching and installation activities, and the use of temporary workspaces. Direct impacts to terrestrial ecology and natural habitats will be minimized by the collocation of the Pipeline Lateral along existing ROW corridors and access roads to the greatest extent practicable.

Construction activities will result in temporary and permanent impacts to existing vegetation within the area of the Pipeline Lateral during site preparation, grading, and excavation of the corridor and alterations to existing access roads and temporary construction facilities as necessary. A summary of common vegetation in the Northern Humid Gulf Coastal Prairies ecoregion is provided in Section 3.4.1.

Construction of the proposed Pipeline Lateral would impact a total of 187.2 acres of land, of which 72.3 acres would be permanently impacted. The remaining 114.9 acres would be temporarily impacted during construction and allowed to revert back to the previous land use once construction of the Pipeline Lateral was completed. The primary land uses along the ROW are comprised of pasture/agriculture, forested upland and wetland areas, and low-density residential and industrial uses. A summary of land use category acreage and potential habitat impacts are summarized in Table 4-3.

TABLE 4-3
Land Use and Potential Habitat Impacts Associated with the Pipeline Lateral
Denbury Lake Charles, Louisiana, EIV

Land Use Category	Construction Acres	Permanent Acres	Total Acres	Potential Habitat Impacts
Open Water	0.1	0.0	0.1	Temporary impacts during construction. Permanent ROW returned to pre-construction contours and conditions.
Developed, Open Space	3.8	22.4	26.1	Temporary impacts during construction. Minor permanent impacts (e.g., no landscape trees re-planted in ROW).
Developed, Low Intensity	20.7	25.6	46.2	
Developed, Medium Intensity	3.3	3.6	6.9	
Developed, High Intensity	1.0	0.9	1.9	
Evergreen Forest	4.3	2.9	7.2	Temporary removal of forested area during construction to revert back after construction. Permanent ROW maintained in herbaceous state to facilitate pipeline maintenance.
Mixed Forest	0.8	1.3	2.2	
Shrub/Scrub	2.2	1.5	3.6	
Grassland/Herbaceous	0.0	0.2	0.3	Temporary land disturbance during construction. Permanent ROW returned to pre-construction conditions.
Pasture/Hay	9.8	29.9	39.7	Temporary disruption of agricultural operations during construction. Permanent ROW returned to pre-construction conditions and agricultural uses.
Cultivated Crops	0.7	1.6	2.3	
Woody Wetlands	25.6	25.1	50.7	Temporary removal of forested area during construction to revert back after construction. Permanent ROW maintained in herbaceous state to facilitate pipeline maintenance.
TOTAL	**72.3**	**114.9**	**187.2**	

Source: Multi Resolution Land Characteristics Consortium, 2001

A summary of common terrestrial wildlife in the Northern Humid Gulf Coastal Prairies ecoregion is provided in Section 3.4.1. Direct impacts to terrestrial wildlife during construction of the Pipeline Lateral are anticipated to be limited to temporary displacement and potential incidental mortality of less mobile terrestrial species. The amount of wildlife displaced by land disturbing activities and noise generation during project construction would be minimal, as the majority of the land that would be disturbed by the Pipeline Lateral has either been previously disturbed or is located immediately adjacent to existing ROW corridors that are routinely maintained. Displaced wildlife would likely inhabit similar adjacent habitats and return to the area following construction. Because sufficient suitable habitats are available for assimilation of displaced animals, any secondary impacts to animal populations in the area surrounding the Pipeline Lateral would likely be negligible.

Potential suitable habitat for migratory birds is likely present along the Pipeline Lateral corridor. Ecological field surveys will be conducted prior to construction that will assess

actual habitat suitability based on field conditions. Because of the similar habitat types in the region that would remain undisturbed, direct impacts to migratory bird species as a result of the proposed Pipeline Lateral are anticipated to be negligible.

Construction-related impacts to recreational areas, parks, wildlife areas, nature preserves, or other conservation areas would not occur.

No agency consultations regarding terrestrial ecology have been conducted for the Pipeline Lateral to date.

4.4.1.2 Mitigative Measures

Following construction, disturbed areas will be seeded in accordance with the seeding recommendations of the local NRCS or the respective landowners. Trees and other woody vegetation in upland and wetland areas will be allowed to re-establish naturally within the temporary ROW and other temporary workspaces cleared for Project construction. Denbury will maintain upland and wetland areas within the 50-foot permanent ROW in an herbaceous state to facilitate periodic maintenance of the Project area.

Impacts to terrestrial wildlife will be mitigated by minimizing the duration of construction and scheduling construction within any critical habitat identified during ecological field surveys to avoid nesting periods to the greatest extent practicable. Migratory bird populations in the Project area would be expected to peak during the winter months. Project construction could be scheduled to avoid disturbing preferred habitats during winter months, which would minimize the potential for impacts.

Project-specific consultations with the Louisiana Department of Wildlife and Fisheries (LDWF) will be conducted following ecological surveys to identify potential construction mitigation measures necessary for wildlife species in the Project area. Wildlife protection measures will comply with applicable federal, state, and local regulations.

4.4.2 Aquatic Ecology

4.4.2.1 Impacts

Construction of the proposed Pipeline Lateral across streams is likely to affect aquatic resources through soil and sediment disturbances, temporary removal of vegetation, potential incidental releases, and increased potential for turbidity and stream bank erosion. Impacts to aquatic resources in the Project area are anticipated to be minimal. The majority of the streams affected by the Project are small unnamed tributaries to Choupique Bayou and Little Bayou d'Inde that likely do not serve as critical habitat for many fish species. The fish species common to the Northern Humid Gulf Coastal Prairies ecoregion are summarized in Section 3.4.2. Ecological field surveys will assess the stream quality, aquatic habitat, and fish species present within the Project area.

No agency consultations regarding aquatic ecology have been conducted for the Project to date.

4.4.2.2 Mitigative Measures

To minimize long-term adverse impacts to aquatic organisms, all streams crossed by the Pipeline Lateral will be restored to pre-construction conditions to the greatest extent practicable.

During construction, specific stream crossing construction measures designated exclusively to minimize impacts on aquatic resources will be implemented. Specific crossing methods and mitigation measures are discussed in Section 4.2. Measures to prevent soil runoff and sedimentation of streams include silt fencing, slope breakers on steep slopes, hay bales across the ROW at critical points, plugs in trenches close to water crossings, and energy dissipating devices and sediment filters for the outlet of hoses during dewatering of the pipeline trench and at the point of discharge of hydrostatic test water.

Incidental spills may occur from storage containers, equipment working in or near streams, and fuel transfers. Spillage of fuels or lubricants into streams would be detrimental to the surrounding aquatic resources. A project-specific SPCC Plan will be developed and implemented to prevent and contain, if necessary, accidental spills into streams. Key components of the SPCC Plan will include limiting or prohibiting fuel storage, refueling, and maintenance of construction equipment within 100 feet of streams.

Following trench backfilling, the pipeline will be hydrostatically tested to ensure it is capable of operating at the design pressure. Water for the hydrostatic test will either be obtained from local water bodies or trucked in from local water sources. If water is obtained from a local water body (i.e., stream), the water will be pumped through screened intakes from a stream(s) located along or near the pipeline route. Upon completion of the testing, the water will generally be discharged back to the source through an energy-dissipating device onto a well-vegetated upland area to ensure impacts to the aquatic resources and water body itself are minimized. Alternatively, discharged water may be trucked offsite.

4.4.3 Threatened and Endangered Species

4.4.3.1 Impacts

No impacts to threatened or endangered species or critical habitat associated with construction or operation of the Pipeline Lateral are anticipated. Section 3.4.3 provides a list of the federal and state threatened or endangered species in Calcasieu Parish. The only species for which potential habitat exists in the area of the Pipeline Lateral is the Crested caracara (*Caracara cheriway*). Ecological field surveys will assess the suitability of habitat and potential presence of Crested caracara prior to the commencement of construction activities. There are no known occurrences of federal or state protected aquatic species in the vicinity of the proposed Pipeline Lateral.

4.4.3.2 Mitigative Measures

Project-specific consultations with the USFWS and Louisiana Natural Heritage Program section of LDGF will be conducted to identify mitigation measures to protect threatened and endangered species and critical habitat in the area of the Pipeline Lateral. Mitigation measures will comply with applicable federal, state, and local regulations.

4.5 Solid Waste Disposal

Impacts related to waste generation during Pipeline Lateral construction, proposed mitigation, and existing waste disposal areas within two miles of the pipeline corridor are presented below.

4.5.1 Impacts

Construction of the proposed Pipeline Lateral is anticipated to generate waste primarily consisting of non-hazardous solids such as timber cleared from the ROW, construction mats and scrap, packaging materials, and general refuse (e.g., trailer office materials and debris from employees). The solid waste generated will be collected from work areas and recycled or disposed of in temporary dumpsters maintained during construction. A private contractor will then empty the dumpsters on an as-needed basis and dispose of the refuse at a licensed solid waste disposal facility.

Project construction will require clearing or disturbance of approximately 29.3 acres of forested vegetation. Large trees cleared from the construction area will be sold whole as timber or cut, and either provided to the landowner or removed. Limbs and brush will be buried, chipped, burned, or otherwise disposed of as directed by the landowner and as required under federal, state, and local regulations.

Non-hazardous liquids associated with construction include fluids utilized during HDD operations. The HDD construction method utilizes a drilling fluid comprised primarily of water and bentonite, which is a naturally occurring, non-toxic, inert drilling fluid additive. Following HDD operations, the bentonite slurry is typically spread in upland areas as a soil supplement if permitted, or removed from the HDD site and disposed of in approved landfills.

Potential solid and liquid hazardous wastes associated with construction include sandblast abrasives (depending on use and type), paint thinner, and various solvents. Any hazardous wastes generated during construction of the proposed Pipeline Lateral will be disposed of at an EPA approved disposal site(s).

Pipeline construction contractors will be required to develop a Waste Management Plan (WMP), which will include specifications for handling, containment, and disposal of all wastes generated during construction. The WMP must be submitted for approval before construction begins. Construction contractors will characterize wastes and determine the locations for hazardous materials storage areas (if needed) within designated areas. Any such storage areas would be maintained in accordance with applicable federal, state, and local regulations.

A negligible amount of general refuse will likely be generated during operation and maintenance (O&M) of the ROW corridor. No permanent O&M facility will be constructed, maintained, or staffed as part of the Pipeline Lateral following construction activities; therefore, waste generation will be limited to periodic ROW O&M activities.

Known hazardous waste sites, as described in Section 3.5.2, will not be impacted by the construction or operation of the Pipeline Lateral.

4.5.2 Mitigative Measures

As stated above, all contractors associated with the Pipeline Lateral will be required to develop a project-specific WMP, which will include specifications for handling, containment, and disposal of all wastes (non-hazardous and hazardous) generated during construction. The WMP must be submitted to Denbury for approval before construction begins. Construction contractors will characterize wastes and determine the locations for

hazardous materials storage areas (if needed), transportation, and disposal. Any storage areas would be maintained in accordance with applicable federal, state, and local regulations. Once Denbury awards work to contractors and the contractor WMP has been approved, federal, state, and local waste management permits and regulations for the storage, handling, and disposal of waste will be obtained and complied with.

4.6 Land Use

4.6.1 Environmental Consequences

Construction and operation of the Pipeline Lateral would result in short-term negligible direct noise impacts to onsite workers and minor direct impacts to nearby residents and wildlife. Operation of construction equipment would result in noise levels of approximately 95dBA within the immediate construction area. This work would be a short-term minor impact to potentially sensitive receptors. Operation of the pipeline would not create noise impacts to the area. Should the pipeline be inspected by aerial overflights, these would be episodic events that would not adversely impact potentially sensitive receptors. Because the noise impacts from the Pipeline Lateral would be of short duration and limited to the construction phase, there would be minimal potential for interaction with other projects, so no cumulative impacts from noise would occur.

During construction, noise levels would be elevated, but primarily during daytime hours. Construction noise levels would be highest during clearing, trench excavation, final grading, and at HDD sites. Peak noise levels would be expected to be approximately 95dBA during these times and approximately 75 dBA at other times. Onsite persons at each location would be aware of the operation of equipment during construction. Nearby receptors would experience interference with outdoor conversations, depending on proximity to the construction area. However, elevated noise levels would be temporary and site noise conditions would revert to background levels after construction.

Wildlife in proximity to construction areas would be exposed to the elevated noise and would be expected to temporarily relocate from the active construction area. Following construction, any displaced animals would be expected to resume normal activity and return to use of the temporarily abandoned areas. Any construction-related noise impacts to wildlife would be temporary and minor. No noise impacts to wildlife would be expected during operation of the pipeline.

4.6.2 Impacts

Impacts to land use would result from the new ROW corridor associated with the proposed Pipeline Lateral. Construction of the proposed Pipeline Lateral would impact a total of 187.2 acres of land, of which 72.3 acres would be permanently impacted. The remaining 114.9 acres would be temporarily impacted during construction and allowed to revert back to the previous land use once construction of the Pipeline Lateral was completed.

Table 4-4 provides a tabulated summary of temporary and permanent impacts to land uses within the construction boundaries of the Pipeline Lateral. Land use categories as defined by the Multi Resolution Land Characteristics Consortium (2001) are described below.

- **Open Water -** All areas of open water, generally with less than 25 percent cover of vegetation or soil.
- **Developed, Open Space -** Includes areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for less than 20 percent of total cover. These areas most commonly include large-lot single-family housing units, parks, golf courses, and vegetation planted in developed settings for recreation, erosion control, or aesthetic purposes.
- **Developed, Low Intensity -** Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20-49 percent of total cover. These areas most commonly include single-family housing units.
- **Developed, Medium Intensity -** Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50 to 79 percent of the total cover. These areas most commonly include single-family housing units.
- **Developed, High Intensity -** Includes highly developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses, and commercial/industrial uses. Impervious surfaces account for 80 to100 percent of the total cover.
- **Evergreen Forest -** Areas dominated by trees generally greater than 5 meters tall, and greater than 20 percent of total vegetation cover. More than 75 percent of the tree species maintain their leaves all year. Canopy is never without green foliage.
- **Mixed Forest -** Areas dominated by trees generally greater than 5 meters tall, and greater than 20 percent of total vegetation cover. Neither deciduous nor evergreen species are greater than 75 percent of total tree cover.
- **Shrub/Scrub -** Areas dominated by shrubs less than 5 meters tall with shrub canopy typically greater than 20 percent of total vegetation. This class includes true shrubs, young trees in an early successional stage, or trees stunted from environmental conditions.
- **Grassland/Herbaceous -** Areas dominated by grammanoid or herbaceous vegetation, generally greater than 80 percent of total vegetation. These areas are not subject to intensive management such as tilling, but can be utilized for grazing.
- **Pasture/Hay -** Areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle. Pasture/hay vegetation accounts for greater than 20 percent of total vegetation.
- **Cultivated Crops -** Areas used for the production of annual crops, such as corn, soybeans, vegetables, tobacco, and cotton, and also perennial woody crops such as orchards and vineyards. Crop vegetation accounts for greater than 20 percent of total vegetation. This class also includes all land being actively tilled.
- **Woody Wetlands -** Areas where forest or shrubland vegetation accounts for greater than 20 percent of vegetative cover and the soil or substrate is periodically saturated with or covered with water.

TABLE 4-4
Land Use Impacts Associated with the Pipeline Lateral
Denbury Lake Charles, Louisiana, EIV

Land Use Category	Construction Acres	Permanent Acres	Total Acres
Open Water	0.1	0.0	0.1
Developed, Open Space	3.8	22.4	26.1
Developed, Low Intensity	20.7	25.6	46.2
Developed, Medium Intensity	3.3	3.6	6.9
Developed, High Intensity	1.0	0.9	1.9
Evergreen Forest	4.3	2.9	7.2
Mixed Forest	0.8	1.3	2.2
Shrub/Scrub	2.2	1.5	3.6
Grassland/Herbaceous	0.0	0.2	0.3
Pasture/Hay	9.8	29.9	39.7
Cultivated Crops	0.7	1.6	2.3
Woody Wetlands	25.6	25.1	50.7
TOTAL	**72.3**	**114.9**	**187.2**

Source: Multi Resolution Land Characteristics Consortium (2001)

No special land uses such as recreational areas, publicly-owned lands, historical sites, or protected water bodies would be impacted by the Pipeline Lateral. Approximately 176.6 acres of prime farmland would be impacted during construction (USDA, 2010). Impacts to prime farmland will be limited to the temporary disturbance to soil and the loss of crop production during construction. Agricultural practices would resume after the completion of construction activities.

As shown in Table 4-4, construction of the Pipeline Lateral would result in the permanent conversion of 29.3 acres of forested land. These areas would be revegetated with lower growth herbaceous species.

4.6.3 Mitigative Measures

The proposed Pipeline Lateral was collocated along existing ROW corridors to the extent possible so as to significantly reduce land use impacts to the surrounding area. The ROW will be re-contoured and re-vegetated as near to pre-construction conditions as is practicable following construction to allow for operational activities. The land use impact of the newly created permanent ROW is likely to moderate over time as vegetation becomes re-established. Site restoration activities are further discussed in Section 4.3.1.2. Soil mitigation measures including topsoil segregation and erosion and sedimentation control are discussed in Section 4.6.3.

Construction of the Pipeline Lateral is not anticipated to preclude future land uses in the area. The primary limitation to landowners would be that no structures would be allowed to be constructed within the 50-foot permanent ROW.

4.7 Geology and Soils

4.7.1 Impacts

Construction and operation of the Pipeline Lateral will be unlikely to affect the physiography and geology of the area.

Land-disturbing activities will occur to approximately 187.2 acres during construction of the Pipeline Lateral, which will increase the potential for temporary impacts to soils, including erosion and sedimentation, compaction, and topsoil mixing. Construction will temporarily impact approximately 176.6 acres classified by the NRCS as prime farmland soils.

4.7.2 Mitigative Measures

Best management practices (BMPs) to protect groundwater from incidental releases or spills of materials would be implemented as necessary. Denbury will have operational policies and procedures to manage such materials, so that an accidental spill should not occur. However, if such a spill were to occur, Denbury's SPCC plan will provide regulation on how to contain, manage, and clean up the spill.

Each of the soil map units crossed by the Pipeline Lateral are classified as Not Highly Erodible by the NRCS. All soils, regardless of erosion potential rating, generally have increased erosion potential when exposed, excavated, or stockpiled. Soil erosion will be mitigated through temporary erosion and sedimentation control measures during construction and implementation of permanent measures, such as revegetation, following construction.

Soil compaction will be mitigated by plowing or tilling severely compacted soils prior to revegetation.

Topsoil segregation will be implemented in all active agricultural areas and wetlands. Topsoil (down to six inches below ground surface) will be excavated and stockpiled separately from the underlying subsoil. Once the pipeline is installed, the subsoil will be placed in the trench first, followed by the topsoil. Denbury will ensure that appropriate control measures (e.g., silt fence or hay bales) are used to prevent erosion and sedimentation from these stockpiles along wetlands, water bodies, and roadways.

Congress passed the Agriculture and Food Act of 1981 containing the Farmland Protection Policy Act (FPPA) (Subtitle I of Title XV, Section 1539-1549). The FPPA is intended to minimize the impact federal programs have on the unnecessary and irreversible conversion of farmland to nonagricultural uses. For the purpose of FPPA, farmland includes prime farmland, unique farmland, and land of statewide or local importance. No land within the boundaries of the Pipeline Lateral is classified as unique farmland or land of statewide importance by the NRCS. The Pipeline Lateral will impact approximately 176.6 acres of soils mapped as prime farmland soils. The NRCS utilizes a standardized Farmland Conversion Impact Rating Form (NRCS Form AD1006) to determine whether alternative sites for an individual project should be considered if the potential adverse impacts to farmland soils exceed a recommended allowable level. The primary variables in calculating the Farmland Conversion Impact Rating are the current and projected surrounding land uses, the areal extent of the impacted prime farmland soils compared to the average farm unit in the

respective county, the amount of on-farm investments, and current utilization of the farmland soils for agriculture. An NRCS Form AD1006 will be completed for the Project Lateral following CFR § 658.5 (b).

4.8 Cultural and Archaeological Resources

4.8.1 Native American Tribal and Religious Practices

No Native American lands or reservations are located within the proposed APE. Therefore, no impacts to Native American tribes or Native American lands as a result of the Pipeline Lateral are anticipated. Prior to construction, further consultation with Native American tribes in the vicinity of the Pipeline Lateral will be initiated to verify that the Pipeline Lateral will not impact any Native American tribes, their lands or historical interests in the affected area.

4.8.2 Historic Areas

The Louisiana SHPO does not currently have a complete list of archaeology records available for a desktop review of the area traversed by the Pipeline Lateral. It cannot be determined at this time if there are any known archaeological resources within the APE, or if the area been previously surveyed for archaeological resources. Prior to construction, further consultation with the SHPO will be initiated to determine what records should be reviewed and if an archaeology survey of the APE is needed.

A review of the NRHP and the Louisiana Cultural Resources Map indicated that no historically significant resources have been previously documented within the anticipated APE (National Register of Historic Places, 2010; Louisiana Cultural Resources Map, 2010). However, the Louisiana Cultural Resources Mapping feature is not complete at this time. Prior to construction, further consultation with SHPO will be initiated to conduct a comprehensive records review and to determine if a historic resources survey of the APE is needed.

4.8.2.1 Impacts

Denbury does not anticipate any impacts to known cultural resources as a result of the Pipeline Lateral. There are no known cultural resources in the anticipated APE, and no direct or indirect impacts to any known cultural resources associated with the construction or operation of the Pipeline Lateral are anticipated.

4.8.2.2 Mitigative Measures

If field reconnaissance discovers sites within the APE that may be culturally significant, Denbury will evaluate routing options to avoid any potentially significant sites.
If avoidance is not possible through design, Phase II archaeological evaluation will be undertaken to assess whether the site(s) qualify as historic properties as defined by 36 CFR 800.

If unanticipated archaeological deposits or human remains are encountered during construction, Denbury will follow its Unanticipated Discovery Plan and all activities would be halted in that location. Appropriate authorities and SHPO archaeological staff would be contacted to initiate post review discovery procedures.

Human remains must be treated with sensitivity and care when they are encountered or are expected to be encountered on an archaeological project. In Louisiana, all unmarked burials and abandoned cemeteries are the responsibility of the Division of Archaeology under R.S. 8:671-681. This includes all Native American grave sites as well as many historic Euro-American, African-American, and other cemeteries.

4.9 Noise Environmental Consequences

There would be short-term negligible direct noise impacts to onsite workers and minor direct impacts to nearby residents and wildlife from construction. Operation of construction equipment would result in noise levels of approximately 95dBA within the construction areas. This work would be a short-term minor impact to potentially sensitive receptors. Operation of the pipeline would not create noise impacts to the area. Should the pipeline be inspected by aerial overflights, these would be episodic events that would not adversely impact potentially sensitive receptors. Because the noise impacts from the Pipeline Lateral would be of short duration, limited to the construction phase, there would be minimal potential for interaction with other projects, so no cumulative impacts from noise would occur.

During construction, noise levels would be elevated, but primarily during daytime hours. Construction noise levels would be highest during clearing, trench excavation, final grading, and at HDD areas. Peak noise levels would be expected to be approximately 95 dBA during these times and approximately 75 dBA at other times. Onsite persons at each location would be aware of the operation of equipment during construction. Nearby receptors would experience interference with outdoor conversations, depending on proximity to the construction area. However, elevated noise levels would be of short duration and site noise conditions would revert to background levels after construction.

Wildlife in proximity to construction areas would be exposed to the elevated noise and would be expected to temporarily relocate from the active construction area. Following construction, any displaced animals would be expected to resume normal activity and return to use of the temporarily abandoned areas. Any construction-related noise impacts to wildlife would be temporary and minor. No noise impacts to wildlife would be expected during operation of the pipeline.

4.10 Socioeconomics

Impacts and mitigation measures of demographics, employment, housing, and populations are addressed in the following subsections.

4.10.1 Population and Race

4.10.1.1 Impacts

Construction personnel that may be hired from outside of the proposed pipeline project are could include supervisory personnel, inspectors, and repair workers. These individuals could total 450 to 500 workers who may temporarily relocate to the project area during construction. Impacts to the local population in the proposed project area from non-local workers would be short term and negligible.

4.10.1.2 Mitigative Measures

No mitigation measures for population and race impacts are required.

4.10.2 Employment

4.10.2.1 Impacts

There would be short-term minor benefits to the local community from construction jobs as a result of the proposed action along with any supporting structures such as access ways and utilities lines. Personnel that do relocate to the proposed project area will have a long-term minor impact on the economy with the increase tax base from the new jobs.

4.10.2.2 Mitigative Measures

There should be no long-term impacts to employment as a result of implementation of the preferred alternative, therefore no mitigation for employment impacts are anticipated

4.10.3 Housing

4.10.3.1 Impacts

Construction personnel may temporarily relocate to the project area for the construction of the proposed pipeline project. These individuals would typically not relocate or require housing for their families due to the relatively short duration of the project. If housing were needed in the project area, housing for ownership and rental are available. Therefore, no long-term population or housing impacts will result from the construction of the project.

4.10.3.2 Mitigative Measures

No significant short or long term impacts to housing are anticipated as a result of implementation of the build alternative. No mitigative measures are anticipated for housing impacts.

4.10.4 Environmental Justice

4.10.4.1 Impacts

The proposed pipeline lateral is located in Calcasieu Parish, Louisiana. Most of the land in the vicinity of the construction is undeveloped forest or farmland, with small clusters of residences at two locations along the route. Calcasieu Parish and the Lake Charles MSA has a 27.8 percent and 26.9 percent minority population respectively. The reference population of Louisiana and the United States have minority populations of 35.8 percent and 26.1percent. Because of small difference between the minority populations in the reference area with the project area, the direct impacts associated with the proposed project would not have the potential to cause disproportionately adverse impacts to the minority population. The influx of construction personnel to the project area is expected to have a temporary and negligible impact in the ROI and reference areas.

The percentage of low income population in Calcasieu Parish is 15.9 percent, 4 percentage points below the 20 percent criterion for potential impacts to low-income populations in this study. Based on this criterion, the proposed project will not occur in a low-income population area. Therefore, the direct impacts associated with the proposed action would not have the potential to cause proportionately adverse impacts to low-income population

Because the construction of the pipeline are located in a predominately undeveloped area, outside of the immediate vicinity of concentrations of residences and other areas where children would congregate, the construction and operation of the pipeline would not pose significant environmental health and safety risks to children.

4.10.4.2 Mitigative Measures

No significant short or long-term impacts to low income or minority populations are anticipated as a result of implementation of the build alternative; therefore, no mitigative measures are anticipated for potential impacts to minority, low income or children populations. No mitigative measures will be required for population impacts.

4.11 Public Resources

This section discusses impacts to local fire, police, schools and emergency services in the area of the Pipeline Lateral.

4.11.1 Impacts

Potential adverse impacts on the ability of state local law enforcement agencies to provide protection could occur if the construction of the Pipeline Lateral resulted in an increased need for police services (e.g., from vandalism or other crime during construction or operations). Based on the rural location of the proposed Pipeline Lateral, an increased demand to local police forces is considered unlikely.

The utilization of heavy equipment, work vehicles, and electrical equipment, as well as pipeline welding operations could increase the potential for accidental fires in the area of the Pipeline Lateral during construction. Operation activities are not likely to create any additional fire hazards.

Because construction of the Pipeline Lateral will be short term and temporary; no new students associated with construction employees are anticipated. It is anticipated that Denbury would employ, at most, one additional staff person for pipeline operations. Therefore, there would not be an increased demand for school resources.

Impacts to local emergency services will be minimized to the greatest extent possible by making the health and safety of all staff and the local community the highest priority during construction and operations. A detailed discussion of the occupational health and safety focus for the Pipeline Lateral is provided in Section 3.14.

4.11.2 Mitigative Measures

Mitigation measures to reduce impacts to local police and fire resources include the implementation of BMPs and good housekeeping measures to protect Pipeline Lateral equipment and staff during construction and operations. Adequate fencing and exclusion devices will be utilized at construction equipment storage areas to prevent trespass incidents that involve theft or vandalism, or that could lead to accidents or injury to the greatest extent practicable. Fire protection measures will be implemented during construction and operation to minimize the potential for accidental fires. Steps that will be taken to prevent fires during construction include: maintaining access roads to keep vehicles away from tall grasses and dry vegetation, using diesel vehicles whenever possible to

prevent potential ignition of vegetation by catalytic converters, avoiding idling vehicles, and keeping cutting torches and similar equipment away from grasses and dry vegetation. Burning of cleared vegetation on the ROW will be in consultation with local regulatory agencies and will follow prescribed methodologies.

4.12 Transportation

4.12.1 Impacts

It is anticipated that local traffic will temporarily increase during Pipeline Lateral construction. Heavy equipment transporters and supply vehicle traffic will be traveling to the Pipeline Lateral area and will remain along the Pipeline Lateral ROW during construction. The number of heavy equipment vehicles planned for Pipeline Lateral construction is dependent on the construction strategy to be employed, which will be determined when Denbury selects individual contractors. In addition to increased heavy equipment traffic, smaller vehicles, such as pickups and automobiles utilized by construction staff are expected to locally increase during construction. It is anticipated that construction of the lateral would be in a single spread, with equipment and personnel moving systematically along the ROW from one end of the corridor to the other.

4.12.2 Mitigative Measures

Adverse construction and operational impacts to traffic safety or travel times associated with Pipeline Lateral construction are not anticipated. While construction-related traffic may cause short-term traffic delays (because of large, slow-moving heavy equipment transporters and delivery trucks), the delays would be temporary and mitigated through the following measures:

- Providing notices to adjacent landowners when construction will take place to help minimize access disruptions
- Providing proper road signage and warnings of "Equipment on Road," "Truck Access," or "Road Crossings"
- Implementing traffic diversion equipment (such as advance signage and pilot cars) whenever possible when slow or oversize loads are being hauled
- Encouraging carpooling for the construction workforce to reduce traffic volume
- Employing flaggers as necessary to direct traffic when large equipment is exiting or entering public roads to minimize the risk of accidents
- Maintaining at least one travel lane at all times so that roadways will not be closed to traffic due to construction vehicles entering or exiting public roads

Advance warning in the form of signage and notices to landowners may reduce the effect construction vehicles have on the area roadways. By providing notices to landowners, citizens would be aware of temporary access disruptions as well as potential delays and may be able to adjust their travel accordingly. To further reduce the effect of construction vehicles, flaggers would efficiently guide large or oversize vehicles as they enter or exit any public roadway.

Although short-term delays may occur, traffic operations would be maintained by keeping at least one travel lane of the transporter route open at all times. This would be important on local roads because they are typically one to two lanes in each direction, and efficient detour routes may not be available due to the nature of the area.

Flaggers may facilitate two-way traffic on one lane by alternately restricting travel directions. This method would not require full lane closures, detours, or reroutes. Flaggers would also monitor through traffic on public roadways as necessary so that they do not conflict with construction vehicles.

Unlike large construction vehicles, the construction workforce would most likely travel during the morning and afternoon peaks of a typical workday. By encouraging carpooling among construction personnel, fewer vehicles can be anticipated on the roadway during this time; therefore, reducing the effect of construction on typical commuters. Once construction is completed, any damage to federal, state, or local roadways resulting from Pipeline Lateral construction would be repaired under the guidance of the appropriate regulatory agency. The construction of new roads or the expansion of the existing road and highway system in Calcasieu Parish is not anticipated for construction or operation of the Pipeline Lateral.

4.13 Visual

4.13.1 Impacts

Construction of the proposed Pipeline Lateral would modify the visual quality of the area by widening existing ROW corridors or creating new ROW corridors to accommodate the pipeline. The proposed Pipeline Lateral will be placed below ground surface and will not be visible to adjacent landowners. A meter station and valve will be aboveground and result in minor visual impacts. Operation of the pipeline will require Denbury to keep a 50-foot permanent pipeline corridor maintained with herbaceous or similar vegetation to allow for visual inspection of the ground surface.

4.13.2 Mitigative Measures

The proposed Pipeline Lateral was collocated along existing linear corridors to the extent possible to reduce new visual impacts to the surrounding area. To mitigate for visual impacts, the pipeline ROW will be re-contoured and re-vegetated as near to pre-construction conditions as is practicable following construction to allow for operational activities. The visual impact of the newly created permanent ROW is likely to moderate over time as vegetation becomes re-established.

4.14 Occupational Safety and Health

4.14.1 Impacts

Construction sites are classified as high-risk environments due to the health and safety risks that are present onsite, including noise hazards; slip, trip, and fall hazards; construction equipment malfunction and injuries; and potential exposure to hazardous materials. Denbury would mitigate these risks through compliance with OSHA standards including 29 CFR 1926, Safety and Health Standards for Construction, applicable state and local labor laws, and through good business practices.

Potential impacts associated with construction activities also consist of unplanned spills or minor releases of potentially hazardous materials or encountering unanticipated contaminated materials or soils. Exposure to hazardous materials may be harmful to human health, even in minimal exposure levels for some contaminants. Appropriate personal protective equipment would be required to minimize health impacts from potential exposure to hazardous materials.

Potential operational impacts to human health and safety include pipeline leaks. Fire and explosion hazards are not generally factors in the pipeline transmission of CO_2. Carbonic acid corrosion is a potential risk in facilities that process or transport CO_2. CO_2 reacts with water to form carbonic acid that corrodes steel. If corrosion becomes severe enough, a leak may develop. $CO_2$is denser than air and if the density of the gas is high enough, CO_2will settle in low areas, depressions, and basements of buildings, displacing breathing air. If humans entered this space or area, these conditions would present an adverse physiological response.

4.14.2 Mitigative Measures

Denbury would mitigate the safety and health risks associated with construction activities through compliance with OSHA standards including 29 CFR 1926, Safety and Health Standards for Construction, applicable state and local labor laws, and through good business practices.

Denbury will require its contractor(s) to develop a WMP, which will include specifications for handling, containment, and disposal of all wastes generated during the Pipeline Lateral construction. The WMP must be submitted to Denbury for approval before the work begins. Hazardous liquids will be situated off the ROW, within the boundaries of Denbury's construction and storage yards. This will minimize potential spills and releases by keeping materials away from active construction and in a centralized, monitored location. All containers used to accumulate hazardous waste, hazardous substances or toxic substances (regardless of size or quantity) will be:

- Marked or labeled clearly with a hazardous waste label to identify their content in accordance with the appropriate regulations
- Maintained in good condition to prevent leaks or spills
- Placed inside impervious secondary containment
- Placed at least 20 feet from the edge of the ROW
- Closed and secured at all times except when removing or adding materials
- Arranged so that there is sufficient aisle space between containers
- Placed in an area that is protected from the weather
- Placed inside portable containment when permanent containment is not feasible
- Inspected weekly at a minimum or at a frequency in accordance with the appropriate regulations

Any hazardous wastes that may be generated during construction of the Pipeline Lateral would be disposed of in EPA- and LDEQ-approved disposal sites. Appropriate personal protective equipment would be required to minimize health impacts from potential exposure to hazardous materials.

In order to minimize hazards to human health and/or the environment from any unplanned sudden or non-sudden releases of oils, toxic, hazardous, or other polluting materials to the air, soil, surface water or groundwater, an SPCC Plan and Preparedness, Prevention and Contingency (PPC) Plan would be prepared prior to construction. The SPCC/PPC Plan will be developed to comply with the Federal Water Pollution Control Act, Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), Resource Conservation and Recovery Act (RCRA), Toxic Substances Control Act (TSCA), and CWA. This plan would address and identify the type and quantity of material handled, measures taken for spill preparedness and prevention, company and contractor emergency response procedures, spill incident reporting procedures, and arrangements with local emergency response teams.

To minimize impacts to human health and safety during operation of the pipeline, Denbury has selected a pipeline route that would avoid populated areas, to the greatest extent practicable. Furthermore, and in conjunction with Denbury's HSE program described in Section 3. 14, Denbury would institute a leak detection program and would implement operational HSE procedures such as lock-out/tag-out and operator testing for CO_2 in low-lying areas or crawl spaces prior to entering a potentially harmful situation. In addition, to reduce the potential for metallurgical and corrosion of the pipeline due to the interaction of CO_2 gas with pipeline materials, a project-specific plan will be developed.

4.15 Cumulative Impacts

Cumulative impacts are the sum of the incremental impacts from a proposed action and impacts from past, present, and reasonably foreseeable future actions. Based on the information presented in the proposed Pipeline Lateral project EIV, the Cumulative impacts for this project would be minor.

Indirect (secondary) effects are caused by an action (such as the construction and operation of the proposed Pipeline Lateral) and occur later in time or farther removed in distance, but occurring in the reasonably foreseeable future. Generally, these impacts are induced by the proposed action but are not a direct effect. Indirect effects can occur within the full range of impact types, such as changes in land use, economic vitality, neighborhood character, traffic congestion, air quality, noise, vibration, and water and natural resources. Examples of indirect effects can include growth-inducing effects and other effects related to induced changes in land use patterns, population density, and growth rates, and related effects on air and water and other natural systems.

The President's Council on Environmental Quality (CEQ) defines a cumulative impact as:

> "*…the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions. Cumulative*

impacts can result from individually minor but collectively significant actions taking place over a period of time." (40 CFR § 1508.7)

For a cumulative impact to occur, the action must affect a given resource and must have the potential to interact with other actions with regard to that resource, either directly or collectively. Additionally, cumulative impacts must be assessed at the geographic scale at which the project may impact given resources and the scope of the cumulative impacts analysis may vary among resources (FHWA, 1992).

Cumulative impacts must be considered over a specified time period to assess the influence of an action. Cumulative impacts may carry forward for decades and the actual time of influence attributable to a single project generally diminishes through time (FHWA, 1992). The temporal assessment of cumulative impacts is tailored to the resource.

In accordance with CEQ guidance, past actions are considered collectively in describing the existing conditions within the spatial area and temporal scope of analysis for each resource. The cumulative impact assessment also includes identification of reasonably foreseeable future actions. In some cases, information regarding specific actions that have been recently commenced is available. Local and regional planning agencies and documents were used as available that contain information relating to future land use, growth, and traffic projections and measures.

Table 4-5 identifies whether there is potential for interaction and provides a summary of potential cumulative impacts that could result from construction and operation of the proposed Pipeline Lateral.

TABLE 4-5
Cumulative Impact Summary
Denbury Lake Charles, Louisiana, EIV

Resource Area	Potential Cumulative Impacts
Project Area and Topography	No cumulative impacts are expected; impacts limited to temporary construction land disturbances. Topography will be returned to pre-construction conditions to the greatest extent practicable.
Climate, Meteorology, and Air Quality	No cumulative impacts are expected; impacts limited to temporary increased dust and combustion equipment emissions during construction.
Water Quality/Quantity; Floodplains and Wetlands	Impacts to surface and groundwater resources limited to temporary construction water body, floodplain, and wetland crossings and water use for hydrostatic testing. Cumulative effects of water body and wetland impacts in the region have the potential to impose additional losses on wetlands ecosystems, but current Federal policies under Section 404 of the Clean Water Act should avoid or minimize these losses or establish measures for mitigation to make these impacts less than significant.
Ecology	Cumulative effects that have the potential to affect ecological resources vary with the affected habitat. Regardless of the development of the Pipeline Lateral, natural resources associated with land surface areas, including vegetation and wildlife, are likely to be displaced or lost in areas where industrial or residential growth occurs at formerly natural areas. However, State and Federal protections for unique habitats and species may be expected to avoid, minimize, or mitigate these effects through current and future enforcement programs.

TABLE 4-5
Cumulative Impact Summary
Denbury Lake Charles, Louisiana, EIV

Resource Area	Potential Cumulative Impacts
Waste	No cumulative impacts are expected. Impacts of the Pipeline Lateral would be limited to the construction ROW and there would be limited potential for offsite impacts due to the unlikely event of a spill or release from temporary waste storage areas on site. There is no potential for interaction of the Pipeline Lateral project with other projects with regard to hazardous materials that would result in cumulative effects.
Land Use	The presence of the Pipeline Lateral project is not expected to have a negative impact on land uses in Calcasieu Parish. The Pipeline Lateral is co-located with existing utility corridors for most of the Pipeline Lateral corridor. The addition of a new utility corridor in Calcasieu Parish is expected to add negligible cumulative impacts to an area where several utility corridors are already present.
Geology and Soils	No cumulative impacts are expected. Impacts of the Pipeline Lateral would be limited to the Pipeline Lateral ROW and there would be no potential offsite impacts. There is no potential for interaction of the Pipeline Lateral with other projects with regard to soils and geology.
Cultural and Archaeological Resources	No cumulative impacts are expected. Impacts of the Pipeline Lateral would be limited to the Pipeline Lateral ROW and there are no potential impacts to historic properties or viewsheds of historic properties. There is no potential for interaction of the Pipeline Lateral ROW with other projects with regard to cultural resources.
Noise	No cumulative impacts are expected. Traffic and traffic-related noise and ambient noise levels in the area would increase during Pipeline Lateral construction. Noise from operation of the Pipeline Lateral ROW would be negligible.
Socioeconomics	Increases in economic growth related to continued development in the region are expected to be within existing projections. No effects on Environmental Justice issues.
Public Resources	No cumulative impacts are expected. Impacts are minimal and limited to potential temporary increase in policing and emergency services needs during construction.
Transportation	No cumulative impacts are expected, with impacts limited primarily to the duration of construction to temporary construction land disturbances. There is no potential for interaction of the Pipeline Lateral ROW with other projects with regard to transportation.
Visual	There would be limited potential for the Pipeline Lateral to interact with other projects with regard to visual quality. Once the facility is constructed, the Pipeline Lateral would not further alter visual quality.

4.16 Summary of Impacts

A summary of the potential environmental impacts are presented in Table 4-6.

TABLE 4-6
Summary of Impacts
Denbury Onshore, LLC Lake Charles, LA EIV

Resource Area	Summary of Impacts
Project Area and Topography	Temporary impacts during land clearing and pipeline trenching and installation activities to 187.2 acres of land. No permanent impacts are anticipated.
Air Climate, Meteorology, and Air Quality	Temporary impacts during construction include increased dust and combustion equipment operations. No permanent impacts are anticipated.

TABLE 4-6
Summary of Impacts
Denbury Onshore, LLC Lake Charles, LA EIV

Resource Area	Summary of Impacts
Water Quality/Quantity; Floodplains and Wetlands	Temporary, localized impacts during construction stream crossings; Potential releases to streams during HDD operations; Surface water withdraws for hydrostatic testing; Temporary, localized impacts to floodplain and during construction stream and wetland crossings; Permanent conversion of forested wetlands to herbaceous wetlands within permanent 50 foot wide ROW.
Ecology	Temporary impacts to vegetation and displacement of wildlife during construction; 50 foot wide permanent ROW will be maintained for operations and maintenance activities; Permanent impacts to wildlife are anticipated to be minimal.
Solid Waste Disposal	Temporary construction impacts associated with land clearing, construction supply packing materials, and general refuse; Negligible solid waste generated during operations and maintenance activities.
Land Use	Temporary impacts to 95 foot wide ROW during construction; Permanent conversion of land to 50 foot wide ROW for operations and maintenance activities; ROW co-locates with existing utility ROWs for approximately 90% of route.
Geology and Soil	Construction activities will increase the potential for temporary erosion and sedimentation, compaction, and topsoil mixing. Construction will temporarily impact approximately 176.6 acres classified by the NRCS as prime farmland soils.
Native American Tribal and Religious Practices	No impacts.
Noise	Temporary noise impacts during construction; Negligible permanent impacts during operations and maintenance.
Socioeconomics	No impacts.
Public Resources	Potential increased need for public services (e.g., police, fire, emergency services) during construction. No permanent impacts are anticipated.
Transportation	Local traffic increases during Pipeline Lateral construction; Movement of heavy equipment during construction. No permanent impacts are anticipated.
Visual	Modification of the visual quality of the area by widening existing ROW corridors or creating new ROW corridors to accommodate the pipeline.
Occupational Safety and Health	Increased potential for noise hazards; slip, trip, and fall hazards; construction equipment malfunction and injuries; and potential exposure to hazardous materials.

SECTION 5.0

Potential Liability to DOE of Existing Conditions at the Site

Potential liabilities to which DOE may be exposed as part of the existing conditions of the Proposed Project may include, but may not be limited to, the unexpected presence of solid or hazardous waste sites along the ROW and encroachment of the ROW by future population center expansion. Denbury has no knowledge, previous or current, of any research or demonstration projects proposed or being conducted along the proposed Project corridor that would conflict with development of the Pipeline Lateral.

The presence of solid or hazardous waste sites along the ROW that were not identified to state or federally waste management agencies may be encountered once excavation begins. In this event, work will be stopped, and DOE would be notified and appropriate agencies contacted. The responsibility of any additional action with regard to the waste site investigation is not DOE's or any other entity involved (Denbury or Denbury's contactors) with the proposed Project. Liability in this event would be limited to the delay of the proposed Project's completion and additional environmental evaluation similar to this EIV to re-route the pipeline ROW.

There is potential for hitting buried utilities during construction given that the proposed line is piggy-backing on exiting ROW and there is likely a high volume of existing lines in those areas. Both DOE and Denbury are both relying on the utility information provided by others, and utility blueprints may contain errors, leading to difficulty with older utilities lines. Since April 1982, operators have been required to participate in "One Call" public utility programs in populated areas to minimize unauthorized excavation activities in the vicinity of pipelines. The One Call program is a service used by public utilities and some private sector companies (for example, oil pipelines and cable television) to provide preconstruction information to contractors or other maintenance workers on the underground location of pipes, cables, and culverts. Denbury is a participant in the One Call program.

While current land use in the proposed Project ROW is characterized by pastures, croplands, wetland areas, residential and commercial land use, future expansion of population centers could possibly impinge upon the ROW as completed. Institution controls such additional fencing and signage may be required to limit access to the completed ROW. While the proposed Lake Charles lateral would be a new pipeline to transport captured CO_2, it will be connecting to existing pipelines with Denbury's pipeline system. The Green Pipeline is an approximately 320-mile pipeline designed to transport booth natural and man-made CO_2. The Green Pipeline will be one of the first pipelines designed to transport anthropogenic CO_2 in the Gulf Coast Area.

The Secretary of Transportation has primary authority to regulate interstate CO_2 pipeline safety under the Hazardous Liquid Pipeline Act of 1979 as amended (49 United States Code [USC] §601). Under the act, the DOT regulates the design, construction, operation and

maintenance, and spill response planning for CO_2 pipelines (49 C.F.R. §190, 195-199). The DOT administers pipeline regulations through the Office of Pipeline Safety (OPS) within the PHMSA. Although CO_2 is listed as a Class 2.2 (non-flammable gas) hazardous material under DOT regulations (49 CFR §172.101), the agency applies nearly the same safety requirements to CO_2 pipelines as it does to pipelines carrying hazardous liquids such as crude oil, gasoline, and anhydrous ammonia (49 CFR §195). To date, CO_2 pipelines in the United States have experienced few serious accidents. According to OPS statistics, there were 12 leaks from CO_2 pipelines reported from 1986 through 2006 — none resulting in injuries to people. Based on the limited sample of CO_2 incidents, analysts conclude that, mile-for-mile, CO_2 pipelines appear to be safer than the other types of pipeline regulated by OPS (Parfomak and Folger, 2007).

Since the Pipeline Safety Act was signed into law in 1968, states have been very active in assisting the U.S. DOT Secretary in carrying out the nation's pipeline safety program. State pipeline safety personnel represent more than 80 percent of the state/federal inspection workforce, and state inspectors are the "first line of defense" at the community level to promote pipeline safety, underground utility damage prevention, and public education and awareness regarding pipelines (National Association of Regulatory Utility Commissioners, 2009).

According to data collected by DOT on pipeline incidents, the dominant cause for accidents involving pipelines is outside forces. Outside forces incidents result from the encroachment of mechanical equipment such as bulldozers and backhoes; or from earth movements due to soil settlement, washouts, or geologic hazards; weather effects such as winds, storms, and thermal strains; and willful damage.

Denbury will design, construct, test, operate, and maintain the proposed pipeline facilities in accordance with the DOT Minimum Federal Pipeline Safety Standards in 49 CFR §195, Transportation of Hazardous Liquids by Pipeline. These regulations are intended to ensure adequate protection for the public and to prevent accidents and failures. Part 195 specifies material selection and qualification, minimum design requirements, and protection from internal, external, and atmospheric corrosion. The safety standards specified in Part 195 require each pipeline operator to:

- Develop an emergency plan prepared by the pipeline company, working with local fire departments and other agencies to identify personnel to be contacted, equipment to be mobilized, and procedures to be performed to respond to a hazardous condition caused by the pipeline.
- Establish and maintain a liaison with the appropriate fire, police, and public officials in order to coordinate mutual assistance when responding to emergencies.
- Establish a continuing education program to enable customers, the public, government officials, and those engaged in excavation activities to recognize a pipeline emergency and report it to appropriate public officials.

In addition, the standards in 49 CFR §195 define area classifications based on population density. More stringent safety considerations are required in more populated areas, and require higher safety factors in pipeline design, testing, and operation. Pipe wall thickness and pipeline design pressures, hydrostatic test pressures, maximum allowable operating

pressure, inspection and testing of welds, and frequency of pipeline patrols and leak surveys must also conform to higher standards in more populated areas.

The Project is located primarily within low population density areas. If a subsequent increase in population density adjacent to the ROW were ever to indicate a change in class location for the pipeline, Denbury would modify its facilities or operations to comply with the DOT code of regulations for the new class location.

SECTION 6.0

Ability to Meet Compliance Requirements at the Site

6.1 Applicable Regulatory Requirements and Coordination

NEPA is the environmental component of planning for federal projects and projects with federal funding. NEPA is integrated with other planning activities to ensure that such decisions consider environmental and socioeconomic factors in a systematic manner. Requirements of applicable permits and regulations are also included in the evaluation performed under the NEPA process.

Federal statutes, regulations, and Executive Orders (EOs) applicable to one or more components of the Proposed Action and No Action Alternative as described in this EIV include, but are not necessarily limited to:

6.1.1 Federal Statutes

- National Environmental Policy Act (42 USC 4321-4370)
- Endangered Species Act of 1973 (ESA) (16 USC 1531-1543)
- Fish and Wildlife Coordination Act (16 USC 661, et seq.)
- Migratory Bird Treaty Act (16 USC 701, et seq.)
- Clean Water Act of 1977 (CWA) and the Water Quality Act of 1987 (WQA) (33 USC 1251 et seq., as amended)
- Farmland Protection Act of 1981 (7 USC 4201 et. seq., as amended)
- Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) (as amended by the Superfund Amendments and Reauthorization Act of 1986 [SARA])
- Resource Conservation and Recovery Act of 1976 (RCRA) (42 USC 6901)
- Toxic Substances Control Act (TSCA) (15 USC 2601 et seq., as amended)
- National Historic Preservation Act (NHPA) of 1966 (16 USC 470 et seq., as amended)
- Archeological Resources Protection Act of 1979 (16 USC 470)
- Clean Air Act (CAA) (42 USC 7401 et seq., as amended)
- Noise Control Act of 1972 (42 USC 4901 - 4918)

6.1.2 Regulations

- CEQ Regulations for Implementing NEPA (Title 40 CFR, Parts 1500-1508 (40 CFR 1500-1508)

- Protection of Historic Properties (36 CFR Part 800)
- DOE Compliance with the National Environmental Policy Act (10 CFR Part 1021)
- DOE Compliance with Floodplain and Wetland Environmental Review Requirements (10 CFR Part 1022)

6.1.3 Executive Orders

- EO 11514, Protection and Enhancement of Environmental Quality (amended by EO 11991)
- EO 11990, Protection of Wetlands
- EO 12372, Intergovernmental Review of Federal Programs
- EO 11988, Floodplain Management
- EO 12088, Federal Compliance with Pollution Control Standards
- EO 12898, Federal Actions to Address Environmental Justice in Minority Populations and Low Income Populations
- EO 13045, Protection of Children from Environmental Health Risks and Safety Risk
- EO 13010, Critical Infrastructure
- EO 13025, Amendment to EO 13010, the President's Commission on Critical Infrastructure Protection
- EO 13112, Invasive Species
- EO 13148, Greening the Government through Leadership in Environmental Management
- EO 13186, Responsibility of Federal Agencies to Protect Migratory Birds
- EO 13211, Actions Concerning Regulations that Significantly Affect Energy Supply, Distribution, or Use.
- EO 13287, Preserve America
- EO 13414, Federal Leadership in Environmental, Energy, and Economic Performance

6.1.4 DOE Policies, Orders and Guidance

- DOE O 451.1B, National Environmental Policy Act Compliance Program (Change 1, September 28, 2001)
- Secretarial Policy on the National Environmental Policy Act (June 13, 1994)
- Questions and Answers on the Secretarial Policy Statement on the National Environmental Policy Act (July 1994)
- DOE P 430.1, Land and Facility Use Planning (July 9, 1996) (with Secretary of Energy Memorandum, December 21, 1994)
- DOE P 141.1, Management of Cultural Resources (May 2001)

- DOE Interim Guidance: Need to Consider Intentional Destructive Acts in NEPA Documents (December 2006)

6.1.5 Applicable Permits Required for Proposed Action

Table 6-1 contains federal, state, and local permits applicable to one or more components of the Proposed Action as described in this EIV. Additional permits and clearances may be required if the project scope differs from what is described in this EIV.

TABLE 6-1
Applicable Permits for the Proposed Action
Denbury Lake Charles, Louisiana, EIV

Permit/Approval	Administering Agency	Anticipated time for Permit/Clearance Approval	Comment
Section 404/10 Compliance (Nationwide Permit [NWP] 12)	U.S. Army Corps of Engineers (USACE), New Orleans District	3 months	Assumes standard Nationwide Program timelines will apply 30-Day review period to determine if PCN application is complete and 45 days to review and issue permit Allows for early submittal of U.S. Fish and Wildlife Service (USFWS), and U.S. Department of Agriculture (USDA) applications and their clearances during the USACE review period
Threatened and Endangered Species Consultation	U.S. Fish and Wildlife Service, Lafayette Ecological Services Field Office	2 months	Assumes 2 months for USFWS to review and issue clearance as part of the pre-survey NEPA agency consultation. Does not include time if formal Section 7 consultation is required.
Approval for crossing conservation easements, Conservation Restoration Program lands, Prime Farmland, and Wetland Restoration Program lands (if necessary)	U.S. Department of Agriculture, Natural Resources Conservation Service (NRCS)	2 months	Assumes 2 months for NRCS to review and issue clearance given the pre-application/pre-survey consultations
Threatened and Endangered Species Consultation	Louisiana Department of Wildlife and Fisheries (LDW&F)-Natural Heritage Program	2 months	Assumes 2 months for LDW&F to review and issue clearance given the pre-application/pre-survey consultations
Section 401 Water Quality Certification (joint application through USACE Section 404 permit)	Louisiana Department of Environmental Quality (LDEQ)	3 months	Assumes joint application with the USACE Section 404 application and timeline assumptions

TABLE 6-1
Applicable Permits for the Proposed Action
Denbury Lake Charles, Louisiana, EIV

Permit/Approval	Administering Agency	Anticipated time for Permit/Clearance Approval	Comment
Hydrostatic Test Water Discharge Permit (LAG 670000)	Louisiana Department of Environmental Quality	1 month	Notice of Intent to be filed prior to project implementation.
Louisiana Pollutant Discharge Elimination System Stormwater Permit due to Construction and SWPPP	Louisiana Department of Environmental Quality	1 month	Notice of intent to be filed prior to project implementation.
Archaeological and Historic Structures Consultation/Clearance	Louisiana Department of Culture, Recreation, and Tourism	1 month	Assumes standard 30-day review period and familiarity with the project during pre-application and pre-survey consultations

SECTION 7.0

Experience and Approach to the Identification and Resolution of Environmental Issues

7.1 Education/Experience of Key Project Members

Randy Robichaux is the health, safety, and environmental manager for Denbury Onshore and oversees all environmental activity for the company including permitting, mitigation efforts, and corrective actions. Randy's resume is provided in Appendix F. In addition to the support staff at Denbury, Randy utilizes the services of qualified consultants to help deliver key permitting strategies and environmental support.

7.2 Denbury's Permitting Experience

The U.S. CO_2 pipeline network is extremely small when compared to the U.S. oil and gas pipeline system. Denbury and an affiliate are currently constructing the Green Pipeline to transport CO2 from both natural and man-made sources to reenergize petroleum reservoirs. We have entered into purchase contracts with owners of potential sources of man-made CO_2 and are in various stages of discussions with several other entities. Assuming these plants are ultimately constructed, Denbury plans to use this CO_2 to recover oil that would not otherwise be produced. In addition to increased domestic oil production, our potential use of man-made CO_2 in our EOR operations, will help reduce the release of CO_2, a greenhouse gas, into the earth's atmosphere.

Denbury and an affiliate are currently constructing a 24-inch pipeline from Donaldsonville, Louisiana to Hastings Field, south of Houston, Texas (The Green Pipeline Project) and will transport up to 800 million standard cubic feet per day of CO_2. The approximately 320-mile pipeline, estimated to cost a total of $825 million, is designed to transport both natural and man-made CO_2. The Green Pipeline will be one of the first pipelines designed to transport anthropogenic CO_2 in the Gulf Coast area. The pipeline has been designed to operate under the rules and regulations of the DOT and is compliant with all local, state and federal regulations including pre-pipeline construction approvals for wetland-delineation, habitat evaluations and culture resource studies, along with other environmental and safety statutes.

Denbury has always taken the opportunity to avoid adverse impacts to ecologically and culturally sensitive areas. Construction methodologies and/or compensatory mitigation is provided to offset all unavoidable impacts, including replacing wetland acreage. Pipeline construction methods include alternative routing, reduction in construction width, installation of mats, push methods and horizontal directional drilling.

Routing is paramount to avoid sensitive sites and creates opportunities to utilize other ecologically sensitive construction methods. The reduction of ROW widths can be achieved through proper planning and by chipping woody vegetation, reducing impacts by as much

as one third. The installation of mats within the working ROW reduces compaction and soil disturbance which facilitates post construction rehabilitation.

When conditions dictate, the "push method" of construction provides for further reduction of ROW width. This method of flooding the pipeline trench, fabricating the joints of pipe at a single location and pushing the pipe down the flooded ditch on floats as more pipe is attached, is capable of reducing impacts by over 50 percent.

The use of horizontal directional drilling can be used to completely avoid surface features and is a great option for archeological sites, narrow wetlands or site specific habitat concerns (i.e. denning or nesting areas). Additionally, properly installed erosion control devices are strategically positioned along the ROW, and these devices are maintained until the impacted area has fully recovered. Denbury works closely under the guidelines of the U.S. Army Corps of Engineers and other federal, state and local regulators to ensure that the highest quality of compliance is achieved.

Denbury expects the pipeline to be fully operational by late 2013.

7.3 Denbury's Environmental Policies

Denbury currently has several written environmental policies, procedures, or plans currently in place and considered essential to the business operation and been implemented with the construction of the Green Pipeline. These include a waste management plan, a health safety and environmental policy, a health and safety guidelines for contractors, and the Corporate Responsibility Guide presented in Appendix G.

SECTION 8.0

References

Autin, W. J., A. T. Davison, B. J. Miller, and F.E. Lindfors-Kearns, 1985. Use of Mt. Pleasant Bluff in correlation of the Prairie Formation, southeastern Louisiana: Geological Society of America Abstracts with Programs, v. 17, p. 150.

Bureau of Labor Statistics (BLS), U.S. Department of Labor. 2010. Civilian labor force and Unemployment by state and metropolitan area. Available at: http://www.bls.gov/news.release/metro.t01.htm.

Bureau of Labor Statistics. 2007. *News Release of Nonfatal Occupational Injuries and Illnesses from the Survey of Occupational Injuries and Illnesses*. Available at: http://www.bls.gov/iif/osh_nwrl.htm#industry. Web site accessed February 2010.

California State Lands Commission, Monterey Bay National Marine Sanctuary, and Aspen Environmental Group. 2005. Draft Environmental Impact Report/Environmental Impact Statement. Available at: http://www.montereybay.noaa.gov/new/2005/031505marseir.html.

California State Lands Commission, Monterey Bay National Marine Sanctuary, and Aspen Environmental Group. 2005. Draft Environmental Impact Report/Environmental Impact Statement. Available at: http://www.montereybay.noaa.gov/new/2005/031505marseir.html.

City-Data.com. 2010. Available at: www.city-data.com. Web site accessed February 2010.

Colorado State University CIRA Cooperative Institute for Research in the Atmosphere. 2006. IMPROVE Spatial and Seasonal Patterns and Temporal Variability of Haze and its Constituents in the United States, Report IV; ISSN:0737-5352-74. November.

Council on Environmental Quality (CEQ), 1997. Environmental Justice Guidance Under the National Environmental Policy Act. Dec 1997. Available at: http://www.ceq.hhs.doe.gov/nepa/regs/ej/justice.pdf.

Daigle, J.J., G.E Griffith, J.M. Omernik, P.L. Faulkner, R.P. McCulloh, L.R. Handley, L.M. Smith, and S.S. Chapman. 2006. Ecoregions of Louisiana: Reston, Virginia, U.S. Geological Survey.

Federal Highway Administration (FHWA). 1992. NEPA and Transportation Decision Making: Secondary and Cumulative Impact Assessment in the Highway Project Development Process. Federal Highway Administration Project Development Branch, HEP-31. April 1992. Available at: http://www.environment.fhwa.dot.gov. Web site accessed February 2010.

Federal Highway Administration (FHWA). 2007. Highway Traffic Noise. Available at: http://www.fhwa.dot.gov/environment/noise/3.htm. Web site accessed May 31, 2007.

Federal Highway Administration (FHWA). 2007. Highway Traffic Noise. Available at: http://www.fhwa.dot.gov/environment/noise/3.htm. Web site accessed May 31, 2007.

Louisiana Cultural Resources Map. Louisiana State Historic Preservation Office. Available at: http://kronos.crt.state.la.us/website/lahpweb/viewer.htm. Web site accessed February 16, 2010.

Louisiana Department of Education (LDOE). 2006. Geographic Dataset: Schools in the State of Louisiana. Downloaded from the Louisiana Map 2.0, Available at: http://map.la.gov/. Web site accessed February 2010.

Louisiana Department of Education. 2007.

Louisiana Department of Environmental Quality (LDEQ). 1988. Recharge Potential of Louisiana Aquifers. Available at: http://www.deq.louisiana.gov/portal/tabid/2588/Default.aspx. Web site accessed March 1, 2010.

Louisiana Department of Environmental Quality (LDEQ). 2005. Aquifer Baseline Monitoring Program – Fiscal Years 2004-2006: Chicot Aquifer Summary. Available at: http://www.deq.louisiana.gov/portal/default.aspx?tabid=1717. Web site accessed March 1, 2010.

Louisiana Department of Environmental Quality (LDEQ). 2009. Louisiana Annual Network Assessment, LDEQ AQ Assessment Division, May 30.

Louisiana Department of Environmental Quality (LDEQ). 2010a. Calcasieu Estuary Bayou d'Inde. Available at: http://www.deq.louisiana.gov. Web site accessed February 2010.

Louisiana Department of Environmental Quality (LDEQ). 2010b. Remediation Services. Available at: http://www.deq.louisiana.gov. Web site accessed February 2010.

Louisiana Department of Health and Hospitals (LDHH). 2006. Geographic Dataset: Care Facilities Licensed by LDHH. Downloaded from the Louisiana Map 2.0. Available at: http://map.la.gov/. Web site accessed February 2010.

Louisiana Department of Health and Hospitals (LDHH). 2007. Geographic Dataset: Hospitals in the state of Louisiana. Downloaded from the Louisiana Map 2.0. Available at: http://map.la.gov/. Web site accessed February 2010.

Louisiana Department of Social Services (LDSS). 2006. Geographic Dataset: Care Facilities Licensed by LDSS. Downloaded from the Louisiana Map 2.0. Available at: http://map.la.gov/. Web site accessed February 2010.

Louisiana Department of Social Services (LDSS). 2006. Geographic Dataset: Statewide Day Cares. Downloaded from the Louisiana Map 2.0. Available at: http://map.la.gov/. Web site accessed February 2010.

Louisiana Department of Transportation and Development (LA DOTD). 2010. Estimated Annual Average Daily Traffic Count Sites. http://www.dotd.la.gov/highways. Web site accessed February 2010.

Louisiana Environmental Data Center (LEDC). 2010. Emission Inventory for Calcasieu Parish. 2008. Available at: http://www.deq.louisiana.gov/portal/tabid/2729/Default.aspx.

Louisiana Geologic Survey (LGS). 2010. Geologic Review. Available at: http://www.lgs.lsu.edu. Web site accessed February 2010.

Louisiana Natural Heritage Program. 2008. Rare, Threatened, & Endangered Species & Natural Communities - Calcasieu Parish.

Meteorology Data for the State of Louisiana, Louisiana Environmental Data Center (LEDC). Available at: http://www.deq.louisiana.gov/portal/tabid/2729/Default.aspx.

Multi Resolution Land Characteristics Consortium. 2001. National Land Cover Database. United States Department of the Interior.

National Climatic Data Center (NCDC). Lake Charles Historic Severe Weather Data. Available at: http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwevent~storms www.city-data.com. Web site accessed February 2010.

National Conference of State Legislatures (NCSL). 2010. National Conference of State Legislatures Available at: http://www.ncsl.org/?tabid=13278.*Web*. Web site accessed February 18, 2010.

National Register of Historic Places. National Register of Historic Places website. Accessed February 15, 2010. Available at: http://www.nps.gov/nr/research/index.htm.

National Scenic Byways Program. 2010. Louisiana Scenic Byways. Available at: http://www.byways.org. Web site accessed February 2010.

Natural Resources Conservation Service (NRCS), United States Department of Agriculture. 2010. Web Soil Survey. Available at: http://websoilsurvey.nrcs.usda.gov. Web site accessed February 2010.

Natural Resources Conservation Service (NRCS), United States Department of Agriculture. 2010. Web Soil Survey. Available at: http://websoilsurvey.nrcs.usda.gov. Web site accessed February 2010.

Natural Resources Conservation Service. 2009. Major Land Resource Areas. Available at: http://soils.usda.gov/survey/geography/mlra. Web site accessed July 9, 2009.

NatureServe. 2010. NatureServe Explorer Listed Species for Calcasieu Parish. Available at: http://www.natureserve.org. Web site accessed February 2010.

Parfomak and Folger. 2007. "Carbon Dioxide (CO_2) Pipelines for Carbon Sequestration: Emerging Policy Issues." *Congressional Research Service (CRS) Report for Congress*. P. 21. April 19.

Roth, David Mark, National Weather Service. 1998."A Historical Study of Tropical Storms and Hurricanes that have affected Southwest Louisiana and Southeast Texas," Lake Charles, Louisiana, SR/SSD 98-16, April 1.

Texas Commission on Environmental Quality (TCEQ). 2010a. Climate Data for the State of Texas. 1974 to 2003. Available at: http://www.tceq.state.tx.us/compliance/monitoring/air/monops/tx_climate.html.

Texas Commission on Environmental Quality (TCEQ). 2010b. Windrose for Beaumont, Texas 1988 to 1992. Available at: http://www.tceq.state.tx.us/assets/public/compliance/monops/air/windroses/bptall.gif.

Texas Commission on Environmental Quality (TCEQ). 2010c. Available at: http://www5.tceq.state.tx.us/airperm/index.cfm?fuseaction=airpermits.start.

The Engineering Toolbox. 2007. Sound levels Web sites. Available at: http://www.engineeringtoolbox.com/outdoor-noise-d_62.html and http://www.engineeringtoolbox.com/sound-level-d_719.html. Web site accessed May 25, 2007.

The Engineering Toolbox. 2007. Sound Levels Web sites. Available at: http://www.engineeringtoolbox. com/outdoor-noise-d_62.html, and http://www.engineeringtoolbox.com/sound-level-d_719.html. Accessed May 25, 2007.

The Nature Conservancy (TNC). 2010. Gulf Coast Prairies and Marshes. Available at http://www.nature.org. Web site accessed February 2010.

U.S. Army Corps of Engineers (USACE). 2010. Calcasieu River Basin. Available at: www.mvn.usace.army.mil. Web site accessed February 2010.

U.S. Environmental Protection Agency (EPA). 1974. *Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety.* Office of Noise Abatement and Control, March 1974.

U.S. Environmental Protection Agency (EPA). 2010a.AirData Database for NAAQS Monitoring. Available at: http://oaspub.epa.gov/aqspub1/AQS_Annsum.AnnualSummary.

U.S. Environmental Protection Agency (EPA). 2010b. Region 6 Louisiana Site Status Summaries. Available at: http://www.epa.gov/earth1r6. Web site accessed February 2010.

U.S. Environmental Protection Agency (EPA). 2010c. Toxics Release Inventory Program. Available at: www.epa.gov/TRI/. Web site accessed February 2010.

U.S. Environmental Protection Agency (EPA). 2010d.AirData Database for NAAQS Monitoring. Available at: http://www.epa.gov/air/data/repsco.html?co~48245~Jefferson%20Co%2C%20Texas.

U.S. Fish and Wildlife Service (USFWS).2010._National Wetlands Inventory. Available at: http://www.fws.gov/wetlands/ Web site accessed March 1, 2010.

U.S. Geologic Survey (USGS). 2010a. Louisiana Geologic Map Data. Available at: http://tin.er.usgs.gov/geology/state. Web site accessed February 2010.

U.S. Geologic Survey (USGS). 2010b. Louisiana Seismic Hazard Map. Available at: http://earthquake.usgs.gov. Website accessed February 2010.

United States Census Bureau (USCB). 2000a. Census 2000 Demographic Profile Highlights - United States. Available at: http://factfinder.census.gov/servlet/SAFFFacts?_event=&geo_id=01000US&_geoContext=01000US&_street=&_county=&_cityTown=&_state=&_zip=&_lang=en&_sse=on&ActiveGeoDiv=&_useEV=&pctxt=fph&pgsl=010&_submenuId=factsheet_1&ds_name=ACS_2008_3YR_SAFF&_ci_nbr=null&qr_name=null&reg=null%3Anull&_keyword=&_industry. Web site accessed February 2010.

United States Census Bureau (USCB). 2000b. Census 2000 Demographic Profile Highlights - Louisiana. Available at: http://factfinder.census.gov/servlet/SAFFFacts?_event=&geo_id=04000US22&_geoContext=01000US%7C04000US22&_street=&_county=&_cityTown=&_state=04000US22&_zip=&_lang=en&_sse=on&ActiveGeoDiv=geoSelect&_useEV=&pctxt=fph&pgsl=040&_submenuId=factsheet_1&ds_name=ACS_2008_3YR_SAFF&_ci_nbr=null&qr_name=null&reg=null%3Anull&_keyword=&_industry=Accessed Web site accessed February 2010.

United States Census Bureau (USCB). 2000c. Census 2000 Demographic Profile Highlights - Calcasieu Parish. Available at: http://factfinder.census.gov/servlet/SAFFFacts?_event=Search&geo_id=04000US22&_geoContext=01000US%7C04000US22&_street=&_county=calcasieu&_cityTown=calcasieu&_state=04000US22&_zip=&_lang=en&_sse=on&ActiveGeoDiv=geoSelect&_useEV=&pctxt=fph&pgsl=040&_submenuId=factsheet_1&ds_name=DEC_2000_SAFF&_ci_nbr=null&qr_name=null&reg=null%3Anull&_keyword=&_industry. Web site accessed February 2010.

United States Census Bureau (USCB). 2000d. Profile of General Demographic Characteristics: 2000, Profile of Selected Social Characteristics: 2000, Profile of Selected Economic Characteristics: 2000, Profile of Selected Housing Characteristics: 2000 -Lake Charles MSA, Louisiana.

United States Census Bureau (USCB). 2008a. 2006-2008 American Community Survey 3-Year Estimates, Demographic Profile Highlights, Selected Economic Characteristics -United States. Available at: http://factfinder.census.gov/servlet/ACSSAFFFacts?_event=&geo_id=01000US&_geoContext=01000US&_street=&_county=&_cityTown=&_state=&_zip=&_lang=en&_sse=on&ActiveGeoDiv=&_useEV=&pctxt=fph&pgsl=010&_submenuId=factsheet_1&ds_name=null&_ci_nbr=null&qr_name=null&reg=null%3Anull&_keyword=&_industry. Web site accessed February 2010.

United States Census Bureau (USCB). 2008b. 2006-2008 American Community Survey 3-Year Estimates, Demographic Profile Highlights, Selected Economic Characteristics - Louisiana. Available at: http://factfinder.census.gov/servlet/ACSSAFFFacts?_event=Search&geo_id=01000US&_geoContext=01000US&_street=&_county=&_cityTown=&_state=04000US22&_zip=&_lang=en&_sse=on&ActiveGeoDiv=geoSelect&_useEV=&pctxt=fph&pgsl=010&_submenuId=factsheet_1&ds_name=ACS_2008_3YR_SAFF&_ci_nbr=null&qr_name=null&reg=null%3Anull&_keyword=&_industry. We site accessed February 2010.

United States Census Bureau (USCB). 2008c. 2006-2008 American Community Survey 3-Year Estimates, Demographic Profile Highlights, Selected Economic Characteristics -Calcasieu

Parish, Louisiana. Available at: http://factfinder.census.gov/servlet/ACSSAFFFacts?_event=&geo_id=05000US22019&_geoContext=01000US%7C04000US22%7C05000US22019&_street=&_county=calcasieu&_cityTown=calcasieu&_state=04000US22&_zip=&_lang=en&_sse=on&ActiveGeoDiv=geoSelect&_useEV=&pctxt=fph&pgsl=050&_submenuId=factsheet_1&ds_name=DEC_2000_SAFF&_ci_nbr=null&qr_name=null&reg=null%3Anull&_keyword=&_industry. Web site accessed February 2010.

United States Census Bureau (USCB). 2008d. 2006-2008 American Community Survey 3-Year Estimates, Demographic Profile Highlights, Selected Economic Characteristics -Lake Charles MSA, Louisiana. Available at: http://factfinder.census.gov/servlet/ADPTable?_bm=y&-geo_id=31000US29340&-qr_name=ACS_2008_3YR_G00_DP3YR5&-context=adp&-ds_name=&-tree_id=3308&-_lang=en&-redoLog=false&-format. Web site accessed February 2010.

Wild and Scenic Rivers Council. 2010. National Wild and Scenic Rivers. Available at: http://www.rivers.org. Website accessed February 2010.

National Association of Regulatory Utility Commissioners. 2009. Resolution on DOT and Congressional Appropriations, July 22. Available at: http://www.naruc.org.

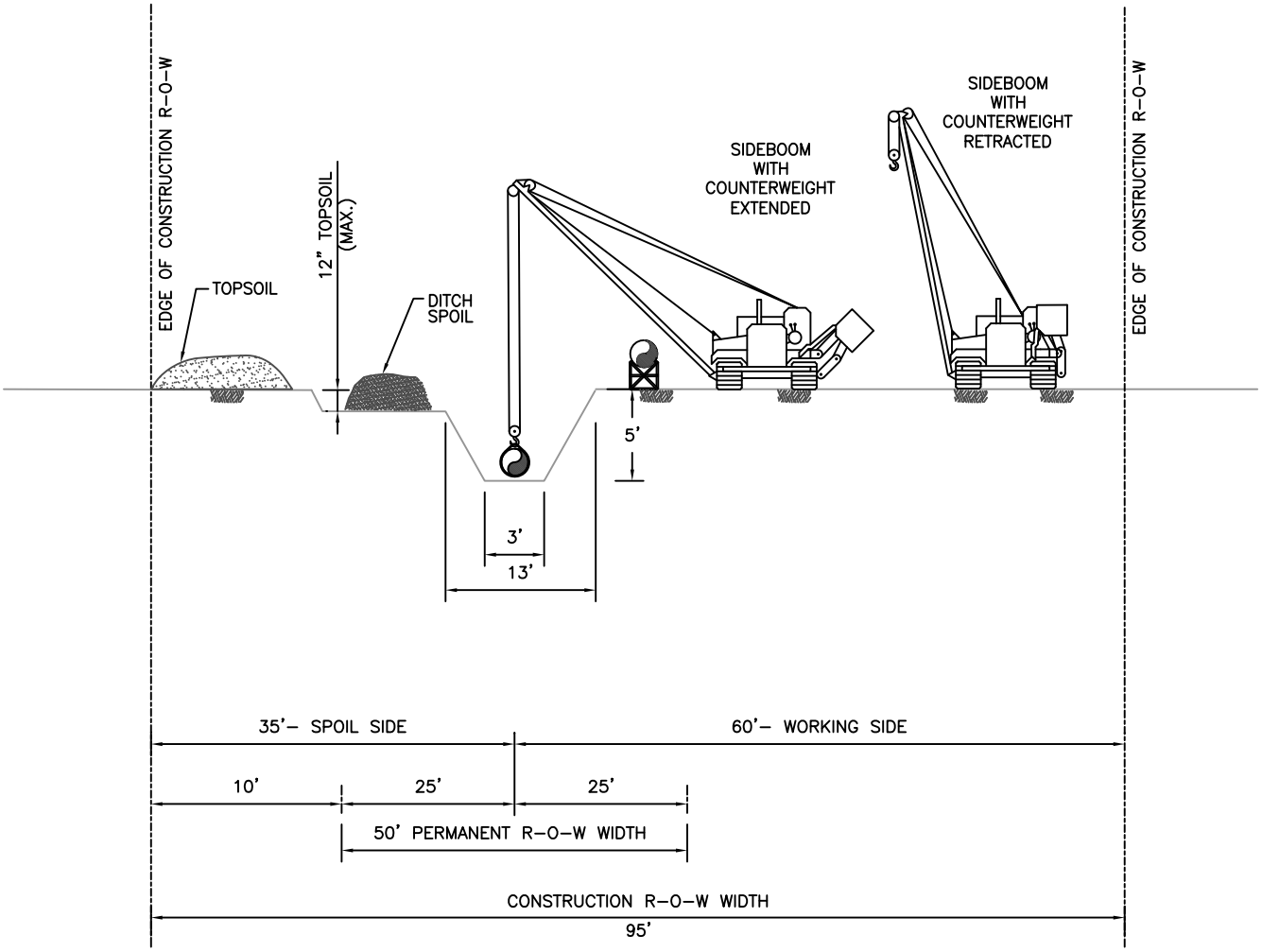
.

List of Agencies Contacted

All interagency cooperation will be conducted with DOE acting as the lead agency. This EIV was prepared based on desktop analysis only and available public information. No agency consultation has been conducted to date.

APPENDIX A

Typical Construction ROWs



CROSS SECTION

NOTES:

TOPSOIL STRIPPING ONLY REQUIRED IN AREAS INDICATED ON THE ALIGNMENT SHEETS OR AS REQUIRED BY PERMITTING AGENCY OR LANDOWNER

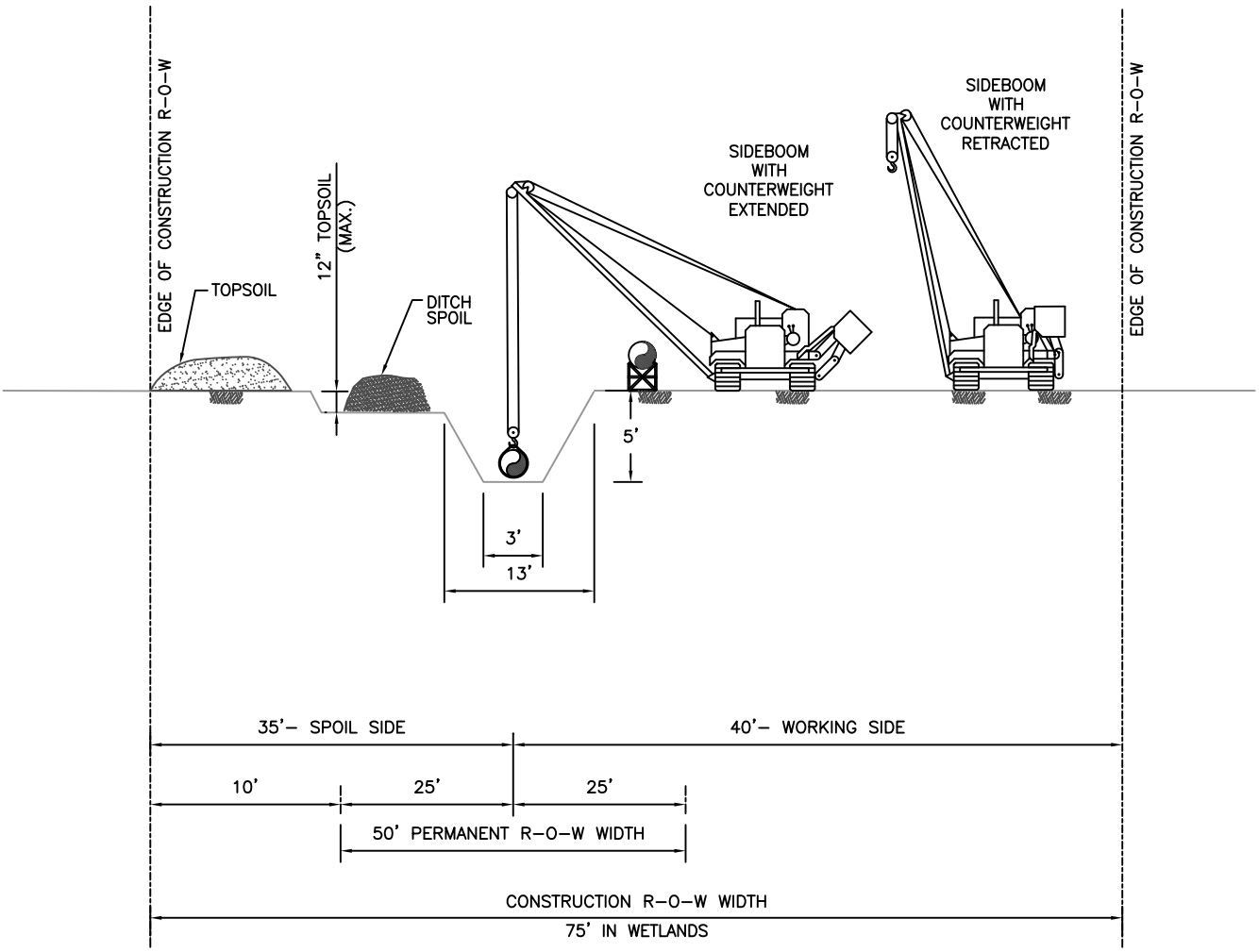
P.L./STA. ACCT. NO.		
AFE NO.		
REV.	BY	DATE

DENBURY - MOSS POINT
CO2 PIPELINE
TYPICAL UPLAND
R.O.W. CONFIGURATION FOR
20" PIPELINE

DRAWN	DATE	SCALE	APPR. BY	CONST.YR.
DJC	8/09	NTS		

PREVIOUS DWG. NO.

DRAWING NO.



CROSS SECTION

NOTES:

TOPSOIL STRIPPING ONLY REQUIRED IN AREAS INDICATED ON THE ALIGNMENT SHEETS OR AS REQUIRED BY PERMITTING AGENCY OR LANDOWNER

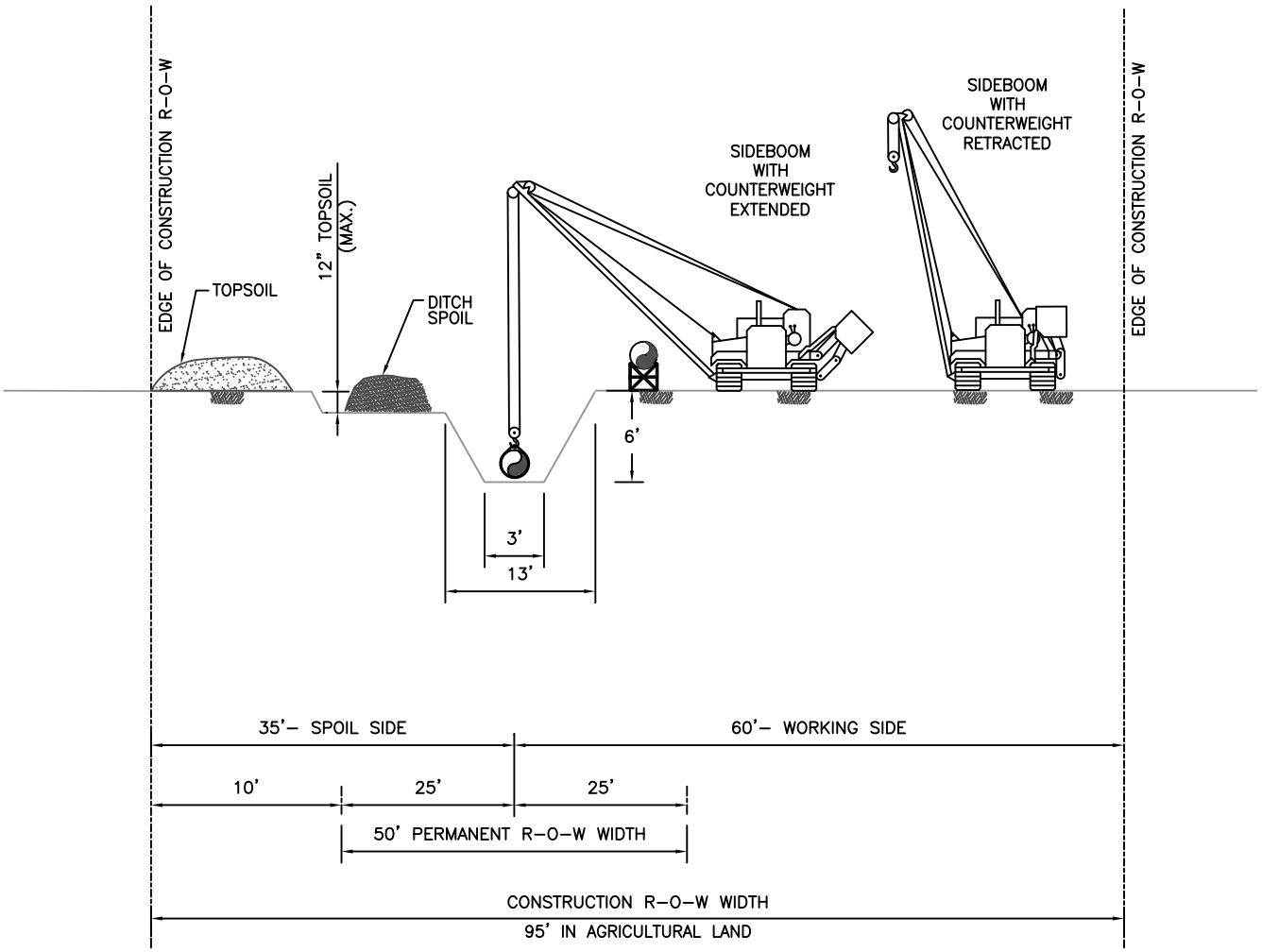
P.L./STA. ACCT. NO.		
AFE NO.		
REV.	BY	DATE

DENBURY - MOSS POINT
CO2 PIPELINE
TYPICAL WETLAND
R.O.W. CONFIGURATION FOR
20" PIPELINE

DRAWN	DATE	SCALE	APPR. BY	CONST.YR.
DJC	8/09	NTS		

PREVIOUS DWG. NO.

DRAWING NO.



CROSS SECTION

NOTES:

TOPSOIL STRIPPING ONLY IN DITCHLINE UNLESS OTHERWISE NOTED.

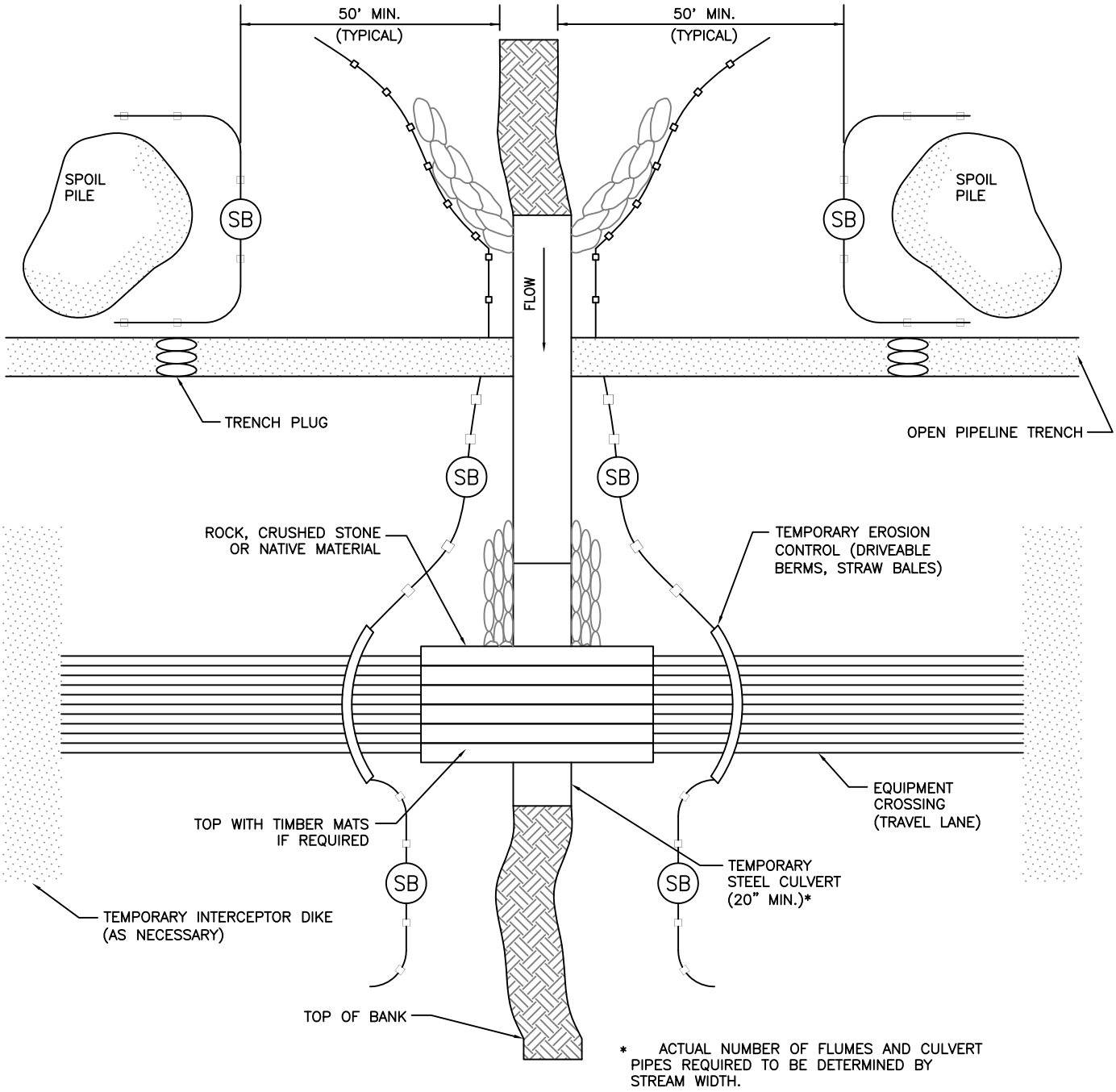
P.L./STA. ACCT. NO.		
AFE NO.		
REV.	BY	DATE

DENBURY - MOSS POINT
CO2 PIPELINE
TYPICAL AGRICULTURAL
R.O.W. CONFIGURATION FOR
20" PIPELINE

DRAWN	DATE	SCALE	APPR. BY	CONST.YR.
DJC	8/09	NTS		

PREVIOUS DWG. NO.

DRAWING NO.



NOTES:

1. SB–TEMPORARY SEDIMENT BARRIER OF SILT FENCE AND/OR STRAW BALES, OR APPROPRIATE MATERIALS.
2. COMPLETE PIPE INSTALLATION, BACKFILLING, AND RESTORATION OF STREAM CONTOURS (NOT INCLUDING ROCK BREAKING MEASURES) WITHIN THE TIMEFRAME SPECIFIED IN THE PROCEDURES FOR MINOR (0–10'), INTERMEDIATE (11'–99'), AND MAJOR (+100') WATERBODIES. IF A FLUME IS INSTALLED WITHIN THE WATERBODY DURING MAINLINE ACTIVITIES, IT CAN BE REMOVED JUST PRIOR TO LOWERING IN THE PIPELINE. THE TIMEFRAME STARTS AS SOON AS THE FLUME IS REMOVED.
3. STABILIZE STREAM BANKS AND INSTALL TEMPORARY SEDIMENT BARRIERS WITHIN 24 HOURS OF COMPLETING INSTREAM CONSTRUCTION ACTIVITIES.
4. ADDITIONAL TEMPORARY WORKSPACE ON EACH SIDE OF CROSSING WILL BE 25' x 150' TOTAL WITH 50' SETBACKS.

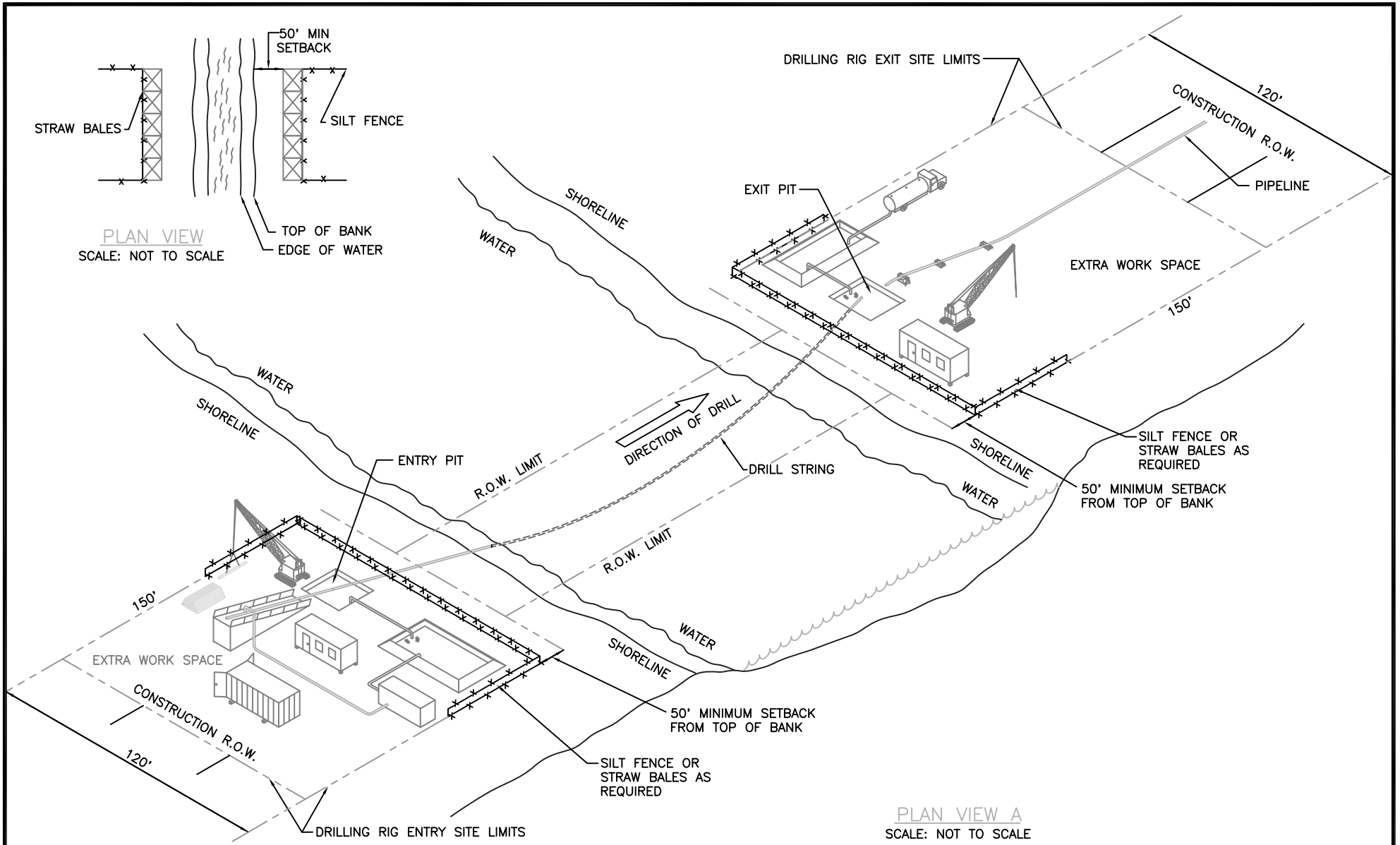
P.L./STA. ACCT. NO.		
AFE NO.		
REV.	BY	DATE

DENBURY – MOSS POINT
CO2 PIPELINE
TYPICAL CONSTRUCTION
OPEN CUT WET CROSSING

DRAWN	DATE	SCALE	APPR. BY	CONST.YR.
DJC	8/09	NTS		

PREVIOUS DWG. NO.

DRAWING NO.



NOTES:

1. EXTRA WORK SPACE NOT LOCATED IN WETLANDS WHEN POSSIBLE.
2. RIGHT-OF-WAY LIMITS FOR WETLAND AND UPLAND ARE 75' AND 95' RESPECTIVELY.

P.L./STA. ACCT. NO.		
AFE NO.		
REV.	BY	DATE

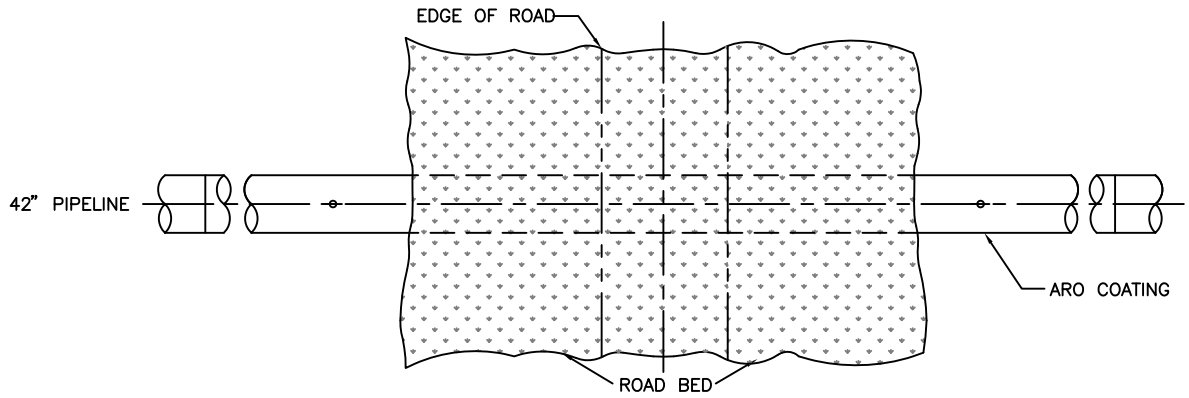
Topical 406

DENBURY – MOSS POINT CO2 PIPELINE TYPICAL CONSTRUCTION WATERBODY CROSSING WITH HDD PLAN

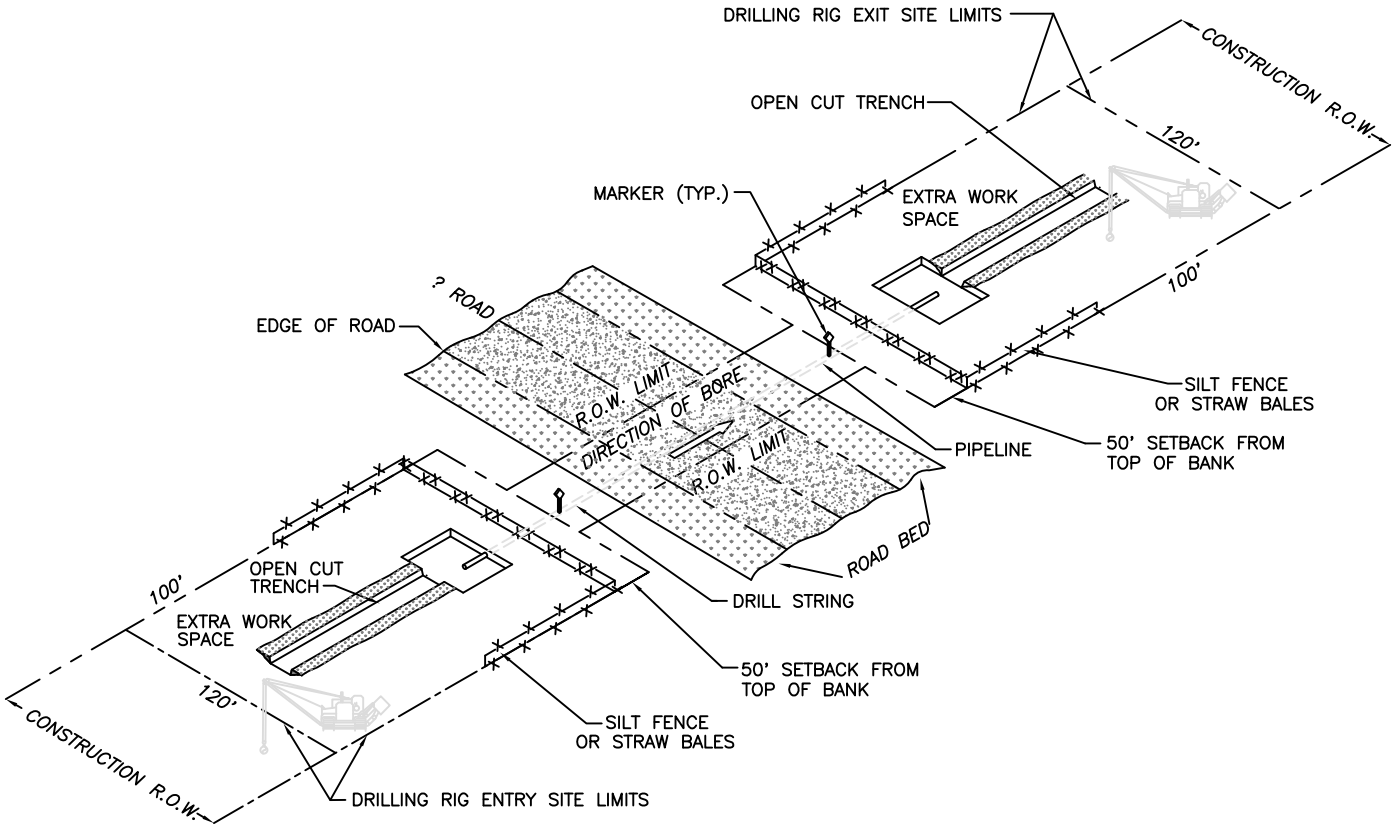
DRAWN	DATE	SCALE	APPR. BY	CONST.YR.
LB	8/09	NTS		

PREVIOUS DWG. NO.

DRAWING NO.



PLAN VIEW
SCALE: NOT TO SCALE



PLAN VIEW 'A'
SCALE: NOT TO SCALE

NOTES:

1. EXTRA WORK SPACE NOT LOCATED IN WETLAND WHEN POSSIBLE AND PRACTICAL.
2. RIGHT-OF-WAY LIMITS FOR WETLAND AND UPLAND ARE 75' AND 95' RESPECTIVELY.
3. WORK AREA WILL BE TEMPORARILY MATTED FOR MARSH AREAS.

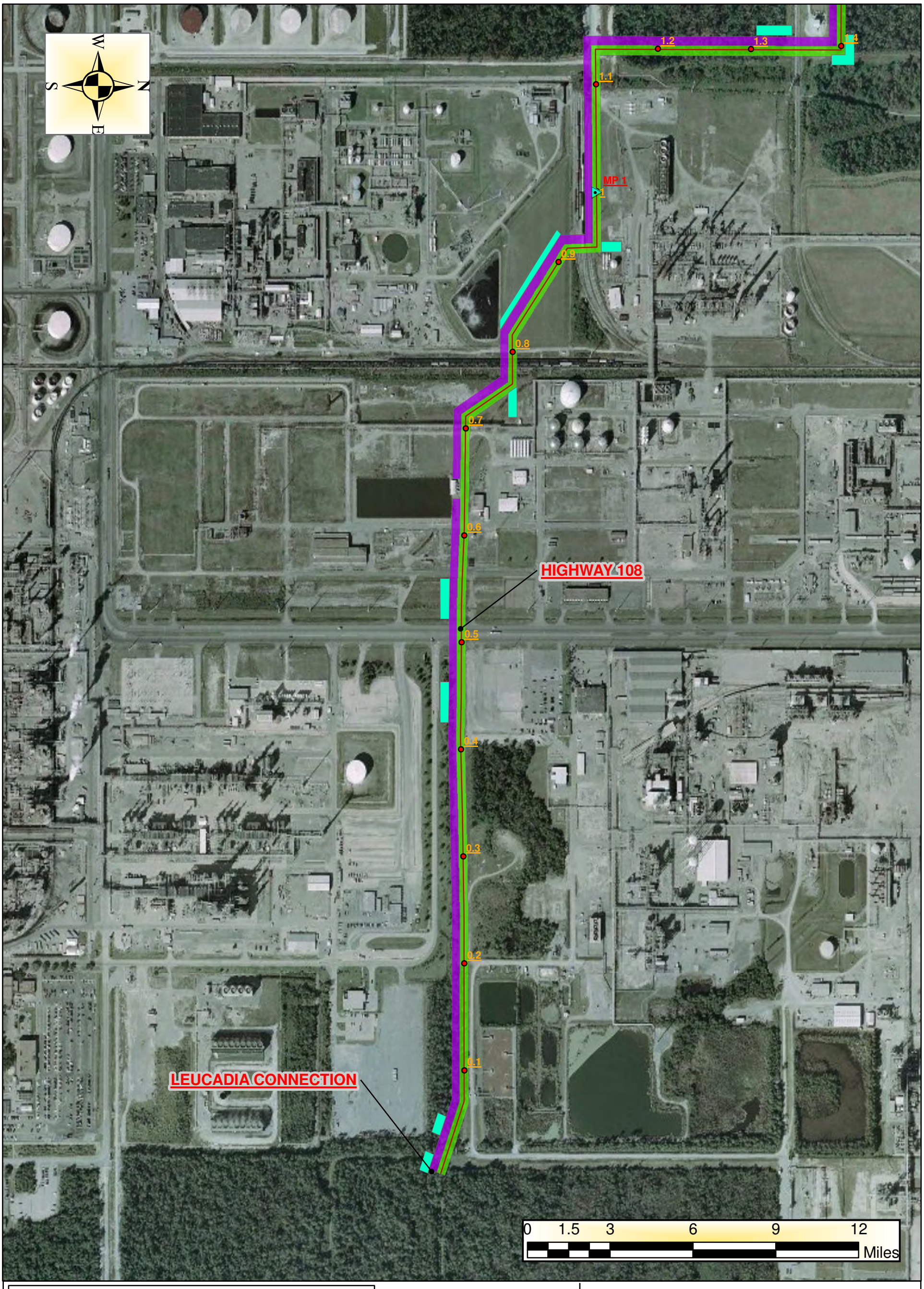
P.L./STA. ACCT. NO.		DENBURY - MOSS POINT CO2 PIPELINE TYPICAL CONSTRUCTION BORED ROAD CROSSING
AFE NO.		
REV. / BY / DATE		

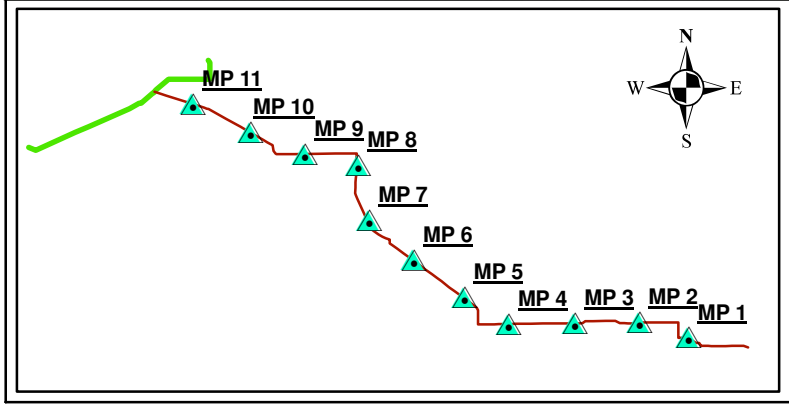
DRAWN	DATE	SCALE	APPR. BY	CONST.YR.
RJC	12/09	NTS		

PREVIOUS DWG. NO.
DRAWING NO.

APPENDIX B

Route Maps





Legend

- Mile_Post_84
- 10th_Mile_Post_84
- Proposed_Centerline_84
- Existing_Pipeline_lines_84
- Meter_Site_84
- Pipe_Contractor_Yard_84
- Valve_Site_84
- Atws_Areas_84
- Main_Route_Temp_Row_84
- Main_Route_Perm_Row_84

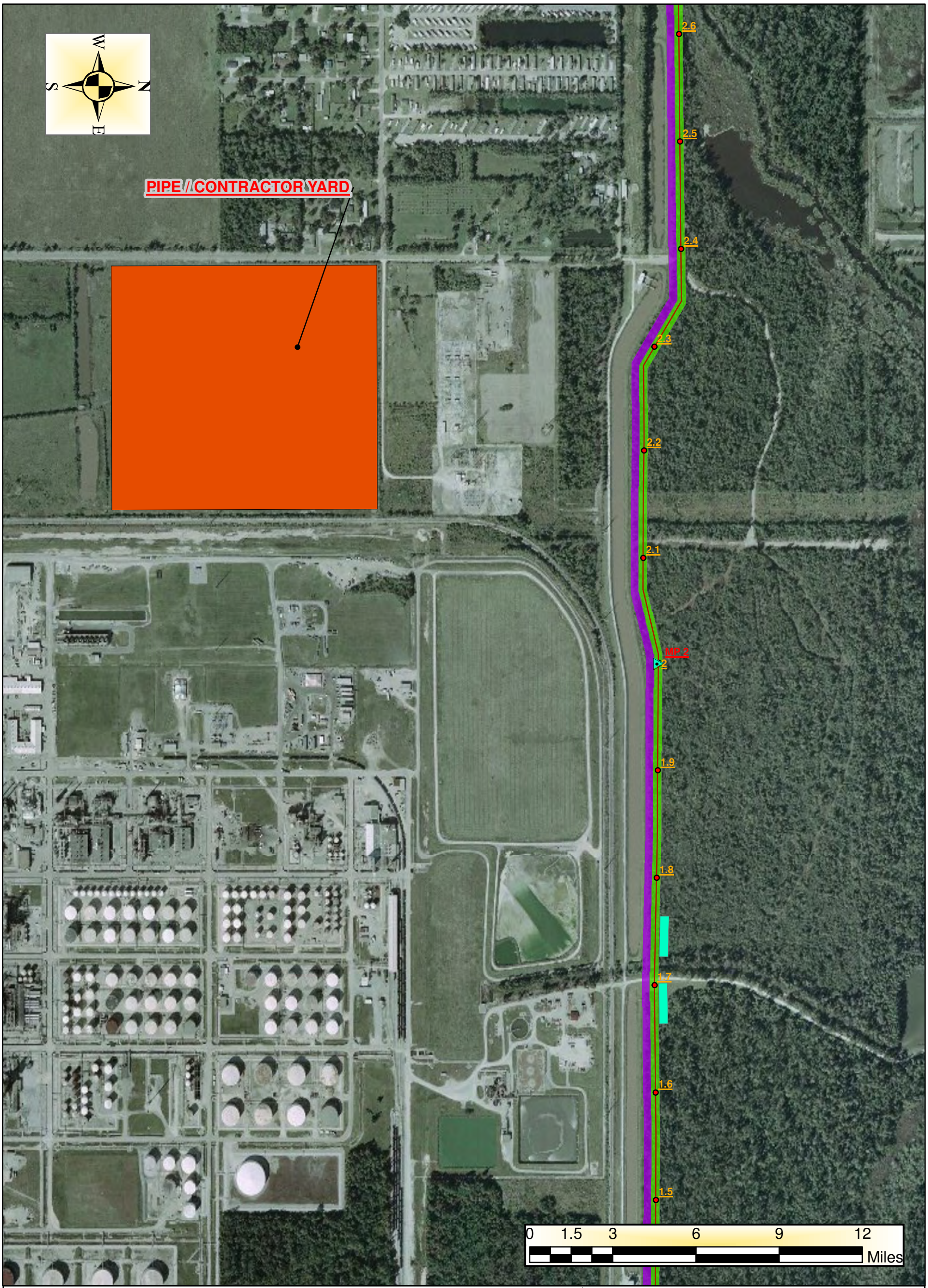
ENGlobal DENVER, COLORADO

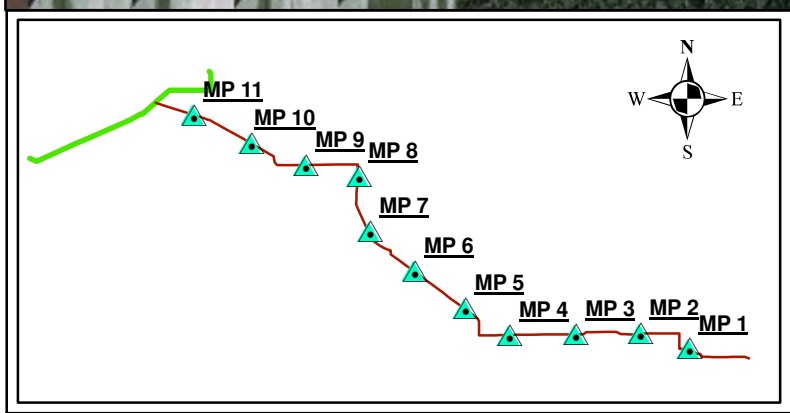
DENBURY ONSHORE,LLC.

LEUCADIA PROPOSED CO2 PIPELINE ROUTE MAP

SCALE: AS SHOWN
FEBRUARY 2010

SHEET 1 OF 9





Legend

- Mile_Post_84
- 10th_Mile_Post_84
- Proposed_Centerline_84
- Existing_Pipeline_lines_84
- Meter_Site_84
- Pipe_Contractor_Yard_84
- Valve_Site_84
- Atws_Areas_84
- Main_Route_Temp_Row_84
- Main_Route_Perm_Row_84

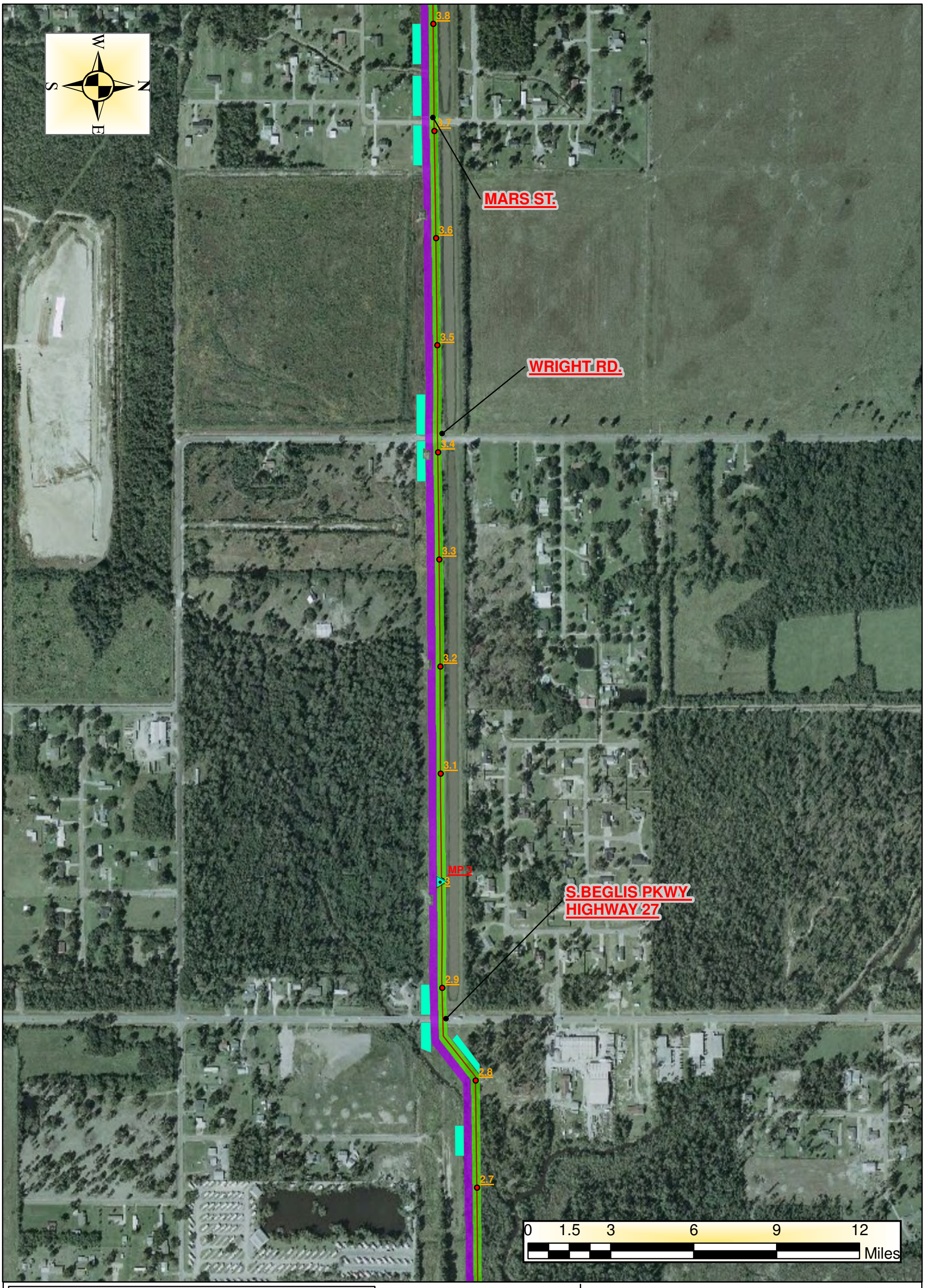
ENGlobal DENVER, COLORADO

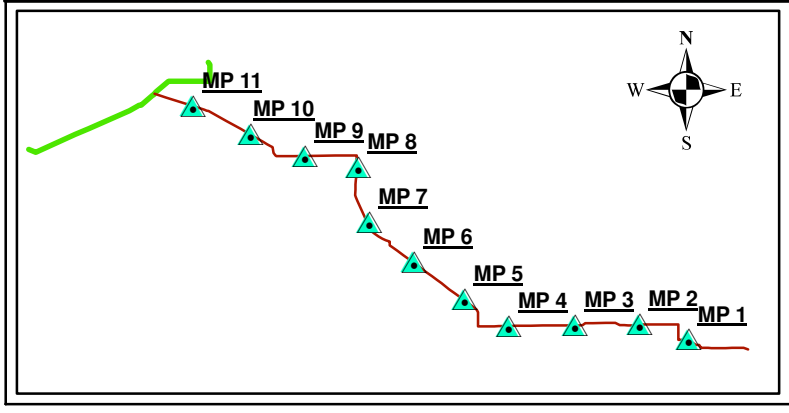
DENBURY ONSHORE,LLC.

LEUCADIA PROPOSED CO2 PIPELINE ROUTE MAP

SCALE: AS SHOWN
FEBRUARY 2010

SHEET 2 OF 9





Legend

- Mile_Post_84
- 10th_Mile_Post_84
- Proposed_Centerline_84
- Existing_Pipeline_lines_84
- Pipe_Contractor_Yard_84
- Valve_Site_84
- Atws_Areas_84
- Main_Route_Temp_Row_84
- Main_Route_Perm_Row_84

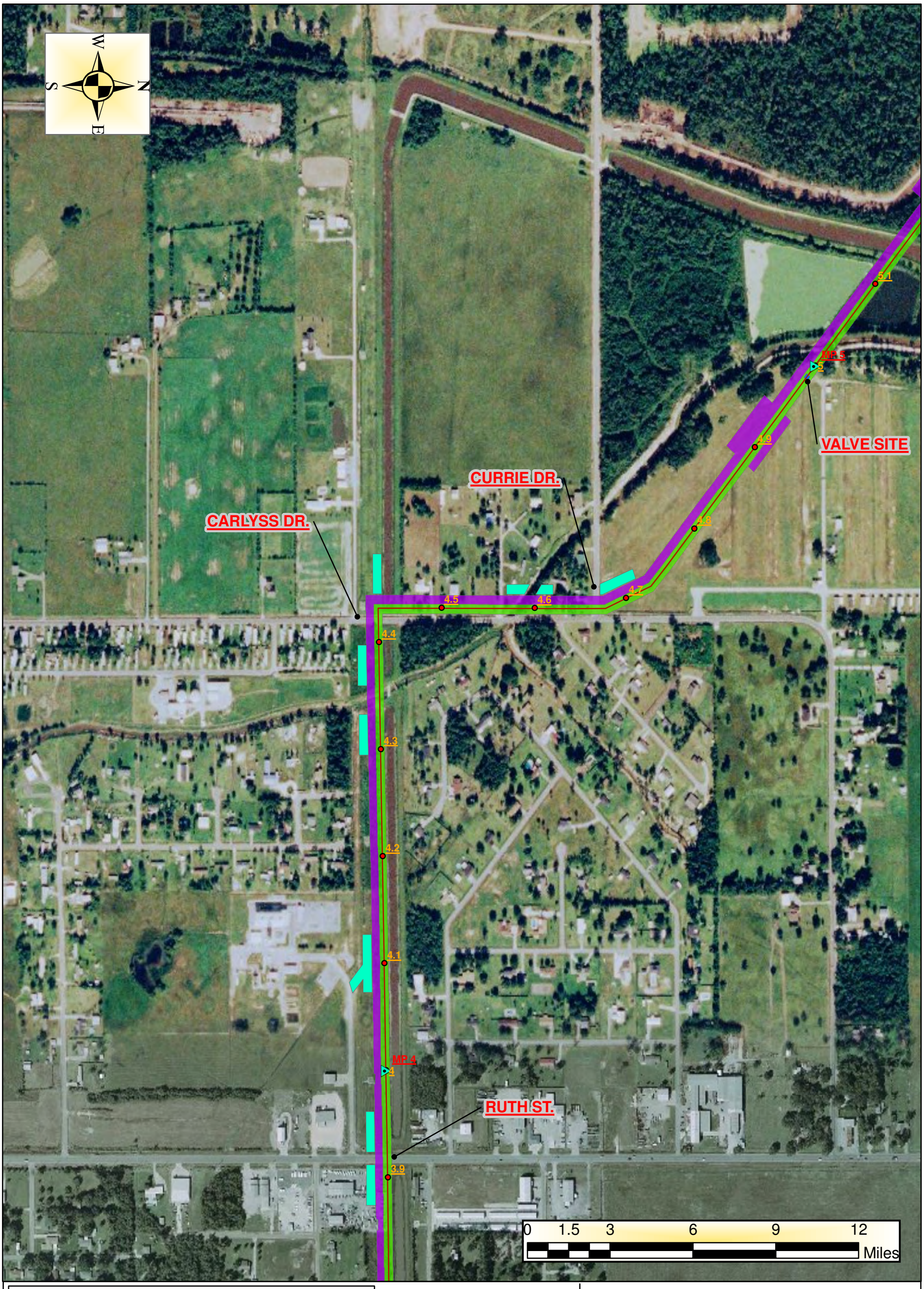
ENGlobal DENVER, COLORADO

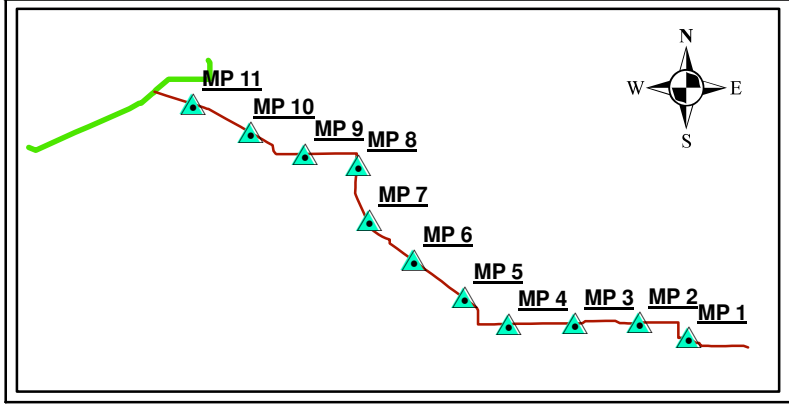
DENBURY ONSHORE,LLC.

LEUCADIA PROPOSED CO2 PIPELINE ROUTE MAP

SCALE: AS SHOWN
FEBRUARY 2010

SHEET 3 OF 9





Legend

- Mile_Post_84
- 10th_Mile_Post_84
- Proposed_Centerline_84
- Existing_Pipeline_lines_84
- Pipe_Contractor_Yard_84
- Valve_Site_84
- Atws_Areas_84
- Main_Route_Temp_Row_84
- Main_Route_Perm_Row_84

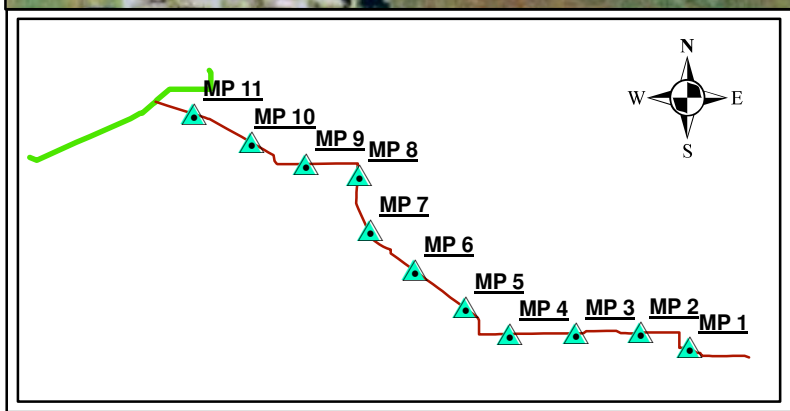
ENGlobal DENVER, COLORADO

DENBURY ONSHORE,LLC.

LEUCADIA PROPOSED CO2 PIPELINE ROUTE MAP

SCALE: AS SHOWN
FEBRUARY 2010

SHEET 4 OF 9



Legend

- Mile_Post_84
- 10th_Mile_Post_84
- Proposed_Centerline_84
- Existing_Pipeline_lines_84
- Pipe_Contractor_Yard_84
- Valve_Site_84
- Atws_Areas_84
- Main_Route_Temp_Row_84
- Main_Route_Perm_Row_84

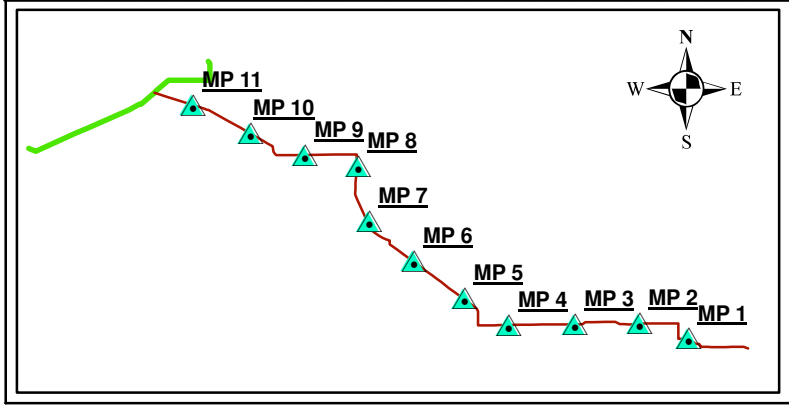
ENGlobal DENVER, COLORADO

DENBURY ONSHORE,LLC.

LEUCADIA PROPOSED CO2 PIPELINE ROUTE MAP

SCALE: AS SHOWN
FEBRUARY 2010

SHEET 5 OF 9



Legend

- Mile_Post_84
- 10th_Mile_Post_84
- Proposed_Centerline_84
- Existing_Pipeline_lines_84
- Pipe_Contractor_Yard_84
- Valve_Site_84
- Atws_Areas_84
- Main_Route_Temp_Row_84
- Main_Route_Perm_Row_84

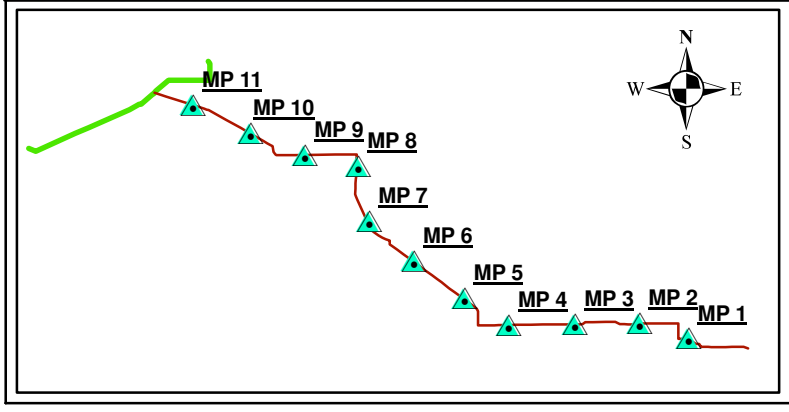
ENGlobal DENVER, COLORADO

DENBURY ONSHORE,LLC.

LEUCADIA PROPOSED CO2 PIPELINE ROUTE MAP

SCALE: AS SHOWN
FEBRUARY 2010

SHEET 6 OF 9



Legend

- Mile_Post_84
- 10th_Mile_Post_84
- Proposed_Centerline_84
- Existing_Pipeline_lines_84
- Pipe_Contractor_Yard_84
- Valve_Site_84
- Atws_Areas_84
- Main_Route_Temp_Row_84
- Main_Route_Perm_Row_84

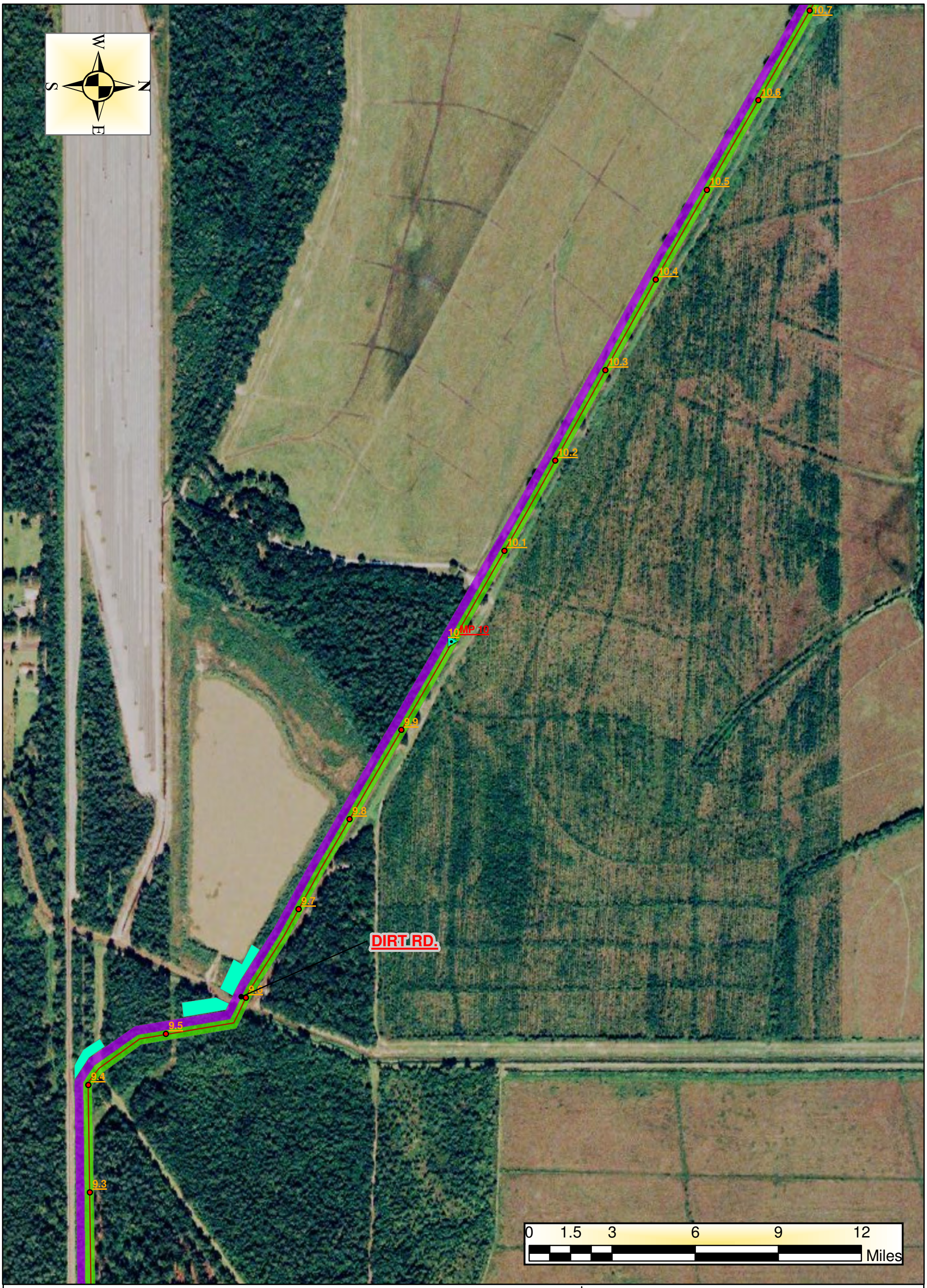
ENGlobal DENVER, COLORADO

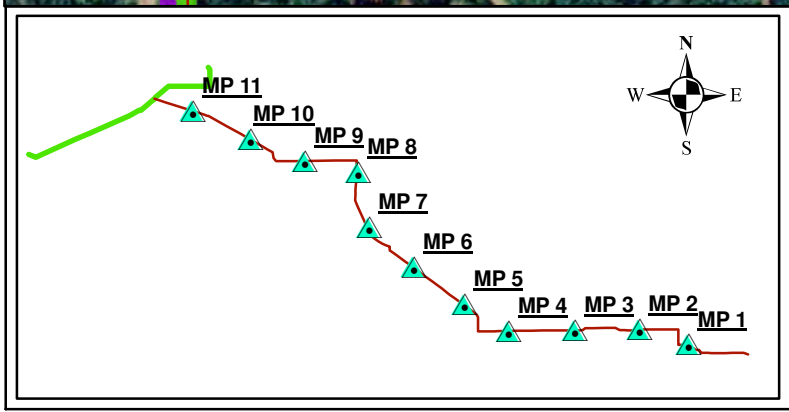
DENBURY ONSHORE,LLC.

LEUCADIA PROPOSED CO2 PIPELINE
ROUTE MAP

SCALE: AS SHOWN
FEBRUARY 2010

SHEET 7 OF 9





Legend

- Mile_Post_84
- 10th_Mile_Post_84
- Proposed_Centerline_84
- Existing_Pipeline_lines_84
- Pipe_Contractor_Yard_84
- Valve_Site_84
- Atws_Areas_84
- Main_Route_Temp_Row_84
- Main_Route_Perm_Row_84

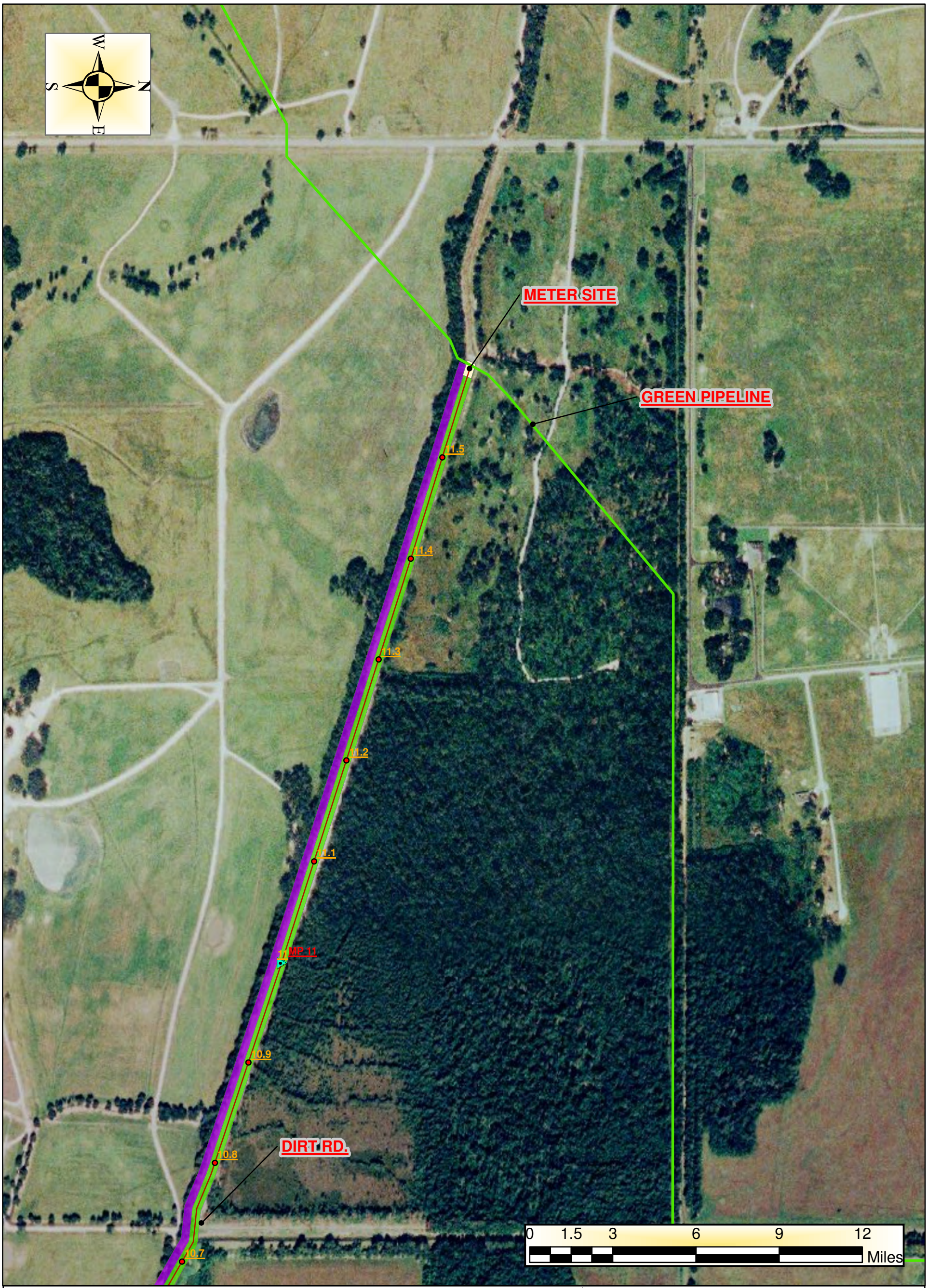
ENGlobal DENVER, COLORADO

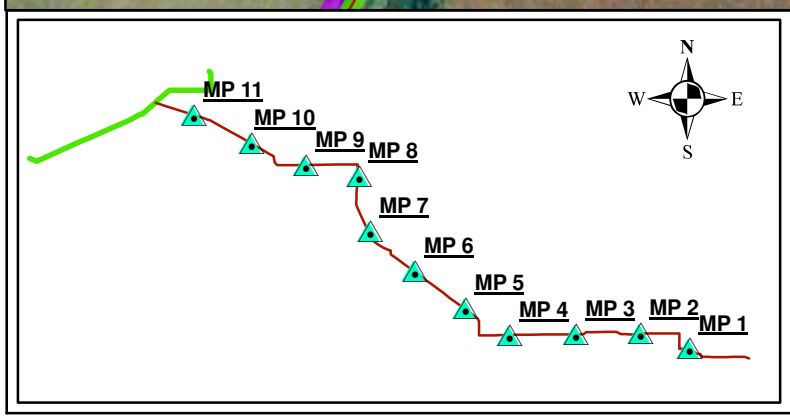
DENBURY ONSHORE,LLC.

LEUCADIA PROPOSED CO2 PIPELINE
ROUTE MAP

SCALE: AS SHOWN
FEBRUARY 2010

SHEET 8 OF 9





Legend

- Mile_Post_84
- 10th_Mile_Post_84
- Proposed_Centerline_84
- Existing_Pipeline_lines_84
- Meter_Site_84
- Pipe_Contractor_Yard_84
- Valve_Site_84
- Atws_Areas_84
- Main_Route_Temp_Row_84
- Main_Route_Perm_Row_84

ENGlobal DENVER, COLORADO

DENBURY ONSHORE,LLC.

LEUCADIA PROPOSED CO2 PIPELINE ROUTE MAP

SCALE: AS SHOWN
FEBRUARY 2010

SHEET 9 OF 9

APPENDIX C

Land Owner Lists

Leucadia Energy
Lake Charles Pipeline Line List
Primary Route

Tract	Owner	Tax Map Parcel Number	Address	City	State	Zip	Phone	Parish	Tax Assessment Number
1	Basell USA Inc (Montell North America, Inc)	171009-0000-340-0002	P. O. Box 1687	Lake Charles	LA	70602		Calcasieu	01298631
2	Basell USA Inc (Montell North America, Inc)	181009-0000-210-0003	P. O. Box 1687	Lake Charles	LA	70602		Calcasieu	00145963
3	Basell USA Inc (Montell North America, Inc)	181009-0000-210-0002	P. O. Box 1687	Lake Charles	LA	70602		Calcasieu	00145963
4	Basell USA Inc (Montell North America, Inc)	181009-0000-240-0002	P. O. Box 1687	Lake Charles	LA	70602		Calcasieu	00182613
5	Citgo Petroleum Corporation	181009-0000-210-0001	P. O. Box 3758	Tulsa	OK	74102		Calcasieu	012118654
6	Occidental Chemical Corporation (Equistar Chemicals LP)	181009-0000-240-0003	P. O. Box 3646	Houston	TX	77253		Calcasieu	00126640
7	**Cities Service Hwy**								
8	Occidental Chemical Corporation (Equistar Chemicals LP)	181009-0000-310-0001	P. O. Box 3646	Houston	TX	77253		Calcasieu	00126640
9	**Defense Plant Corporate Railroad ROW**								
10	Firestone Tire and Rubber Company	181009-0000-340-0001	P. O. Box 1316	Lake Charles	LA	70602		Calcasieu	00136697
11	Occidental Chemical Corporation (Equistar Chemicals LP)	181009-0000-430-0001	P. O. Box 3646	Houston	TX	77253		Calcasieu	00126640
12	Cit-Con Oil Corporation	131010-0000-120-0002	P. O. Box 3758	Tulsa	OK	74102		Calcasieu	00126526
13	Citgo Petroleum Corporation	131010-0000-120-0001	P. O. Box 3758	Tulsa	OK	74102		Calcasieu	00126616
14	Citgo Petroleum Corporation	131010-0000-110-0001	P. O. Box 3758	Tulsa	OK	74102		Calcasieu	00126594
15	Citgo Petroleum Corporation	131010-0000-140-0001	P. O. Box 3758	Tulsa	OK	74102		Calcasieu	00126616
16	Cit-Con Oil Corporation	131010-0000-140-0003	P. O. Box 3758	Tulsa	OK	74102		Calcasieu	00126526
17	John Leroy Glover, Jr, et al	131010-0000-140-0002	P. O. Box 2471	Baton Rouge	LA	70821		Calcasieu	00118362
18	John Leroy Glover, Jr, et al	131010-0000-410-0001	P. O. Box 2471	Baton Rouge	LA	70821		Calcasieu	00118362
19	John Leroy Glover, Jr, et al	131010-0000-440-0001	P. O. Box 2471	Baton Rouge	LA	70821		Calcasieu	00118362
20	James T. Quinn	141010-0000-110-0001	611 Ravia Road	Sulphur	LA	70665		Calcasieu	00171298
21	Trocar Inc.	141010-0000-140-0005-01	P. O. Box 1057	Suphur	LA	70664		Calcasieu	01328297
	David Alexander Foster		4582 Kingwood Drive Suite E #227	Kingwood	TX	77345		Calcasieu	00492957
22	**Sabine River Diversion System Canal**								
23	Edward Tal McCain, et al	141010-0000-140-0005-03	611 Ravia Road	Sulphur	LA	70665		Calcasieu	00158216
24	**Arizona Street/South Beglis Parkwa**								
25	Edward Tal McCain, et al	141010-0000-140-0006	864 Hwy 384	Lake Charles	LA	70607		Calcasieu	00158216
26	James T. Quinn	141010-0000-410-0001	611 Ravia Road	Suphur	LA	70665		Calcasieu	00161319
	Dennis Ray Sumpter, et ux		1003 S. Huntington Street	Suphur	LA	70663		Calcasieu	01080466
	Joe W. Fournet		3402 Stillwater Lane	Sugarland	TX	77479		Calcasieu	00137758
	William R. McDonald		200 Griffith Street	Lake Charles	LA	70601		Calcasieu	00137766
27	Entergy Gulf States La./Entergy Texas, Inc	141010-0000-440-0006	639 Loyola Avenue	New Orleans	LA	70113		Calcasieu	00748239A & 00748239
28	**Wright Road**								
29	Palvest Inc	151010-0920-F-0005	2701 Maplewood Drive	Sulphur	LA	70663		Calcasieu	00542199
30	**Mars Street**								
31	Palvest Inc	151010-0920-C-0005-02	2701 Maplewood Drive	Sulphur	LA	70663		Calcasieu	00842583
	Palermo Land Company Inc.		2701 Maplewood Drive	Suphur	LA	70663		Calcasieu	00166766
32	**Sabine Diversion System Canal**								
33	Mike Shetley Company/Palvest Inc	151010-0920-C-0004-02	2701 Maplewood Drive	Sulphur	LA	70663		Calcasieu	00795909
34	Gerald Glenn Pettefer, et ux	151010-0920-C-0001-03	660 Starlin Street	Sulphur	LA	70663		Calcasieu	00544477
35	**Ruth Street/U.S. Hwy 27**								
36	Big Three Industries, Inc (Air Liquide America Corp)	151010-0000-420-0001	P. O. Box 460149	Houston	TX	77056		Calcasieu	00795852
37	**Carlyss Drive**								
38	**NO INFO FOUND**	161010-0000-120-0001							
39	Carlton Eugene Lovett	161010-0000-110-0004-03	2355 Royal Oak Lane	Sulphur	LA	70663		Calcasieu	01155113
40	**Sabine Diversion System Canal**								
41	Willis Stanley Willson, et ux	161010-0000-110-0004-01	3806 Carlyss Drive	Sulphur	LA	70665		Calcasieu	01189441
42	Edward Buttikofer, Jr	161010-0000-110-0004-04	3802 Carlyss Drive	Sulphur	LA	70665		Calcasieu	0130078
43	Rene' Joseph and Lorraine Guidry	161010-0000-110-0001-07	309 Arnold Street	Suphur	LA	70663		Calcasieu	01090098
44	John Ahart Guidry	161010-0000-110-0001-06	555 Jay's Circle	Sulphur	LA	70665		Calcasieu	01121561
45	Arthur Rene Guidry	161010-0000-110-0001-05	589 Jay's Circle	Sulphur	LA	70665			01121553
46	Agnes Yvette Trahan	161010-0000-110-0001-04	1601 Currie Drive	Sulphur	LA	70665		Calcasieu	01121545
47	John David Westbrook, et al	161010-0000-110-0006-01	P. O. Box 2383	Suphur	LA	70664		Calcasieu	01353271
48	Georgina Rae Delossey Watson	161010-0000-110-0006-02	3642 Carlyss Drive	Sulphur	LA	70665		Calcasieu	01340136
49	**Currie Road**								
50	Bel Commercial LTD	091010-0000-220-0001	P. O. Box 1447	Lake Charles	LA	70602		Calcasieu	01345381
51	Raleigh and Barbara Newman	091010-0000-230-0002	1830 Hodges Street	Lake Charles	LA	70601		Calcasieu	00924296

Leucadia Energy
Lake Charles Pipeline Line List
Primary Route

Tract	Owner	Tax Map Parcel Number	Address	City	State	Zip	Phone	Parish	Tax Assessment Number
52	Raleigh and Barbara Newman	091010-0000-210-0001	1830 Hodges Street	Lake Charles	LA	70601		Calcasieu	00924296
53	Raleigh and Barbara Newman	091010-0000-240-0002	1830 Hodges Street	Lake Charles	LA	70601		Calcasieu	00924296
54	**Sabine River Diversion System Canal**								
55	Christina Eve Duplechain	091010-0000-310-0002	280 Ray Duplechain Road	DeRidder	LA	70643		Calcasieu	01359303
56	William Logan Perkins, et al	091010-0000-420-0003	3336 Hwy 27 South	Suphur	LA	70665		Calcasieu	00890170
57	Perkins-Thomas LLC	091010-0000-420-0001	3044 Hwy 27 South	Sulphur	LA	70665		Calcasieu	00781010
58	William Mitchell Perkins	091010-0000-420-0002	5706 Alder	Lake Charles	LA	70605		Calcasieu	00796174
59	B H Timber, Inc.	091010-0000-430-0001	P. O. Box 788	Baton Rouge	LA	70821		Calcasieu	00115959
60	B H Timber, Inc.	091010-0000-440-0001	P. O. Box 788	Baton Rouge	LA	70821		Calcasieu	00115959
61	B H Timber, Inc.	081010-0000-110-0001	P. O. Box 788	Baton Rouge	LA	70821		Calcasieu	00115959
62	B H Timber, Inc.	051010-0000-220-0001	P. O. Box 788	Baton Rouge	LA	70821		Calcasieu	00115959
63	B H Timber, Inc.	051010-0000-230-0001	P. O. Box 788	Baton Rouge	LA	70821		Calcasieu	00115959
64	**I-10**								
65	B H Timber, Inc.	051010-0000-230-0002	P. O. Box 788	Baton Rouge	LA	70821		Calcasieu	00115959
66	B H Timber, Inc.	051010-0000-240-0001	P. O. Box 788	Baton Rouge	LA	70821		Calcasieu	00115959
67	B H Timber, Inc.	051010-0000-310-0001	P. O. Box 788	Baton Rouge	LA	70821		Calcasieu	00115959
68	B H Timber, Inc.	051010-0000-420-0001	P. O. Box 788	Baton Rouge	LA	70821		Calcasieu	00115959
69	B H Timber, Inc.	051010-0000-410-0001	P. O. Box 788	Baton Rouge	LA	70821		Calcasieu	00115959
70	Curtis Edmond McCain, et ux	051010-0000-440-0002	2238 Pete Seay Drive	Sulphur	LA	70665		Calcasieu	01321091
71	B H Timber, Inc.	051010-0000-440-0004	P. O. Box 788	Baton Rouge	LA	70821		Calcasieu	00115959
72	Bryan David Crawford, et ux	051010-0000-440-0003	2174 Pete Seay Drive	Sulphur	LA	70665		Calcasieu	01324985
73	B H Timber, Inc.	051010-0000-440-0001	P. O. Box 788	Sulphur	LA	70665		Calcasieu	00115959
74	A. J. Simmons, Jr., et ux	320910-2146-0007-03	2167 Hwy 90 West	Sulphur	LA	70663		Calcasieu	01189077
75	A. J. Simmons, Jr., et ux	320910-2146-0007-02	2167 Hwy 90 West	Sulphur	LA	70663		Calcasieu	01189077
76	**U.S. Hwy 90/W. Napoleon**								
78	Burlington Resources Oil & Gas Co., LP	320910-0000-330-0001	411 S. Keeler #AB	Bartlesville	OK	74004		Calcasieu	00115924
79	Burlington Resources Oil & Gas Co., LP	320910-0000-340-0001	411 S. Keeler #AB	Bartlesville	OK	74004		Calcasieu	00115924
80	**Railroad ROW**								
81	Burlington Resources Oil & Gas Co., LP	320910-0000-430-0001	411 S. Keeler #AB	Bartlesville	OK	74004		Calcasieu	00115924
82	Mark Gregory Merrick, et ux	320910-0000-430-0002	2308 W. Burton Street	Sulphur	LA	70663		Calcasieu	01163817
83	David Wayne Williamson, et ux	320910-0000-430-0003	2312 W. Burton Street	Sulphur	LA	70663		Calcasieu	01163825
84	City of Sulphur	320910-430-0004	P. O. Box 1309	Sulphur	LA	70664		Calcasieu	01163914
85	City of Sulphur	310910-0000-120-0001	P. O. Box 1309	Sulphur	LA	70664		Calcasieu	01163914
86	Carolyn J. Gifford, et ux	310910-0000-130-0001	P. O. Box 5676	Lake Charles	LA	70606		Calcasieu	01163876
87	**Steagel Road**								
88	Burlington Resources Oil & Gas Co., LP	310910-0000-420-0002	411 S. Keeler #AB	Bartlesville	OK	74004		Calcasieu	00115924
89	Burlington Resources Oil & Gas Co., LP	310910-0000-430-0001	411 S. Keeler #AB	Bartlesville	OK	74004		Calcasieu	00115924
90	**Sabine River Diversion System Canal**								
91	Union Pacific Railroad Company-Main Line	360911-0000-120-0003	1400 Douglas Street Stop 1640	Omaha	NE	68179		Calcasieu	01350632
92	Union Pacific Railroad Company-Main Line	360911-0000-110-0001	1400 Douglas Street Stop 1640	Omaha	NE	68179		Calcasieu	01350632
93	Rhodes Veteranary Hospital Inc, Profit Sharing Trust	360911-0000-110-0002	2597 WPA Road	Sulphur	LA	70663		Calcasieu	01321274
94	Stream Family Limited Partnership	250911-0000-230-0001	P. O. Box 40	Lake Charles	LA	70602		Calcasieu	01324207
95	Rhodes Veteranary Hospital Inc, Profit Sharing Trust	250911-0000-230-0002	2597 WPA Road	Sulphur	LA	70663		Calcasieu	01321274
96	Rhodes Veteranary Hospital Inc, Profit Sharing Trust	250911-0000-320-0002	2597 WPA Road	Suphur	LA	70663		Calcasieu	01321274
97	Rhodes Veteranary Hospital Inc, Profit Sharing Trust	250911-0000-310-0002	2597 WPA Road	Sulphur	LA	70663		Calcasieu	01321274
98	Rhodes Veteranary Hospital Inc, Profit Sharing Trust	250911-0000-340-0002	2597 WPA Road	Sulphur	LA	70663		Calcasieu	01321274
99	**Sabine Diversion System Canal**								
100	Rhodes Veteranary Hospital Inc, Profit Sharing Trust	260911-0000-210-0001	2597 WPA Road	Sulphur	LA	70663		Calcasieu	01321274
101	Burlington Resources Oil & Gas Co., LP	260911-0000-120-0001	411 S. Keeler #AB	Bartlesville	OK	74004		Calcasieu	00115924
102	Rhodes Veteranary Hospital Inc, Profit Sharing Trust	260911-0000-130-0001	2597 WPA Road	Sulphur	LA	70663		Calcasieu	01321274
103	Gary Wayne Livengood, et ux	260911-0000-130-0002	1929 Honeysuckle Lane	Sulphur	LA	70663		Calcasieu	01228277
104	Gary Wayne Livengood, et ux	260911-0000-420-0002	1929 Honeysuckle Lane	Sulphur	LA	70663		Calcasieu	01345332
105	Rhodes Veteranary Hospital Inc, Profit Sharing Trust	260911-0000-420-0001	2597 WPA Road	Sulphur	LA	70663		Calcasieu	01341764
106	Gary Wayne Livengood, et ux	260911-0000-410-0003	1929 Honeysuckle Lane	Sulphur	LA	70663		Calcasieu	01345332
107	Rhodes Veteranary Hospital Inc, Profit Sharing Trust	260911-0000-430-0001	2597 WPA Road	Sulphur	LA	70663		Calcasieu	01341764
108	Rhodes Veteranary Hospital Inc, Profit Sharing Trust	260911-0000-440-0005	2597 WPA Road	Sulphur	LA	70663		Calcasieu	01341764

Leucadia Energy
Lake Charles Pipeline Line List
Primary Route

Tract	Owner	Tax Map Parcel Number	Address	City	State	Zip	Phone	Parish	Tax Assessment Number
109	Gary Wayne Livengood, et ux	260911-0000-440-0003	1929 Honeysuckle Lane	Sulphur	LA	70663		Calcasieu	01345332

APPENDIX A

Greencore CO_2 Pipeline Project

Toughness Requirements to Arrest Longitudinal Ductile Fractures

Prepared for

CH2M Hill Trigon, Inc.

Denver, Colorado

by

Tensor Engineering Ltd

Calgary, Alberta

October 09, 2009

Table of Contents

1. Introduction 3
2. Purpose 3
3. Background 3
4. Gas Composition 5
5. Pipe Toughness 6
6. Sensitivity Analysis 11
7. Conclusions and Recommendations 18
8. References 18
Appendix A Canadian Code Requirements 19
Appendix B Excerpts from CSA Z662 20

1. Introduction

Longitudinal ductile fractures have posed serious safety risks for high pressure gas pipelines over the last 40 years and the gas pipeline industry has invested significant resources into understanding the phenomenon and into finding economic and effective solutions. Carbon dioxide pipelines share the same safety risks and can use similar methods to resolve the problem.

The solution developed by the gas pipeline industry has been to use the metallurgical properties of the pipe wall to arrest longitudinal ductile fractures rather than the installation of crack arrestors at intervals along the length of the pipe.

2. Purpose

This report has been prepared specifically for the Greencore CO_2 Pipeline Project to determine the required toughness of line pipe that can prevent longitudinal ductile fractures using the metallurgical properties of the pipe wall rather than mechanical fracture arrest devices.

The Greencore CO_2 Pipeline Project will strip 200 MMscfd (6938 T/d) of carbon dioxide from natural gas and transport it 231 miles (372 km) from Wyoming to Montana by pipeline. The pipeline will operate at pressures between 1200 psig (8,274 kPag) and 3705 psig (25,545 kPag), and at temperatures between -20°F (-30°C) and 120°F (50°C).

Pipe for the Project will be API 5L Grade X70 NPS 8 and 10 seamless or ERW linepipe. Wall thickness of the NPS 8 pipe will be 0.317 inch (8.1 mm) in Class 1 locations and 0.380 inch (9.7 mm) in Class 2 Locations. Wall thickness of the NPS 10 pipe will be 0.395 inch (10.0 mm) in Class 1 Locations and 0.474 inch (12.0 mm) in Class 2 Locations.

The report recommends the required toughness for the four pipe sizes under consideration and provides background information on longitudinal ductile fractures in high pressure pipelines. It includes appendices that summarize the special requirements of the Canadian pipeline code [1] governing carbon dioxide pipelines.

3. Background

The possibility that very long ductile fractures can occur in carbon dioxide pipelines was first identified in the late 1970s. [2] Subsequently, fracture arrest devices were retrofitted to existing carbon dioxide pipelines to help reduce risk. Since that time a few new carbon dioxide pipelines were built with mechanical fracture arrest devices, but by using pipe with thicker walls and tougher steels, it has been possible to design and build safer cost-competitive carbon dioxide pipelines that can be operated at higher pressures and which can more effectively control long ductile fractures without the use of mechanical fracture arrest devices.

Carbon dioxide is a liquid while contained but becomes a gas when released. Accordingly, pipeline codes treat carbon dioxide pipelines somewhat like high-

pressure gas pipelines by requiring Category II pipe. In addition, for carbon dioxide pipelines, pipeline codes now require positive control of longitudinal ductile fractures using higher toughness, or specially designed fracture-arrest devices, or both, if the designer considers it appropriate.

The tradition in the gas transmission industry in North America for positively controlling longitudinal ductile fractures has been to rely on increased toughness rather than fracture arrest devices. This trend has been driven largely by concern for safety, and in recent regulatory rulings have required gas pipeline companies to undertake full-scale burst tests to determine how much toughness is required, and to use sufficient toughness to prevent fractures from running rather than use fracture arrest devices.

If a longitudinal sub-critical crack in the pipe wall grows, it weakens the wall of the pipe and can initiate a longitudinal tear in the wall of the pipe. If the pipe wall is strong enough to resist the force of the decompressed pressure pushing against the unrestrained walls of the pipe on either side of the opening, the tear will not propagate. But if the wall of the pipe is not strong enough or tough enough to resist the force, a longitudinal ductile fracture will form and run a long distance along the pipe.

For carbon dioxide pipelines, the force that drives ductile fractures along the pipe is aggravated by the sustained pressure that occurs when the decompressing fluid inside the pipeline enters the two-phase region and starts evolving vapour. Sonic velocity of the carbon dioxide falls to a very low value when the decompression enters the two phase region, and since the fluid escapes from the fracture opening at sonic velocity it chokes the flow of escaping carbon dioxide causing the pressure at the opening to be sustained for a long period of time at the pressure where the decompression path first enters the two-phase region.

In order to prevent the fracture from running along the wall of the pipe, the wall has to be made strong enough and tough enough to withstand the pressure of the escaping gas acting on the unrestrained walls of the pipe at the tip of the fracture. As a practical matter, in a carbon dioxide pipeline, the pressure of the escaping fluid at the tip of a running fracture will be approximately equal to the pressure where the decompression path crosses the phase boundary into the two-phase region.

The solution is to either increase the wall thickness or to increase the toughness of the pipe steel, or both. Increasing wall thickness helps by reducing the stress at the tip of the fracture, and increasing toughness helps by enabling the steel to absorb more energy before it tears.

In the case of pipelines carrying carbon dioxide, increasing wall thickness to prevent longitudinal ductile fractures can be economically viable because it allows operating pressure to be increased which in turn can reduce either the number of compressor station sites or the pipe diameter. The optimum design pressure for any project is influenced by the composition of the carbon dioxide mixture and operating temperature as well as the specific details of costs and economics that are used for the project.

Historically, optimization to minimize the cost of owning and operating carbon dioxide transmission pipelines has driven designers to select higher operating

pressures than is typical for natural gas transmission pipelines. For example, the Cortez Pipeline that transmits carbon dioxide from Wyoming to Texas operates in places at pressures of 2600 psig (18 MPag), and the Weyburn-Souris Pipeline in Montana and Saskatchewan has pump discharge pressures of around 3000 psig (21 MPag).

Because of the thickness of the pipe wall needed to operate at the optimum pressure for carbon dioxide pipelines, longitudinal ductile fractures can often be prevented using normal Category II pipe without the need to specify high levels of toughness. Nevertheless, the required toughness needs to be analyzed on a case-by-case basis, particularly for larger pipe diameters, in order to make sure that the toughness requirements are within the normally achievable range of Category II pipe.

4. Gas Composition

The product quality specification for carbon dioxide delivered to the pipeline requires that it contain at least 95.5 mol% of carbon dioxide. Except for methane and nitrogen, the impurities in the product to be delivered to the pipeline do not have much effect on the thermodynamic properties of carbon dioxide or its phase boundary. The product quality specification limits methane to 2 mol% and nitrogen to 0.2 mol%.

In order to provide a composition for design work, it was assumed for this report that on rare occasions it could happen that the amount of methane and nitrogen in the product would exceed the limits stated in the specification by as much as 100%. .

Table 1 below shows typical composition of pipeline quality product, the requirements of the product quality specification, and the Design-case composition used for this report.

Table 1. Pipeline Product Compositions

Component	Product Quality Specification	Typical Composition from Plant	Design-Case for this Report
CO2	> 95.50%	97.75%	95.50%
CH4	< 2.00%	2.17%	4.00%
C2H6	<0.00%	0.01%	0.00%
H2S	< 0.00%	0.00%	0.10%
COS	< 0.13%	0.02%	0.00%
O2	< 0.00%	0.00%	0.00%
N2	< 0.20%	0.00%	0.40%
H2O	< 0.04%	0.04%	0.00%
Total	97.87%	100.00%	100.00%

5. Pipe Toughness

Determination of pipe toughness requirements to prevent ductile fractures from running was undertaken in three steps. The first step was to determine the pressure at the moving fracture tip over a full range of fracture speeds for decompression from all possible operating temperatures and pressures using the Design-case fluid composition. Operating pressures between 1200 psig (8,274 kPag) and 3705 psig (25,545 kPag), and temperatures between -20°F (-30°C) and 120°F (50°C) were considered.

The second step was to determine the relationship between the pressure at the fracture tip and its speed of propagation along each of the pipelines over a range of toughness values for the diameter, wall thickness and steel strength of each of the pipes using the Battelle fracture velocity "J-Curves". Toughness values up to 40 J (30 ft-lb) were considered.

The final step was to use the two sets of curves (the "Two-Curve" method) generated in steps 1 and 2 above to find the lowest pipe toughness for each of the four pipes that would make the fracture run slow enough that the decompressing gas would be unable to maintain the pressure at the crack tip at a high enough value to sustain crack propagation.

Tensor Engineering Ltd's ductile fracture software was used to calculate toughness requirements for this report. It was originally developed as part of the early investigation of rapid decompression of gases and liquids in the two-phase region and its affect on ductile fracture propagation and arrest in natural gas pipelines. [3] Tensor's software uses the BWRS equation of state to calculate the fluid decompression velocity curves in both the single and two-phase regions and it uses the Battelle fracture equations [4, 5] to generate the fracture velocity "J-Curves".

A large number of initial operating pressures were examined for each of the four pipes being used on the project, and it was found that an initial operating pressure of 1800 psig (12,500 kPa) requires the toughest steel to prevent longitudinal ductile fractures from propagating.

Figures 1 to 8 show fluid decompression curves and Battelle fracture velocity "J-curves" for the four pipes. Fluid decompression curves are shown for initial pressures of 1800 psig (12,500 kPag) and 3705 psig (25,545 kPag) over a range of operating temperatures from 59°F (15°C) to 122°F (50°C). Battelle fracture velocity "J-Curves" are shown for toughness values of 8, 12, 18 and 27 J. Fracture velocity "J-Curves" that are above the fluid decompression curves represent pipe with sufficient fracture toughness to prevent a ductile fracture from running.

For all four pipes the curves show that the higher initial operating pressure of 3705 psig (25,545 kPag) requires less toughness to prevent ductile fractures from running than the lower initial operating pressure of 1812 psig (12,500 kPag).

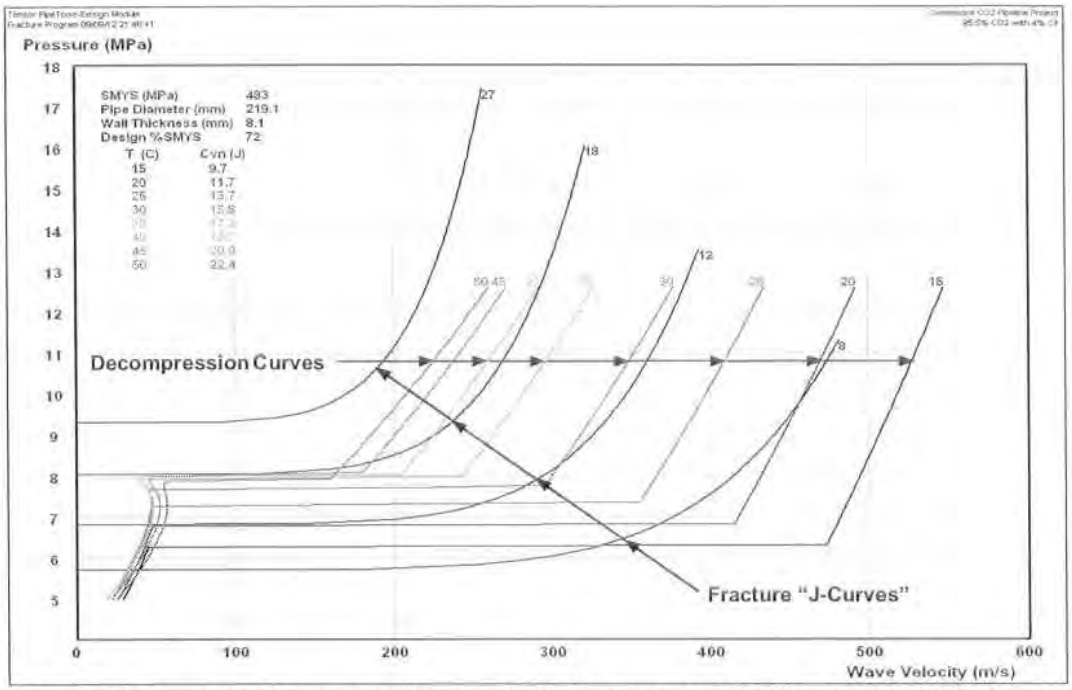


Fig. 1: Decompression curves from an initial pressure of 1800 psig (12.5 MPa) and fracture velocity "J-curves" for X70 NPS 8 pipe with 0.317" (8.1 mm) wall

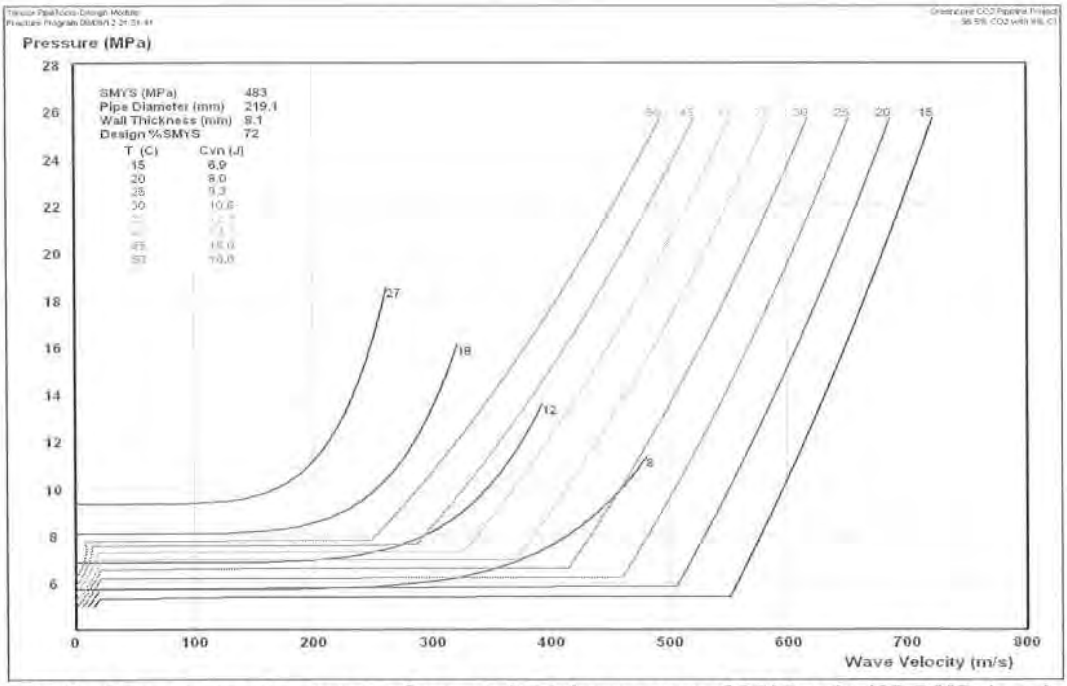


Fig. 2: Decompression curves from an initial pressure of 3705 psig (25.5 MPa) and fracture velocity "J-curves" for X70 NPS 8 pipe with 0.317" (8.1 mm) wall

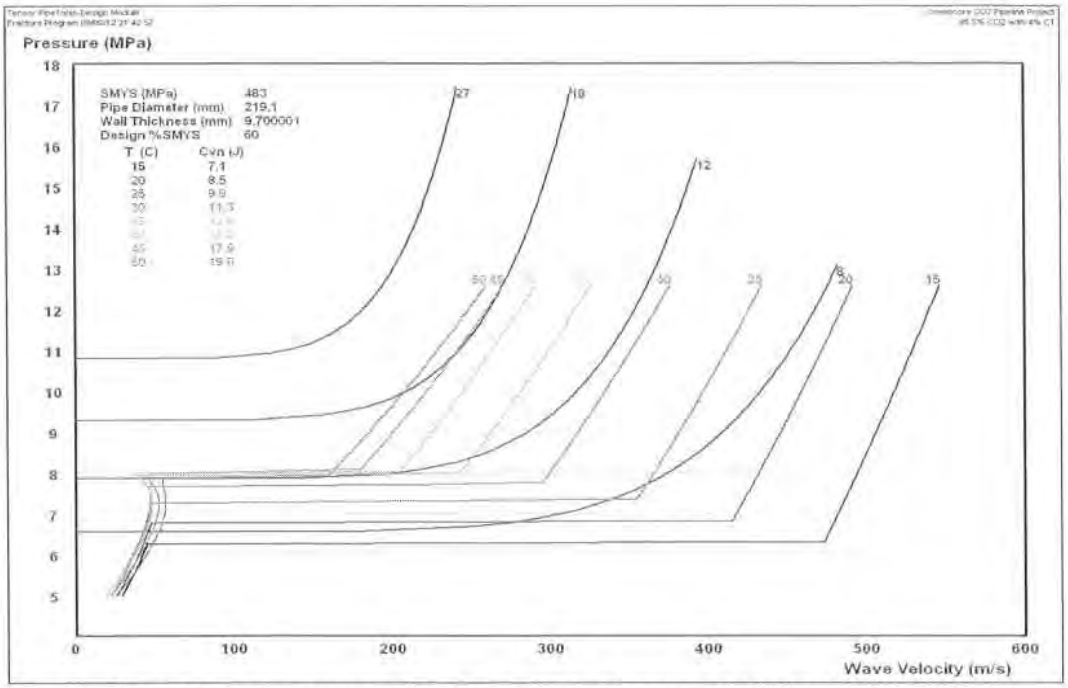


Fig. 3: Decompression curves from an initial pressure of 1800 psig (12.5 MPa) and fracture velocity "J-curves" for X70 NPS 8 pipe with 0.380" (9.7 mm) wall

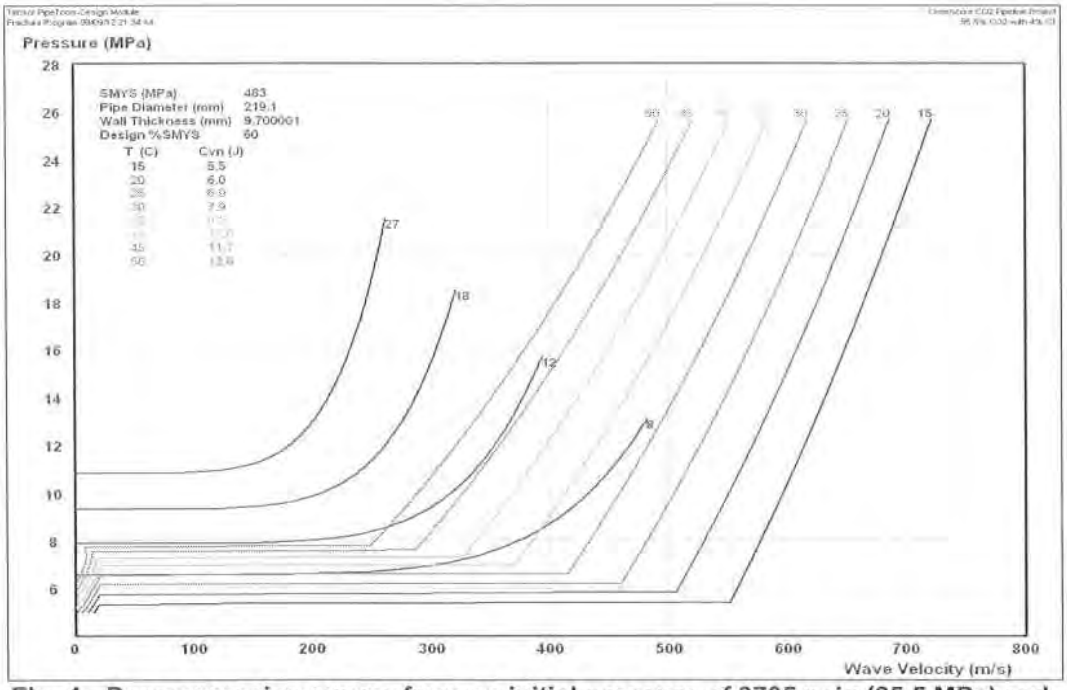


Fig. 4: Decompression curves from an initial pressure of 3705 psig (25.5 MPa) and fracture velocity "J-Curves" for X70 NPS 8 pipe with 0.380" (9.7 mm) wall

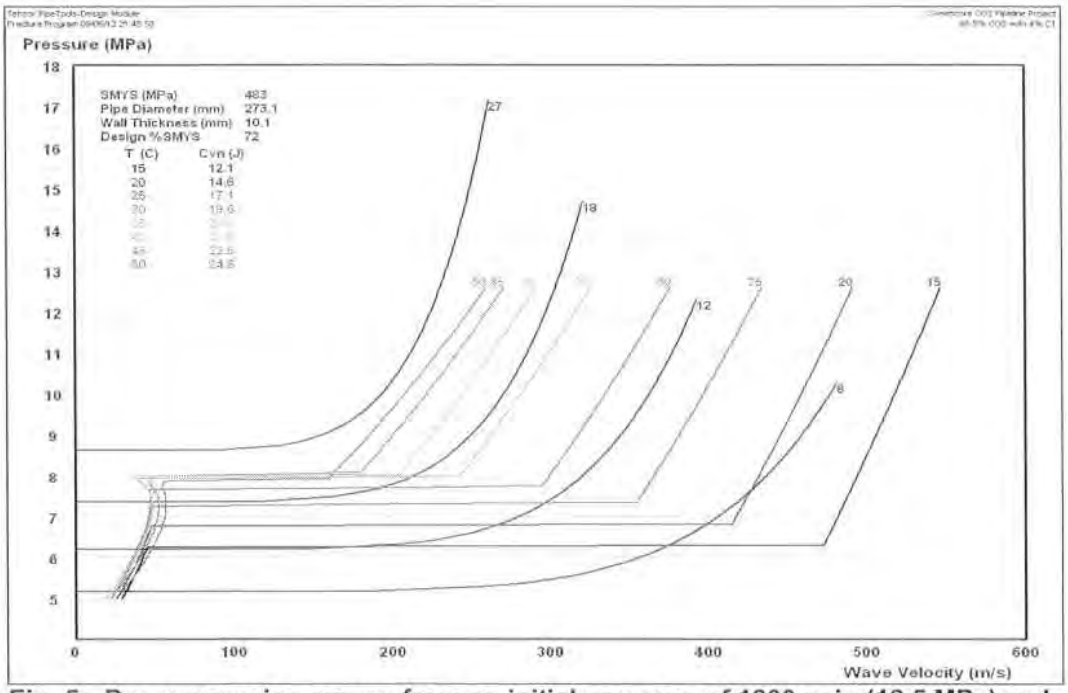


Fig. 5: Decompression curves from an initial pressure of 1800 psig (12.5 MPa) and fracture velocity "J-curves" for X70 NPS 10 pipe with 0.395" (10.1 mm) wall

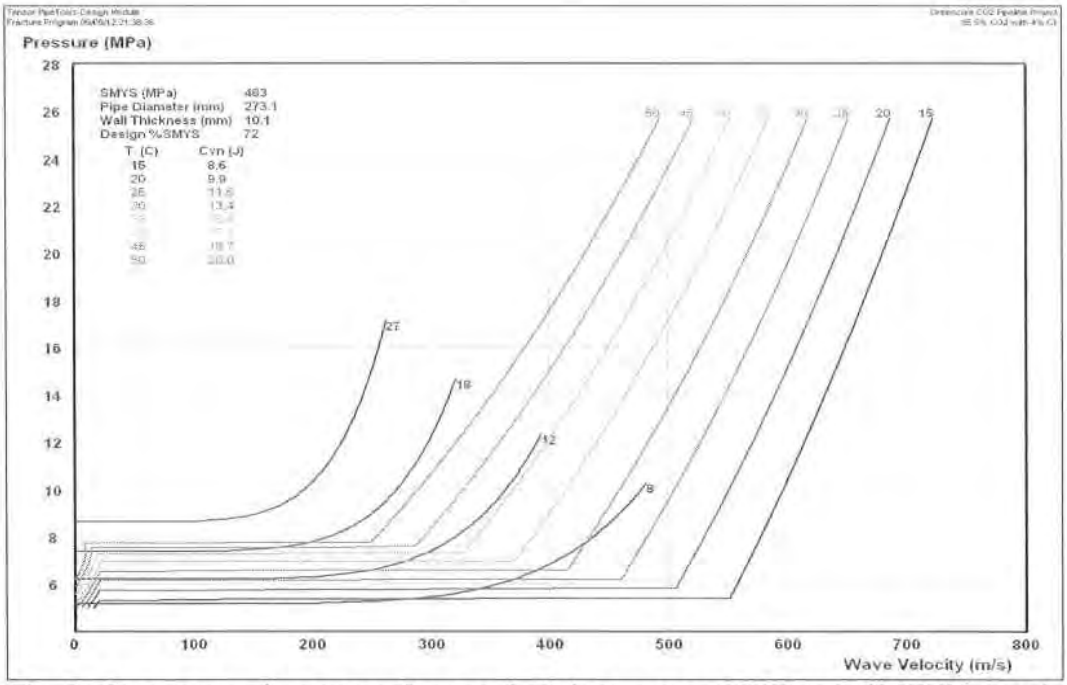


Fig. 6: Decompression curves from an initial pressure of 3705 psig (25.5 MPa) and fracture velocity "J-curves" for X70 NPS 10 pipe with 0.395" (10.1 mm) wall

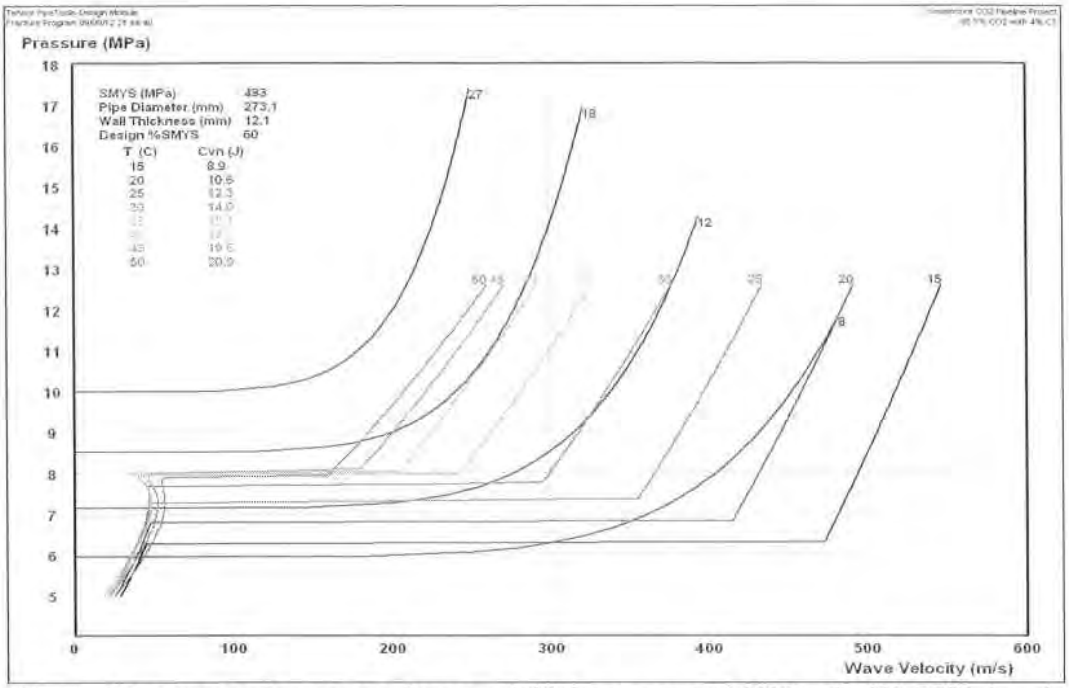


Fig. 7: Decompression curves from an initial pressure of 1800 psig (12.5 MPa) and fracture velocity "J-curves" for X70 NPS 10 pipe with 0.474" (12.1 mm) wall

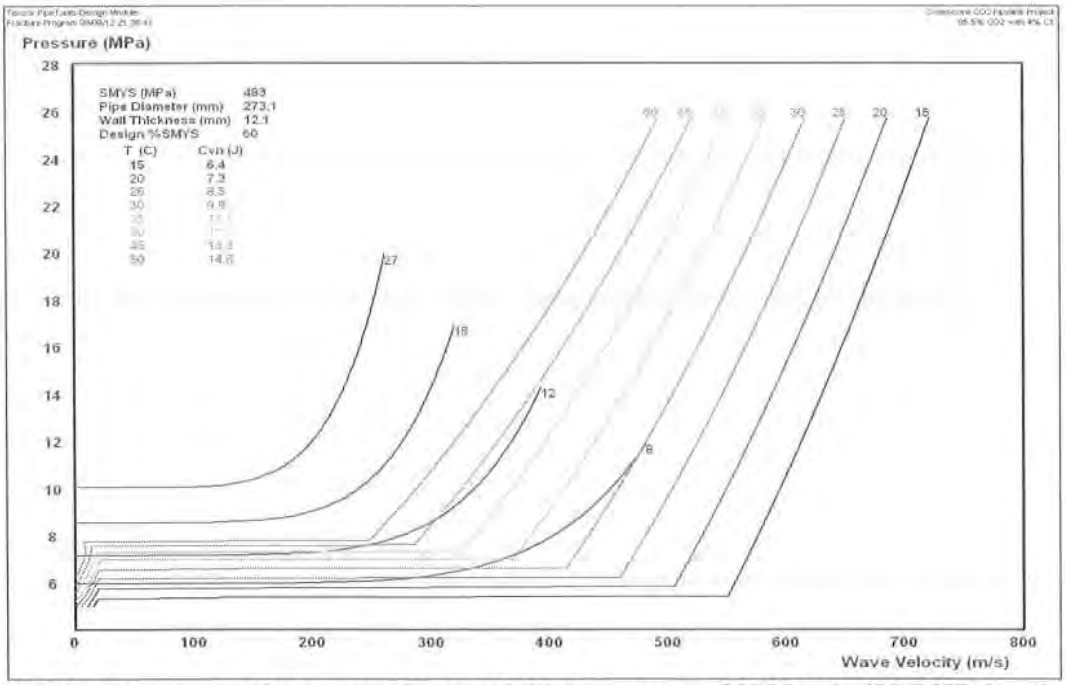


Fig. 8: Decompression curves from an initial pressure of 3705 psig (25.5 MPa) and fracture velocity "J-curves" for X70 NPS 10 pipe with 0.474" (12.1 mm) wall

6. Sensitivity Analysis

Steel toughness required to control longitudinal ductile fractures depends on the composition of products carried in the pipeline but during design it is difficult to predict with certainty the composition of products the pipeline will be asked to carry over its lifetime from sources that may not have been identified yet. In order to future-proof the pipeline it is therefore important to study the effect of possible products from sources in the area served by the pipeline to make sure that the pipe steel is suitable when the pipeline is carrying the worst possible mixture of components.

Figures 1 to 8 show that the toughest steel is required for the case shown on Figure 5 using NPS 10 pipe with a wall thickness of 0.395 in. (8.1 mm). The sensitivity analysis will therefore focus on this one pipe size and investigate the effect that variations in composition will have on its toughness requirements. Table 2 shows product compositions from four additional sources in the area served by the Greencore pipeline.

Table 2. Composition of Possible Future Product from Sources in Area served by the Greencore CO_2 Pipeline

Component	Units	Lost Cabin	Dakota Gas	South Hart	Shute Creek
CO_2	mol%	95.5	96.0	98.3	> 95.0
Methane	mol%	2.0	0.9	0.5	< 2.0
Ethane+	mol%	2.0	1.7	0.6	
H_2S	mol%	0.0	< 2.0	0.0	40 ppm
COS	ppm	< 1250			
CO	mol%	0.0	0.0	0.4	
Nitrogen	mol%	0.2	< 2.0	0.0	< 4.0
Oxygen/Argon		< 10 ppm	< 0.01%	0.0	
Hydrogen	mol%		0.0	0.2	
Mercaptans/Sulfides	gr/100scf	0.0	0.0	0.0	< 35.0

A wide range of compositions based on the compositions given in Table 2 were investigated and the five mixtures shown in Table 3 were selected for presentation because they are representative of the wide range of compositions that are possible. The "Worst Case" mixture contains the maximum amount of each of the impurities seen in each of the four possible future gas streams. The other compositions are the same but with one component removed in each successive case. That is, the "No Ethane Case" is the same as the "Worst Case" but without ethane; the "No H_2S Case" is the same as the "No Ethane Case" but with no H_2S; the "No Methane Case" is the same as the "No H_2S Case" but with ethane removed; and the "Nitrogen Only Case" is the same as the "No Methane Case" but with the CO and H_2 removed.

Table 3. Product Compositions for Sensitivity Studies					
Component	Worst Case (mol%)	No Ethane Case (mol%)	No H_2S Case (mol%)	No Methane Case (mol%)	N_2 Only Case (mol%)
CO_2	89.4	91.4	93.4	95.4	96
CH_4	2.0	2.0	2.0	--	--
C_2H_6	2.0	--	--	--	--
H_2S	2.0	2.0	--	--	--
CO	0.4	0.4	0.4	0.4	--
N_2	4.0	4.0	4.0	4.0	4.0
H_2	0.2	0.2	0.2	0.2	--
Total	100.0	100.0	100.0	100.0	100.0

A procedure similar to the one used in the previous section was followed to determine pipe toughness requirements for each of the five mixtures. The first step was to determine the pressure at the moving fracture tip for each of the five fluid compositions given in Table 3. Operating pressures of 1800 psi (12.5 MPa) and 3705 psi (25.5 MPa), and temperatures between -20°F (-30°C) and 120°F (50°C) were used.

The second step was to determine the relationship between the pressure at the fracture tip and its speed of propagation along each of the pipelines over a range of toughness values for an X70 NPS 10 pipe with a wall thickness of 0.395 in. (8.1 mm) using the Battelle fracture velocity "J-Curves".

The final step was to use the "Two-Curve" method to find the required pipe toughness for each of the five mixtures. Results of the sensitivity analysis are summarized on Table 4 and shown graphically on Figures 9 to 18.

Table 4. Toughness Requirements from Sensitivity Study						
Initial Pressure	Parameter	Worst Case	No Ethane Case	No H_2S Case	No Methane Case	N2 Only Case
1800 psi (12.5 MPa)	Temperature	50°C	30°C	25°C	50°C	50°C
	Toughness	24 0 J	24.9 J	25.3 J	23.8 J	23.6 J
2705 psi (25.5MPa)	Temperature	50°C	50°C	50°C	50°C	50°C
	Toughness	23.8 J	25.2 J	25.6 J	22.9 J	20.7 J

In all cases the toughness required to control longitudinal ductile fractures is less than 20 ft-lb (27 J). In some cases the highest required toughness occurs at the maximum operating pressure and temperature while in other cases it occurs at pressures and temperatures well below the maximum. The highest minimum toughness of all cases studied was 19 ft-lb (26 J) for the "No H_2S Case" which contained methane, N2, CO, and H2 in addition to the CO2.

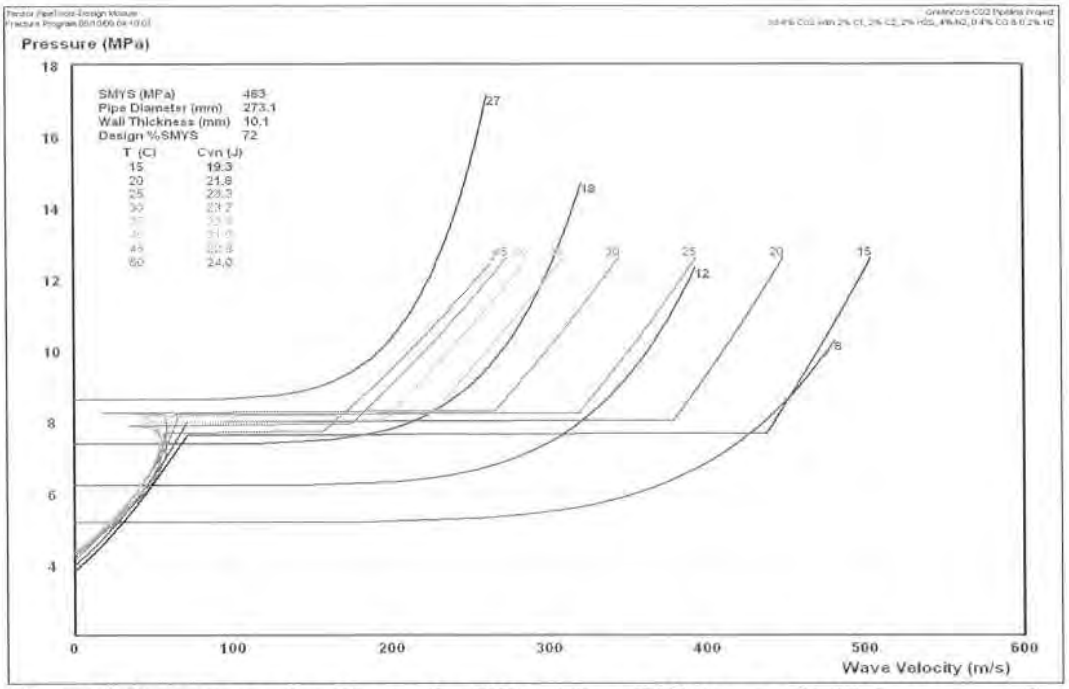


Figure 9 Decompression Curves for "Worst-Case" Mixture and initial pressure of 1800 psi (12.5 MPa) and Toughness J-Curves for X70 NPS 10 Pipe with wall thickness of 0.395" (10.1 mm).

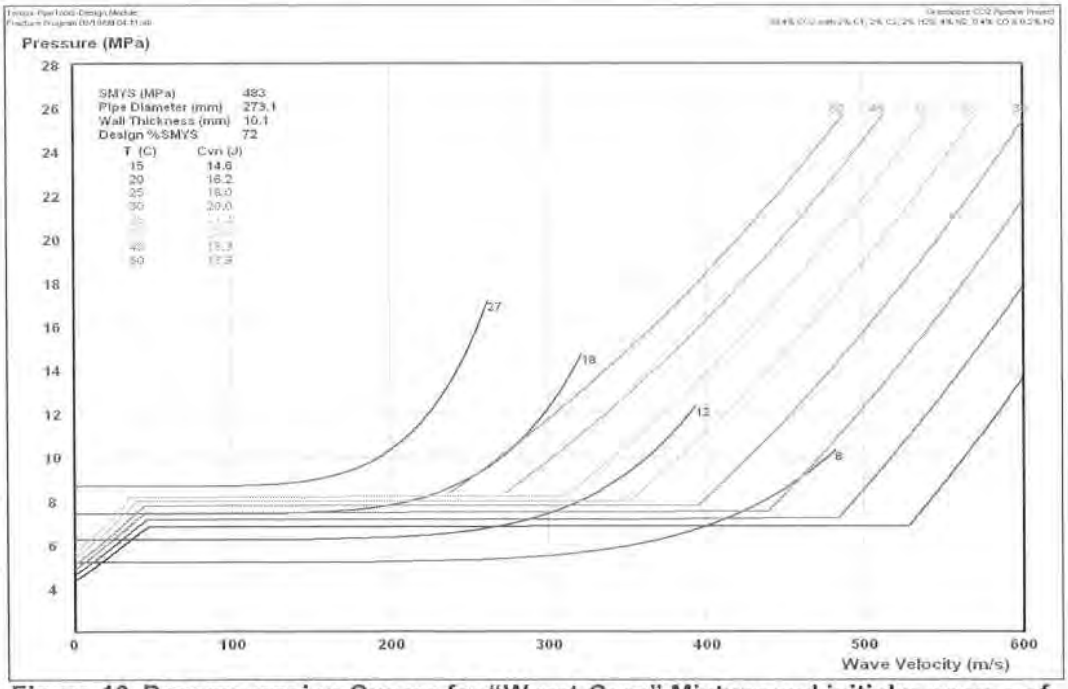


Figure 10 Decompression Curves for "Worst-Case" Mixture and initial pressure of 3705 psi (25.5 MPa) and Toughness J-Curves for X70 NPS 10 Pipe with wall thickness of 0.395" (10.1 mm).

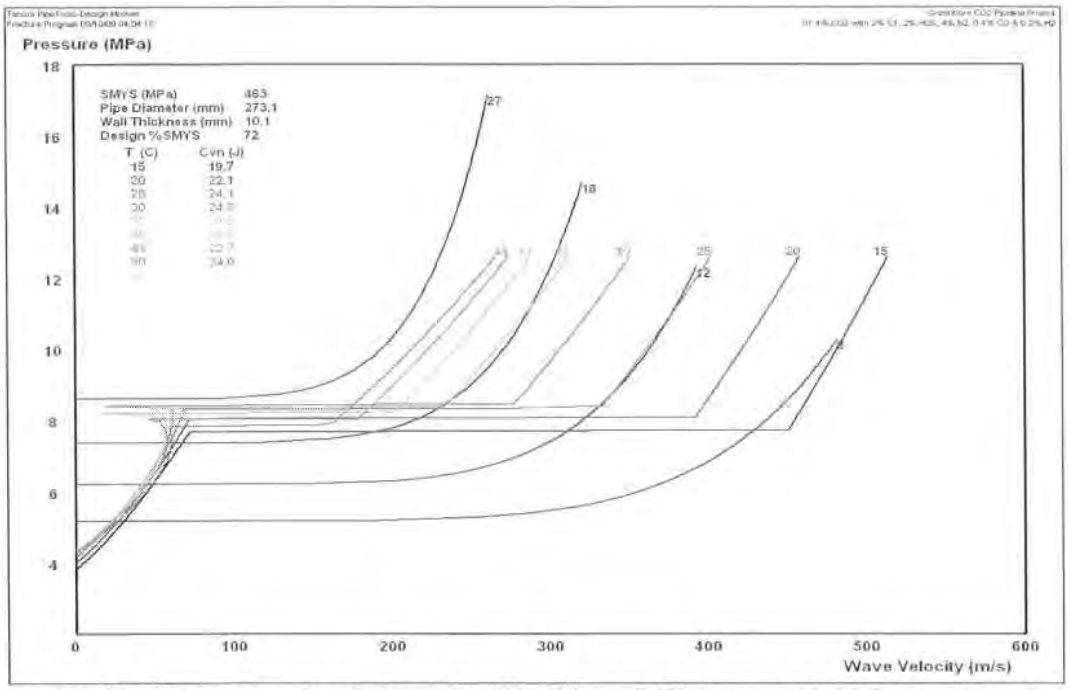


Figure 11 Decompression Curves for "No Ethane" Mixture and initial pressure of 1800 psi (12.5 MPa) and Toughness J-Curves for X70 NPS 10 Pipe with wall thickness of 0.395" (10.1 mm).

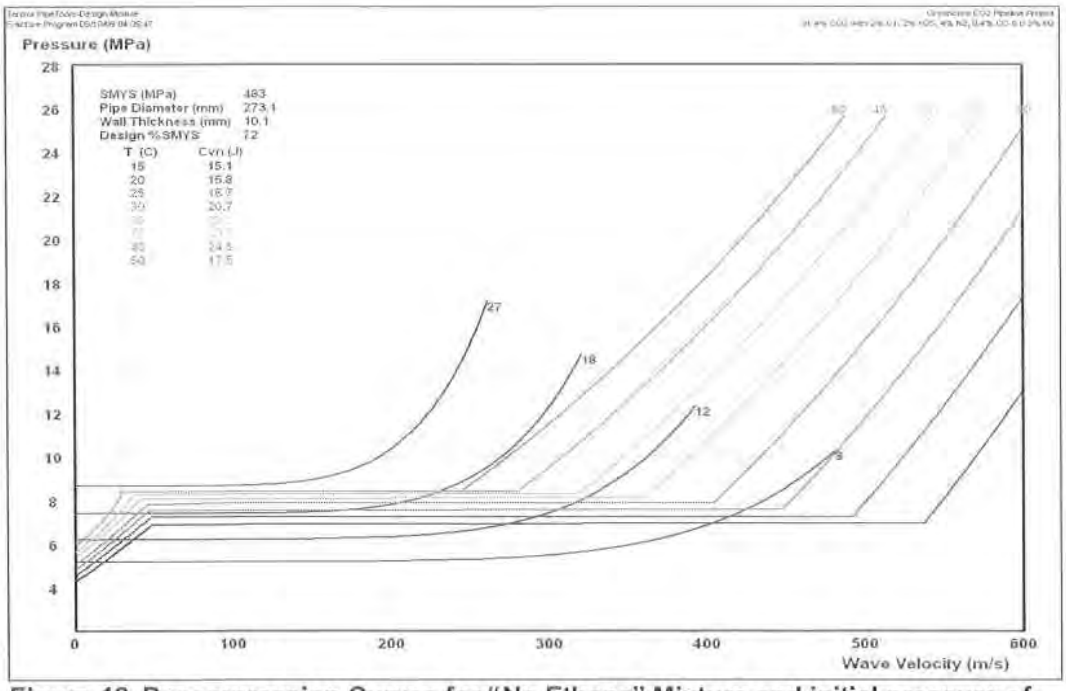


Figure 12 Decompression Curves for "No Ethane" Mixture and initial pressure of 3705 psi (25.5 MPa) and Toughness J-Curves for X70 NPS 10 Pipe with wall thickness of 0.395" (10.1 mm).

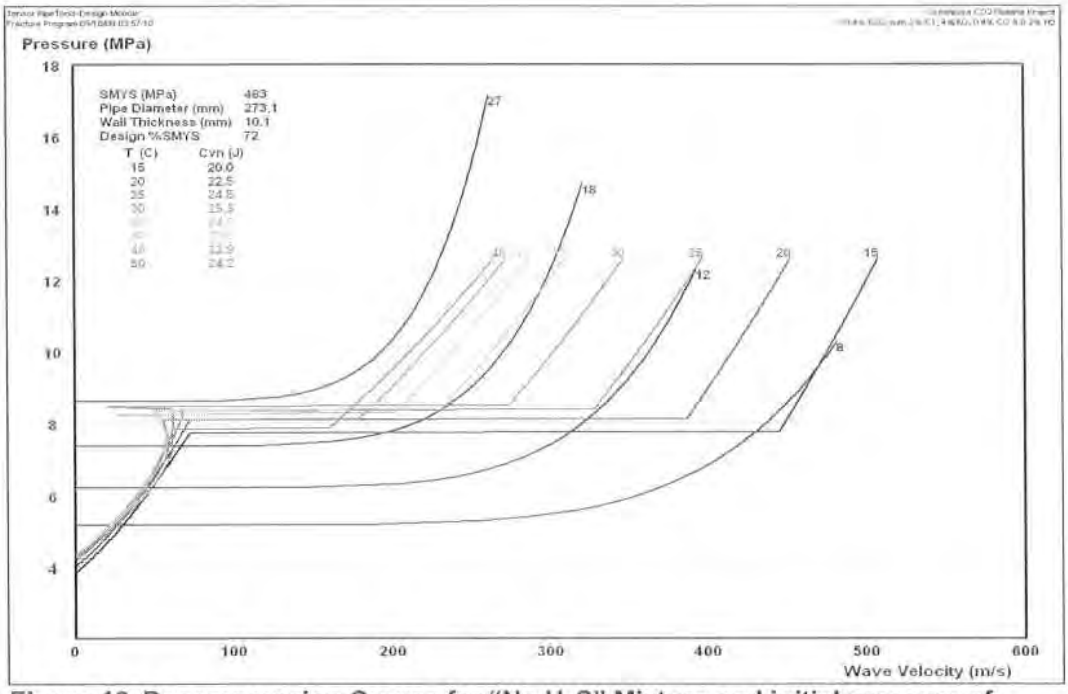


Figure 13 Decompression Curves for "No H_2S" Mixture and initial pressure of 1800 psi (12.5 MPa) and Toughness J-Curves for X70 NPS 10 Pipe with wall thickness of 0.395" (10.1 mm).

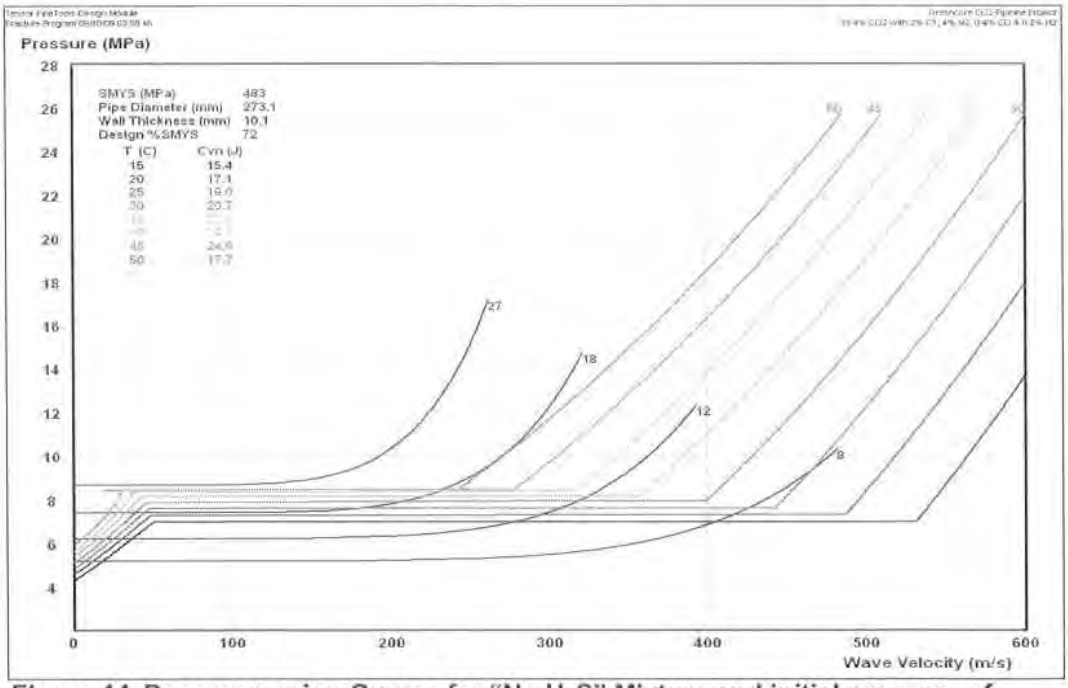


Figure 14 Decompression Curves for "No H_2S" Mixture and initial pressure of 3705 psi (25.5 MPa) and Toughness J-Curves for X70 NPS 10 Pipe with wall thickness of 0.395" (10.1 mm).

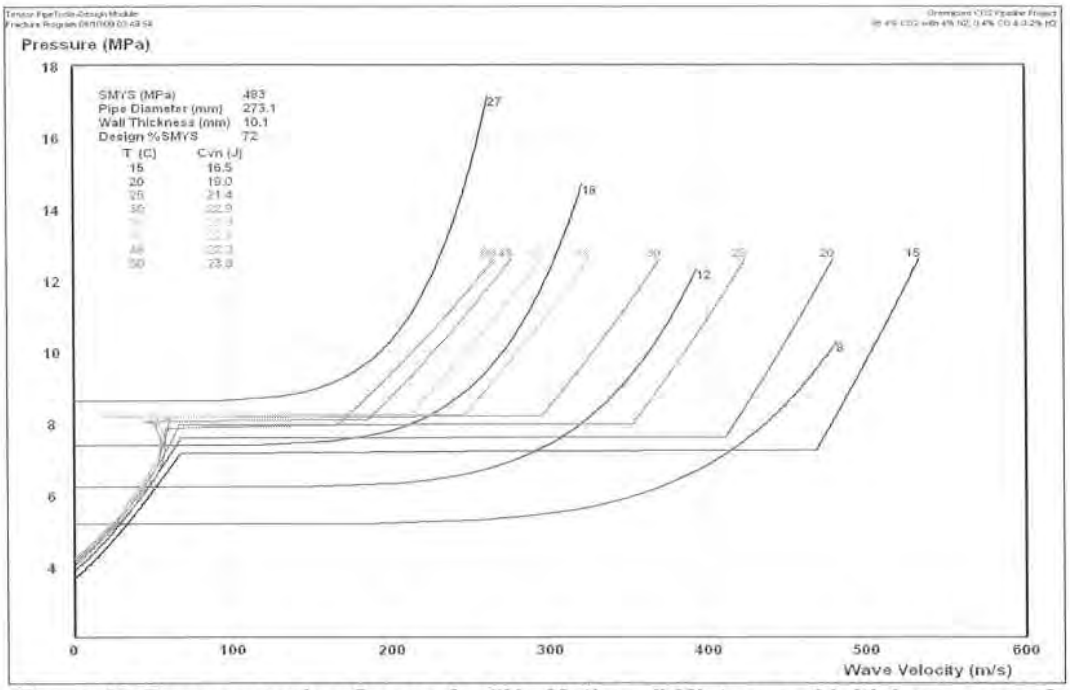


Figure 15 Decompression Curves for "No Methane" Mixture and initial pressure of 1800 psi (12.5 MPa) and Toughness J-Curves for X70 NPS 10 Pipe with wall thickness of 0.395" (10.1 mm).

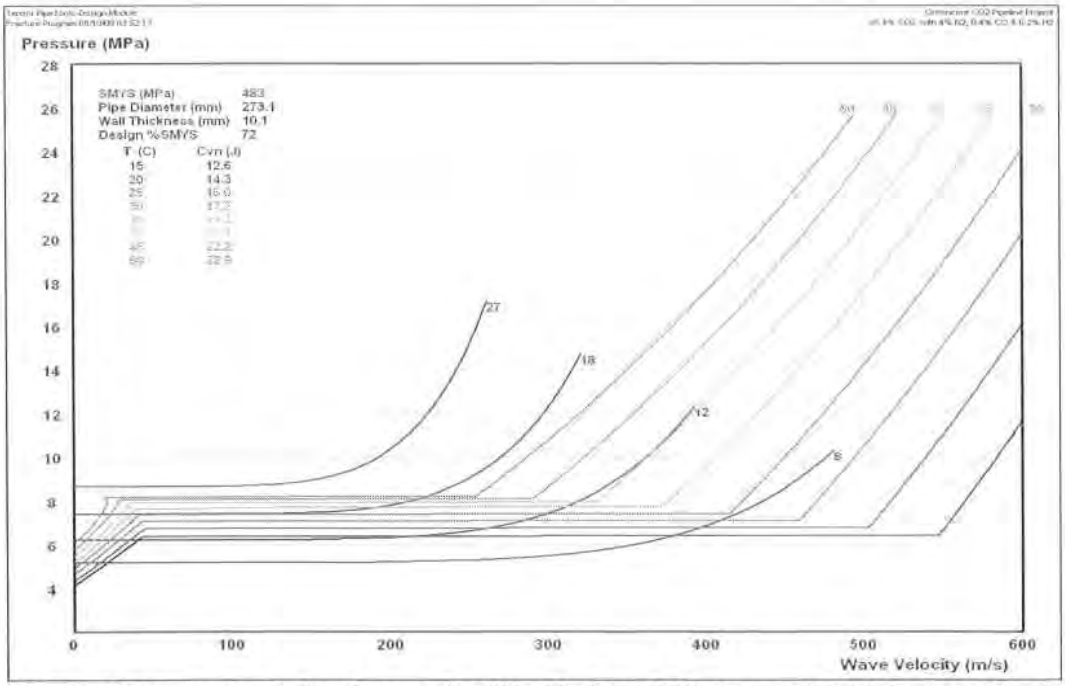


Figure 16 Decompression Curves for "No Methane" Mixture and initial pressure of 3705 psi (25.5 MPa) and Toughness J-Curves for X70 NPS 10 Pipe with wall thickness of 0.395" (10.1 mm).

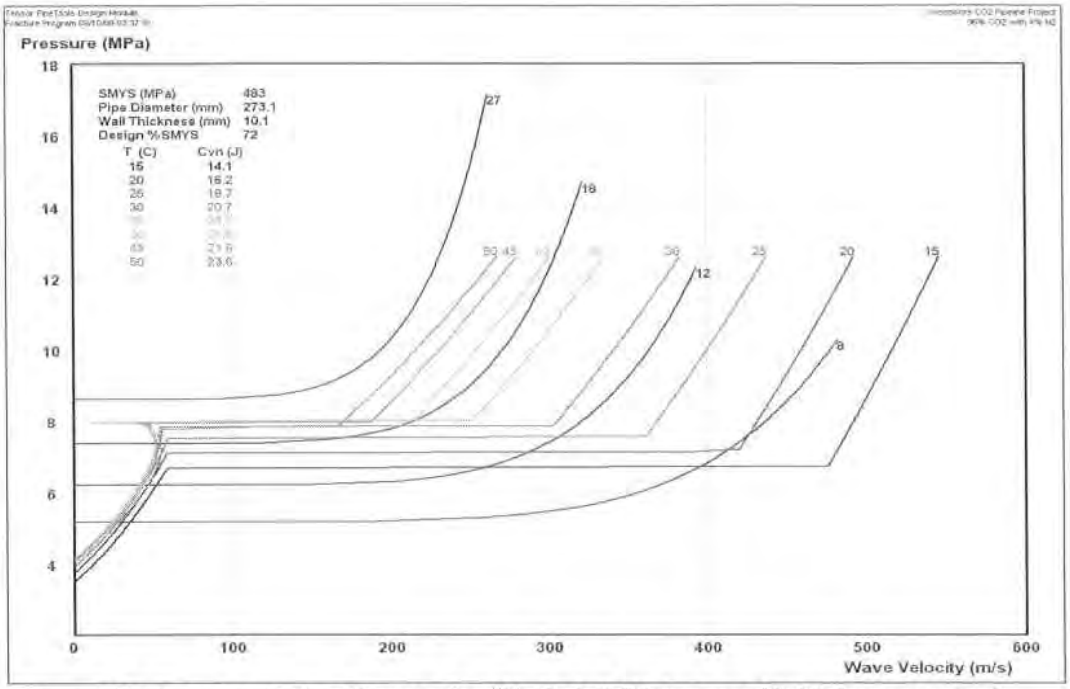


Figure 17 Decompression Curves for "N_2 Only" Mixture and initial pressure of 1800 psi (12.5 MPa) and Toughness J-Curves for X70 NPS 10 Pipe with wall thickness of 0.395" (10.1 mm).

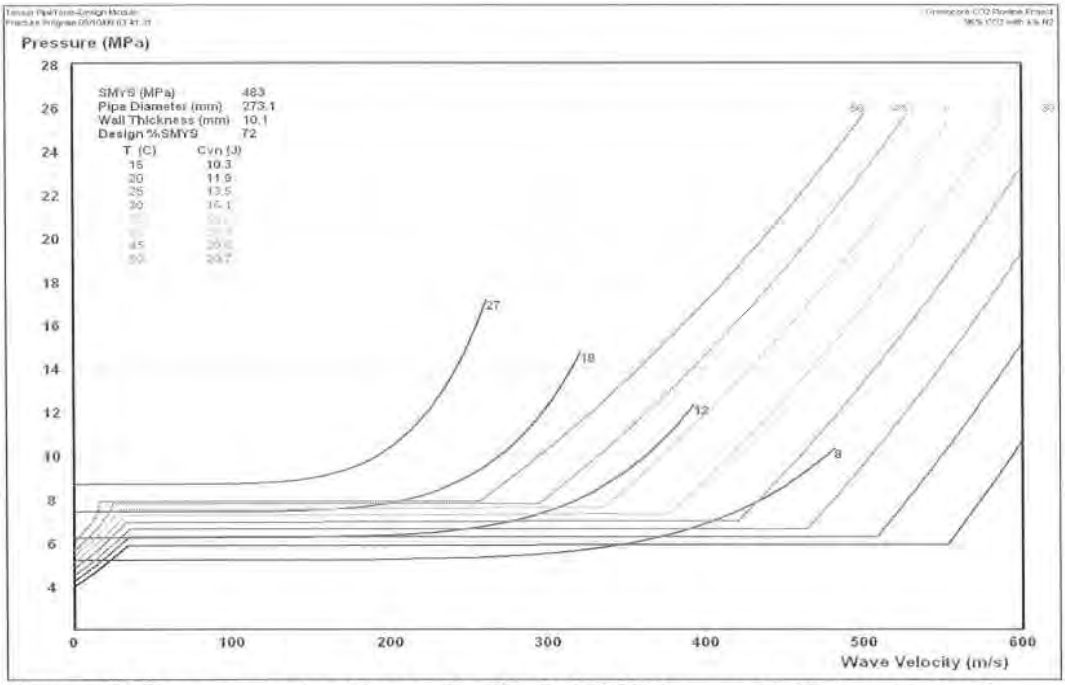


Figure 18 Decompression Curves for "N_2 Only" Mixture and initial pressure of 3705 psi (25.5 MPa) and Toughness J-Curves for X70 NPS 10 Pipe with wall thickness of 0.395" (10.1 mm).

7. Conclusions and Recommendations

Table 5 provides recommended Charpy V-notch toughness (C_{VN}) values based on Figures 1 to 8 for the four pipe sizes being considered for this project.

Table 5. Minimum Toughness Requirement for Grade X70 NPS 8 and 10 Pipe based on the "Design-Case" Composition

Pipe Size	Diameter	Steel SMYS	MAOP	F_S	Wall Thickness	C_{VN}	
NPS	inches	ksi	psi	%	inches	ft-lb	J
8	8.625	70	3705	72	0.317	17	23
8	8,625	70	3705	60	0.380	14	19
10	10.75	70	3705	72	0.395	18	25
10	10.75	70	3705	60	0.474	15	21

Sensitivity studies using a wide range of compositions showed that the toughness requirements shown in Table 5 based on the "Design Case" composition are low by approximately 1 ft-lb (0.74 J) but in all cases the toughness required to prevent longitudinal ductile fractures from propagating will still be less than 20 ft-lb (27 J) and standard API 5L PSL 2 pipe can be used without the need to specify increased toughness or the use of crack arrestors.

8. References

1. CSA Standard Z662-07, "Oil and Gas Pipeline Systems," Canadian Standards Association, 2007
2. King, G. G., "Design of Carbon Dioxide Pipelines," Proc. ASME, ETC&E, Houston, Texas, January 18-22, 1981,
3. King, G. G., "Decompression of Gas Pipelines During Longitudinal Ductile Fractures", Journal of Energy Resources Technology, Volume 101, March 1979.
4. Maxey, W. A., "Fracture Initiation, Propagation, and Arrest", Paper J, 5th Symposium on Line Pipe Research, American Gas Association Catalog No. L30174, 1974.
5. Maxey, W. A., Kiefner, J. F., and Eiber, R. J., "Ductile Fracture Arrest in Gas Pipelines", NG-18 Report 100, American Gas Association Catalog No. L32176, 1975.

Appendix A Canadian Code Requirements

The Canadian Standard Association Standard Z662-07, "Oil and Gas Pipeline Systems" (CSA Z662) is the governing standard for carbon dioxide pipeline systems in Canada. Although pure carbon dioxide is non-toxic and non-flammable, requirements for carbon dioxide pipelines were explicitly added to CSA Z662 in 1996 because of special features that are specific to carbon dioxide pipeline systems.

CSA Z662 defines a carbon dioxide pipeline system as any onshore pipeline system made up of piping and equipment, pressure-regulating stations, and measuring stations, which conveys carbon dioxide, or predominantly carbon dioxide mixtures, in the liquid or quasi-liquid state at pressures above the critical pressure of CO_2 (that is, above 1070 psi or 7.4 MPa).

CSA Z662 only requires the service fluid to be "predominantly carbon dioxide." Special requirements may be needed to handle impurities but the commentary to CSA Z662 makes it clear that the presence of hydrogen sulphide in a carbon dioxide pipeline system does not constitute sour service because material damage is not a concern since carbon dioxide pipelines do not contain water. Therefore, special steels suitable for sour service are not mandatory in Canada for carbon dioxide pipelines that contain mixtures of carbon dioxide, light hydrocarbons, nitrogen, hydrogen and trace amounts of hydrogen sulphide (less than 4 ppm) as proposed for this project. Human error and accidental discharge of water from carbon dioxide purification plants still needs to be considered during design particularly as it relates to the hardness of welds.

CSA Z662 requires pipeline designers to specify the design temperature range for each segment of the pipeline system for the conditions expected during installation, pressure testing, start-up, and operation. The specified design temperatures are to be subsequently used in stress analysis calculations, specification of mechanical properties of piping materials, and determination of design pressures. During rapid depressurization, dry ice (solid carbon dioxide) can form inside the pipeline and the pipe walls can potentially reach temperatures as low as -110°F (-80°C). The rate of pressure relief should therefore be controlled to prevent pipe temperatures from falling to such low levels and possibly allow conventional low temperature line pipe to be used.

CSA Z662 requires all circumferential butt welds for carbon dioxide pipeline systems to be non-destructively inspected by radiographic and/or ultrasonic methods for 100% of their circumferences in accordance with the requirements of Clause 7.10.4, in order to detect and identify root bead imperfections that could develop into corrosion or fracture initiation sites.

For steel carbon dioxide pipelines that have no protective internal linings or coatings and are pressure tested with water, CSA Z662 requires the water to be completely removed after the pressure test, in order to avoid aggressive corrosion that could otherwise occur on start-up of service as a result of the service fluid combining with water and then reacting with the steel. Consideration should be given to delaying the installation of any valves that do not have corrosion-resistant trim until after hydrostatic testing.

Carbon dioxide gas, although nontoxic, is heavier than air and can accumulate in low-lying areas. Because of the risk of asphyxiation that could result from the release of carbon dioxide, CSA Z662 requires that personnel working on in-service carbon dioxide pipelines be trained in safe working procedures for oxygen-deficient atmospheres.

Appendix B Excerpts from CSA Z662

Table 4.2
Location Factor for Steel Pipe
(See Clauses 4.3.3.3 and 15.4.1.3.)

Application	Location factor (L)			
	Class 1 Location	Class 2 Location	Class 3 Location	Class 4 Location
Gas (Sour service)†				
General and cased crossings	0.900	0.750	0.625	0.500
Roads*	0.750	0.625	0.625	0.500
Railways	0.625	0.625	0.625	0.500
Stations	0.625	0.625	0.625	0.500
Other	0.750	0.750	0.625	0.500
HVP and CO2				
General and cased crossings	1.000	0.800	0.800	0.800
Roads	0.800	0.800	0.800	0.800
Railways	0.625	0.625	0.625	0.625
Stations and terminals	0.800	0.800	0.800	0.800
Other	0.800	0.800	0.800	0.800

Notes:

1) *Roads: Pipe, in parallel alignment or in uncased crossings, under the travelled surface of the road or within 7 m of the edge of the travelled surface of the road, measured at right angles to the centreline of the travelled surface.*
2) *Railways: Pipe, in parallel alignment or in uncased crossings, under the railway tracks or within 7 m of the centreline of the outside track, measured at right angles to the centreline of the track.*
3) *Stations: Pipe in, or associated with, compressor stations, pump stations, regulating stations, or measuring stations, including the pipe that connects such stations to their isolating valves.*
4) *Other: Pipe that is*
   a) *supported by a vehicular, pedestrian, railway, or pipeline bridge;*
   b) *between any two components in a fabricated assembly; or*
   c) *in a fabricated assembly, within five pipe diameters of the first or last component, other than a transition piece or an elbow used in place of a pipe bend that is not associated with the fabricated assembly.*

10.7.1 Change of Class Location

10.7.1.1
Where class locations change as a result of increases in population density or location development, pipelines in such locations shall be subject to all of the requirements for the higher class location, or shall be subjected to an engineering assessment to determine the

a. design, construction, and testing procedures followed in the original construction, compared with the applicable requirements of this Standard;

b. condition of the pipeline by field inspections, examinations of operating and maintenance records, or other appropriate means; and
c. type, proximity, and extent of the development that has increased the class location, giving consideration to concentrations of people, such as those associated with schools, hospitals, small subdivisions, and recreation areas built near existing pipelines.

10.7.1.2
Where the engineering assessment (see Clause 10.7.1.1) indicates that the section of pipeline is satisfactory for the changed class location, no change to the maximum operating pressure shall be required.

10.7.1.3
Where the engineering assessment (see Clause 10.7.1.1) indicates that the section of pipeline is not satisfactory for the changed class location, as soon as practicable either the pipe shall be replaced or a revised maximum operating pressure, calculated in accordance with the requirements of Clause 8.5 for the changed class location, shall be used.

10.7.1.4
Pipelines that may be subject to changes in class location shall be inspected annually by the operating company in order to determine whether any change in class location has occurred. Records of such inspections and of any corrective action taken shall be retained.

Table 4.9
Cover and Clearance
(See Clauses 4.7.1, 4.7.2, and 4.8.2.1.)

Location	Type of pipeline	Class location	Cover for buried pipelines, minimum, m	
			Normal excavation	Rock excavation requiring blasting or removal by comparable means
General (other than as indicated below)	LVP or gas	Any	0.60	0.60
	HVP or CO_2	1	0.90	0.60
	HVP or CO_2	2,3, or 4	1.20	0.60
Right-of-way (road or railway)	Any	Any	0.75	0.75
Below travelled surface (road)*	Any	Any	1.20	1.20
Below base of rail (railway)†				
— Cased	Any	Any	1.20	1.20
— Uncased	Any	Any	2.00	2.00
Water crossing	Any	Any	1.20‡	0.60
Drainage or irrigation ditch invert	Any	Any	0.75	0.60

*See Clause 4.8.3.1.
†Within 7 m of centreline of the outside track, measured at right angles to the centreline of the track.
‡Cover not less than 0.6 m shall be permissible where analysis indicates that the potential for erosion is minimal.
Notes:
1) Cover shall be measured to the top of the carrier pipe or casing pipe, whichever is applicable.
2) See also Clause 1.6.

4.4.4

It shall be permissible for the spacing of valves in the pipeline to be as given in Table 4.7 or adjusted based upon factors such as operational, maintenance, access, and system design considerations.

Note: *Valve spacing adjustments should not normally exceed 25% of the applicable distances given in Table 4.7.*

Table 4.7
Valve Spacing, km
(See Clause 4.4.4.)

Type of Pipeline	Class 1 location	Class 2 location	Class 3 location	Class 4 location
	Maximum valve spacing, km			
Gas	NR	25	13 8	
HVP	NR	15	15	15
LVP	NR	NR	NR	NR
CO_2	NR	15	15	15

Note: *NR = not required.*

4.4.5
For HVP and carbon dioxide pipelines, sectionalizing valves shall be located outside cities, towns, and villages, at the transition from Class 1 to a higher class location.

4.4.6
For HVP and carbon dioxide pipelines, in locations where a failure would constitute an extraordinary hazard, sectionalizing valves shall be equipped for remote operation, and the maximum spacing between such valves shall not exceed 15 km.
Note: *Extraordinary hazards might exist in areas such as major industrial complexes, commercial navigable waters, and densely populated areas.*

4.4.7
For HVP and carbon dioxide pipelines, emergency connections to facilitate depressuring or evacuating, or both, of an isolated section of pipeline shall be provided on both sides of, and adjacent to, sectionalizing valves. The capacity of such connections shall be adequate for emergency conditions.

4.4.8
For HVP and LVP pipelines, valves shall be installed on both sides of major water crossings and at other locations appropriate for the terrain in order to limit damage from accidental discharge.
Note: *Consideration should be given to the installation of check valves to provide automatic blockage of the pipeline.*

APPENDIX B

SUPPLEMENTAL SPECIFICATION FOR API SPECIFICATION 5L GRADE X70 PSL2 SEAMLESS AND ELECTRIC WELDED (EW) STEEL LINE PIPE FOR CO_2 SERVICE

1. GENERAL

1.1 **Scope.** This specification covers the manufacture, testing and inspection of 8-5/8 inch and 10-3/4 inch OD, API 5L Grade X70 (L485), PSL 2, seamless and electric weld (EW) steel line pipe to be used to transport supercritical CO_2.

1.2 Pipe furnished to this specification shall meet the requirements of the latest edition of API Specification 5L; "Specification for Line Pipe" and as supplemented herein.

1.3 As used herein "Manufacturer" shall mean the manufacturer of pipe supplied to this specification.

2. PROCESS OF MANUFACTURE AND MATERIAL

2.1 The pipe shall be either seamless or manufactured by high frequency electric welding (HFW) and shall not be cold expanded without prior approval of CH2M Hill.

2.2 The steel shall be fully killed and made to fine grain practice.

3. CHEMICAL COMPOSITION AND TESTS

3.1 The chemical composition of the steel used in the manufacture of the pipe shall meet the requirements for X70 (L485), PSL 2.

3.2 The pipe carbon equivalent (CE) and P_{cm} shall be computed and reported using the following formulae, and shall not exceed 0.40 % for the CE or 0.20% for the P_{cm}

$$C.E. = C + \frac{Mn}{6} + \frac{Cr + V + Mo}{5} + \frac{Ni + Cu}{15}$$

$$P_{cm} = C + Si/30 + (Mn+Cu+Cr)/20 + Mo/15 + Ni/60 + V/10 + 5B.$$

The content of the elements and residuals shall be reported to CH2M Hill.

4. MECHANICAL PROPERTIES AND TESTS

4.1 Tensile Properties

4.1.1 The tensile properties shall be in accordance with API Specifications 5L L485 and the yield strength to tensile strength ratio shall not exceed 0.90.

4.2 Tensile Test Frequency

4.2.1 Tensile test frequency for both seamless and EW pipe shall be one per heat treat lot or one per 400 pipes, whichever gives the greater number of tests.

4.3 Impact Testing

4.3.1 Charpy impact tests shall be performed in accordance with API 5L, PSL 2 at +32°F.

4.3.2 The Charpy test specimens shall achieve a minimum average impact energy of 20 ft-lbs (27 J) with no single value less than 15 ft-lbs (20 J). The minimum shear area shall be as specified in API Specification 5L Para. 9.8.

4.3.3 Impact test frequency shall be one set per heat treat lot or one set per 400 pipes, whichever gives the greater number of tests.

4.4 Metallographic Examination

4.4.1 Metallographic examination of the weld line shall be made in accordance with API 5L Table 18.

5. HYDROSTATIC TESTS

5.1 **Hydrostatic Test Requirements**. Hydrostatic test pressure shall be held for not less than 10 seconds.

5.2 **Test Pressures**. The minimum test pressure shall be that required to develop a stress of 90 percent of the specified minimum yield strength (SMYS) as calculated by the formula in Para. 10.2.6.5 of API Specification 5L. If deformation begins to occur in the pipe during hydrostatic testing the manufacturer may not reduce the pressure without contacting CH2M Hill for approval.

6. DIMENSIONS, WEIGHTS, AND LENGTHS

6.1 **Wall Thickness**. The wall thicknesses will be 0.317 inch and 0.380 inch for the 8" OD and 0.395 inch and 0.474 inch for the 10" OD. The tolerances shall be:

- +15%, -10% for seamless pipe.
- +10%, -10% for welded pipe.

6.2 **Length**. Pipe shall be furnished in double random lengths.

6.3 **Jointers.** Jointers are prohibited

7. PIPE ENDS

7.1 **Plain Ends**. The pipe ends shall be square with the centerline through the end of the pipe to a tolerance of ±0.0625 inch as measured across the face of the bevel land.

8. NON-DESTRUCTIVE INSPECTION

8.1 **Methods of Inspections**. Non-destructive testing of both seamless and EW pipe shall be in accordance with Annex E of API 5L. The EW shall be performed only by ultrasonic inspection. Both ultrasonic and electromagnetic inspection are acceptable for pipe with a nominal wall thickness less than 0.500 inch, however, for pipes with wall thicknesses greater than or equal to 0.500 inch only ultrasonic inspection is acceptable. Inspection procedures shall be approved by CH2M Hill in writing prior to the start of production.

8.2 **Reference Standards.** The reference standard for EW and seamless pipe, including the EW itself shall be N5 internal and external notches in addition to the requirements of API 5L.

9. WORKMANSHIP, VISUAL INSPECTION, AND REPAIR OF DEFECTS

9.1 **Purchaser Inspection.** The purchaser reserves the right to have third party inspection present during the manufacturer of this order.

9.2 **Workmanship and Defects.**

9.2.1 Dents. All dents producing a deviation from the curvature of the pipe wall 1/16 inch (0.0625 in) or greater containing injurious defects shall be rejected. Dents without injurious defects that do not exceed 1/8 inch (0.125 in) deviation from the curvature of the pipe wall are acceptable. Dents exceeding 1/8 inch deviation shall be rejected.

9.2.2 **Other Defects**. Minor imperfections such as scale, pits, etc., in which the extent of the defect is apparent, need not be removed provided, 1) the depth of defect does not exceed 10% of the actual wall thickness; and 2) that the remaining wall thickness is not less that 90 percent of the specified wall as determined by the use of ultrasonic wall thickness measuring instruments. Defects such as sharp gouges or deep longitudinal scratches shall be ground to vanishing even though they may be less than the permissible depth of defect by this Specification and by API 5L.

9.3 **Disposition of Defects**

9.3.1 Defects may be repaired by grinding provided the defect is completely removed, the ground surface is smooth and uniformly contoured, and the remaining wall thickness is measured and found to be within specified limits.

9.4 **Repair of Defects by Welding.**

Weld repair of defects is prohibited.

10. MARKING AND COATING

10.1 **Marking.** In addition to the markings specified by API Specification 5L, the following shall be marked on the pipe: heat number, pipe number, and purchase order number. Color-coding and other markings that might be required will be specified on the purchase order.

10.2 **Coatings.** Unless other specified pipe shall be furnished clean and free of all loose mill scale, rust, water, oil, grease and other foreign mater.

10.3 A light coat of clear lacquer shall be sprayed or brushed over stenciled areas only.

11. HANDLING AND STORAGE

11.1 Pipe shall be handled in the mill and shipping yard in such a way as to minimize any damage to the pipe.

11.2 Pipe shall be stacked in such manner to prevent deformation, corrosion, or other damage during storage.

11.3 Pipe shall be protected during loading, transit, and storage in order to preclude all contamination by oil, grease, salt water, or other chemicals, which could adversely affect coating adhesion.

12. LOADING AND TRANSPORTATION

Pipe shall be loaded and transported in accordance with written procedures approved by CH2M Hill. As a minimum, loading and transportation for rail shipment shall be in accordance with API Specification 5L1, "Recommended Practice for Railroad Transportation of Line Pipe," and/or API RP5L, "Recommended Practice for Marine Transportation of Line Pipe".

13. CERTIFICATION

13.1 The Manufacturer shall certify in writing that the pipe meets the requirements of this specification.

13.2 Certified copies of the material certifications and the result of the tensile, Charpy tests, and others shall be furnished to CH2M Hill.

ADDENDUM

TO SUPPLEMENTAL SPECIFICATION FOR API SPECIFICATION 5L GRADE X70 PSL2 SEAMLESS AND ELECTRIC WELDED (EW) STEEL LINE PIPE FOR CO_2 SERVICE

1. **Scope**

   1.1 The potential exists for future streams to contain sufficient H_2S that sulfide stress cracking (SSC) and/or hydrogen induced cracking (HIC) may be possible. Therefore, certain requirements of API 5L Appendix H are herein appended to the original specification for this consideration. The entire Appendix H is not appended or required only those sections presented below. No SSC tests are required.

2. **Hardness Tests**

   2.1 Hardness testing of the base metal and EW shall be performed in accordance with API 5L Appendix H Para. H.4.4 and H.7.3.3. No hardness value shall exceed 22 HRC (250 HV).

   2.2 One specimen shall be removed from at least one (1) pipe in each lot of 100 pipes produced but not less than one (1) pipe per heat of steel.

3. **HYDROGEN INDUCED CRACKING (HIC) TESTS**

   3.1 HIC resistance of the base metal and EW shall be tested in accordance with API 5L Appendix H Para. H.4.3

   3.2 HIC tests shall be performed on one set of samples for every heat of steel in the order.

APPENDIX E

Meteorological Data

BCOT 2008 BATON ROUGE/CAPITAL - TEMPERATURE UNIT - Fahr

DATE	0	1	2	3	4	5
01/01/08	54	53	51	49	47	46
01/02/08	41	39	38	36	35	34
01/03/08	29	28	27	26	26	25
01/04/08	36	35	34	35	38	39
01/05/08	52	52	52	53	53	54
01/06/08	59	58	58	58	60	61
01/07/08	66	66	64	63	62	62
01/08/08	68	68	68	67	68	67
01/09/08	61	59	58	57	57	56
01/10/08	65	65	68	68	68	68
01/11/08	54	52	51	50	49	47
01/12/08	47	46	45	44	43	42
01/13/08	53	53	53	52	51	51
01/14/08	48	45	43	41	40	39
01/15/08	48	47	46	46	46	46
01/16/08	49	48	48	47	47	47
01/17/08	47	46	46	46	46	46
01/18/08	49	49	47	46	44	44
01/19/08	44	42	42	41	41	39
01/20/08	32	31	30	29	29	28
01/21/08	34	33	32	31	31	31
01/22/08	49	50	51	52	52	52
01/23/08	56	55	54	53	52	52
01/24/08	53	52	51	50	49	47
01/25/08	41	40	40	39	39	38
01/26/08	40	41	42	42	43	43
01/27/08	46	46	44	44	44	43
01/28/08	43	40	39	39	38	38
01/29/08	56	55	55	55	56	56
01/30/08	49	46	43	40	39	37
01/31/08	45	45	46	47	47	47
02/01/08	45	43	41	39	38	37
02/02/08	42	41	40	40	40	40
02/03/08	57	58	58	59	59	59
02/04/08	69	68	68	68	68	68
02/05/08	71	71	71	71	71	71
02/06/08	73	73	66	55	55	56
02/07/08	47	46	43	42	42	41
02/08/08	51	50	48	48	47	47
02/09/08	56	55	55	55	55	56
02/10/08	56	55	53	51	50	49
02/11/08	53	50	49	48	47	46
02/12/08	61	60	60	60	60	56
02/13/08	45	44	43	43	43	41
02/14/08	38	38	37	36	35	35
02/15/08	53	52	52	52	53	54
02/16/08	59	58	58	58	58	59
02/17/08	67	68	70	61	59	59
02/18/08	54	52	51	50	49	48
02/19/08	46	45	44	43	42	42
02/20/08	52	52	53	53	52	52
02/21/08	64	64	64	64	63	64
02/22/08	71	71	71	71	70	70

02/23/08	48	48	47	47	46	46
02/24/08	54	52	50	49	48	48
02/25/08	58	56	55	54	53	52
02/26/08	71	71	71	71	66	62
02/27/08	46	45	44	43	41	40
02/28/08	42	41	41	41	41	41
02/29/08	55	55	55	54	54	53
03/01/08	57	57	56	55	54	54
03/02/08	62	61	60	59	59	58
03/03/08	63	64	64	64	65	65
03/04/08	54	51	49	48	47	45
03/05/08	42	41	40	38	38	38
03/06/08	49	49	48	47	47	47
03/07/08	54	52	53	51	49	47
03/08/08	39	38	36	36	37	38
03/09/08	42	41	40	39	38	38
03/10/08	55	55	54	53	52	51
03/11/08	56	56	55	55	55	55
03/12/08	52	51	50	49	50	49
03/13/08	54	54	52	52	50	50
03/14/08	64	63	63	63	63	64
03/15/08	69	69	69	69	70	70
03/16/08	64	61	59	57	56	55
03/17/08	61	60	60	62	62	64
03/18/08	72	73	73	73	73	74
03/19/08	76	73	65	65	64	64
03/20/08	51	50	50	48	47	45
03/21/08	52	51	51	50	49	48
03/22/08	58	57	57	56	55	54
03/23/08	58	58	57	56	54	53
03/24/08	51	49	47	46	45	44
03/25/08	46	44	43	42	42	42
03/26/08	55	55	55	54	54	53
03/27/08	60	59	59	58	58	58
03/28/08	66	65	65	65	65	65
03/29/08	68	67	65	65	65	66
03/30/08	69	69	68	69	68	68
03/31/08	68	68	68	68	69	69
04/01/08	71	71	71	70	70	71
04/02/08	70	68	68	67	67	67
04/03/08	71	70	70	70	70	69
04/04/08	71	70	70	70	70	70
04/05/08	61	61	61	60	61	61
04/06/08	57	56	56	56	56	56
04/07/08	60	60	58	58	58	57
04/08/08	66	66	65	64	64	64
04/09/08	70	70	71	71	71	71
04/10/08	74	74	74	74	74	75
04/11/08	75	75	75	74	74	75
04/12/08	68	68	66	65	64	62
04/13/08	57	56	54	53	53	52
04/14/08	53	50	51	48	48	48
04/15/08	46	45	44	43	42	42
04/16/08	52	51	50	49	47	47
04/17/08	60	60	60	59	58	58
04/18/08	65	66	65	65	65	65
04/19/08	57	54	52	51	50	49
04/20/08	59	58	58	58	56	55

04/21/08	63	60	59	58	58	57
04/22/08	71	70	69	69	69	69
04/23/08	71	71	71	71	72	72
04/24/08	71	71	71	71	69	68
04/25/08	68	68	67	67	66	67
04/26/08	71	70	70	69	69	69
04/27/08	66	66	67	67	67	67
04/28/08	63	62	61	60	59	58
04/29/08	56	57	56	55	55	55
04/30/08	63	62	59	58	58	57
05/01/08	66	67	68	68	67	68
05/02/08	73	73	73	74	74	75
05/03/08	76	76	76	75	74	67
05/04/08	67	65	61	60	59	58
05/05/08	64	63	62	61	60	59
05/06/08	64	64	62	62	61	61
05/07/08	68	67	66	66	65	66
05/08/08	74	73	73	74	74	74
05/09/08	73	73	73	73	73	73
05/10/08	74	74	74	74	74	74
05/11/08	76	76	76	76	76	76
05/12/08	65	64	62	60	59	58
05/13/08	67	66	65	65	66	67
05/14/08	73	73	73	73	73	73
05/15/08	73	74	74	74	74	71
05/16/08	73	73	73	73	71	71
05/17/08	61	60	59	58	58	57
05/18/08	64	63	63	62	61	61
05/19/08	69	68	67	67	67	68
05/20/08	73	72	71	71	71	71
05/21/08	73	73	74	74	74	75
05/22/08	74	73	73	72	72	73
05/23/08	70	70	70	70	70	70
05/24/08	79	78	78	77	77	78
05/25/08	79	78	77	76	76	76
05/26/08	78	77	77	77	76	76
05/27/08	78	77	77	76	76	76
05/28/08	75	74	73	72	71	71
05/29/08	76	74	74	73	72	72
05/30/08	76	75	73	73	73	72
05/31/08	76	75	75	74	73	73
06/01/08	78	77	76	76	75	75
06/02/08	77	76	76	75	75	76
06/03/08	78	77	77	77	76	77
06/04/08	77	76	76	76	76	76
06/05/08	79	78	78	78	78	78
06/06/08	79	79	78	78	79	79
06/07/08	80	80	79	78	78	78
06/08/08	79	78	78	77	77	77
06/09/08	76	76	75	75	75	76
06/10/08	78	78	76	76	75	76
06/11/08	77	76	76	75	75	76
06/12/08	78	77	77	77	76	76
06/13/08	78	77	77	76	76	76
06/14/08	76	76	76	75	76	75
06/15/08	79	78	77	76	76	76
06/16/08	77	76	77	76	76	76
06/17/08	77	76	75	75	75	75

06/18/08	76	76	75	75	75	75
06/19/08	79	78	78	76	76	75
06/20/08	76	76	75	76	75	75
06/21/08	75	73	74	74	73	74
06/22/08	74	74	74	73	73	73
06/23/08	76	76	75	75	74	74
06/24/08	79	78	77	76	76	76
06/25/08	78	77	77	76	77	78
06/26/08	70	70	70	70	71	71
06/27/08	72	72	72	72	72	73
06/28/08	74	74	73	74	74	75
06/29/08	75	75	75	76	76	76
06/30/08	74	75	75	74	74	74
07/01/08	74	73	73	72	71	71
07/02/08	76	74	73	72	71	70
07/03/08	77	77	76	76	76	76
07/04/08	74	73	73	73	73	73
07/05/08	76	76	74	74	75	75
07/06/08	79	78	78	78	76	76
07/07/08	76	75	74	74	73	73
07/08/08	77	76	76	75	74	74
07/09/08	75	75	75	74	74	75
07/10/08	79	79	78	78	78	78
07/11/08	80	80	79	79	78	78
07/12/08	81	80	80	79	79	79
07/13/08	80	79	78	77	77	77
07/14/08	80	79	78	78	78	78
07/15/08	78	77	77	76	76	76
07/16/08	78	76	75	74	74	73
07/17/08	80	80	79	79	79	78
07/18/08	78	78	78	77	77	76
07/19/08	79	78	77	77	76	76
07/20/08	79	78	78	78	77	77
07/21/08	80	80	79	79	79	80
07/22/08	81	80	80	78	78	77
07/23/08	79	78	78	78	78	78
07/24/08	74	74	74	74	74	73
07/25/08	77	77	77	76	76	76
07/26/08	79	79	78	78	78	78
07/27/08	81	81	81	80	80	79
07/28/08	78	78	78	78	78	79
07/29/08	82	81	80	79	79	79
07/30/08	79	79	79	79	79	79
07/31/08	80	80	80	80	81	81
08/01/08	76	77	77	78	79	79
08/02/08	74	74	75	77	77	78
08/03/08	82	80	76	75	74	74
08/04/08	79	78	77	76	75	75
08/05/08	80	79	79	80	79	80
08/06/08	78	78	77	77	76	76
08/07/08	79	79	78	78	77	77
08/08/08	80	80	80	79	78	77
08/09/08	77	75	74	74	73	72
08/10/08	77	77	76	76	76	75
08/11/08	80	80	81	81	80	80
08/12/08	77	77	77	78	79	80
08/13/08	76	75	75	74	75	75
08/14/08	75	74	74	73	73	72

08/15/08	78	77	77	76	76	76
08/16/08	76	76	76	76	75	75
08/17/08	76	76	75	75	75	74
08/18/08	76	75	75	74	74	73
08/19/08	75	75	75	75	75	75
08/20/08	76	76	76	76	75	75
08/21/08	76	76	76	76	75	75
08/22/08	77	76	76	76	76	76
08/23/08	79	79	78	78	77	76
08/24/08	77	76	76	74	73	72
08/25/08	74	74	74	74	74	74
08/26/08	73	74	73	73	72	73
08/27/08	78	76	76	75	74	74
08/28/08	79	78	77	77	76	77
08/29/08	78	78	77	77	77	78
08/30/08	79	78	77	77	76	76
08/31/08	79	78	78	77	77	76
09/01/08	75	76	77	78	78	78
09/02/08						
09/03/08						
09/04/08						
09/05/08						
09/06/08						
09/07/08						
09/08/08	78	77	76	75	75	74
09/09/08	75	74	74	73	73	73
09/10/08	78	77	76	76	75	75
09/11/08	78	78	78	77	78	77
09/12/08	81	76	78	78	81	78
09/13/08	83	83	83	83	83	82
09/14/08	81	81	81	81	81	81
09/15/08	75	75	74	74	73	73
09/16/08	67	66	65	64	64	63
09/17/08	65	64	64	63	62	62
09/18/08	69	68	67	66	65	65
09/19/08	72	72	71	71	71	70
09/20/08	72	73	72	72	72	71
09/21/08	69	68	68	68	68	67
09/22/08	71	71	70	69	68	68
09/23/08	73	72	71	71	70	71
09/24/08	74	73	72	71	70	69
09/25/08	68	67	66	65	65	64
09/26/08	66	65	63	63	62	62
09/27/08	69	68	66	65	64	63
09/28/08	69	67	67	67	66	66
09/29/08	73	72	71	71	70	69
09/30/08	70	69	69	70	71	71
10/01/08	70	69	68	66	65	64
10/02/08	64	63	61	60	59	59
10/03/08	69	67	65	64	64	63
10/04/08	71	70	68	68	67	66
10/05/08	69	68	67	66	65	65
10/06/08	70	69	69	69	70	70
10/07/08	76	76	76	76	76	76
10/08/08	70	69	67	65	63	62
10/09/08	66	64	62	63	62	61
10/10/08	67	66	65	64	64	64
10/11/08	68	67	67	66	65	65

10/12/08	69	68	67	66	66	66
10/13/08	69	68	67	67	67	68
10/14/08	73	73	72	71	71	72
10/15/08	73	72	71	71	71	72
10/16/08	72	72	71	70	69	69
10/17/08	73	70	69	69	68	67
10/18/08	60	59	57	56	55	55
10/19/08	59	57	56	55	54	53
10/20/08	57	56	56	54	53	52
10/21/08	61	60	59	58	57	57
10/22/08	63	61	59	58	59	58
10/23/08	69	68	68	68	68	67
10/24/08	57	58	58	57	58	58
10/25/08	53	52	52	51	50	50
10/26/08	58	58	58	57	55	55
10/27/08	65	65	67	65	62	60
10/28/08	49	47	47	46	48	46
10/29/08	47	46	44	43	42	41
10/30/08	49	48	48	47	46	47
10/31/08	51	50	50	49	48	47
11/01/08	54	53	52	52	51	51
11/02/08	55	54	53	53	51	51
11/03/08	54	53	52	52	53	52
11/04/08	58	56	56	56	55	54
11/05/08	62	61	61	60	60	60
11/06/08	63	63	62	62	62	62
11/07/08	67	67	66	66	66	64
11/08/08	52	51	49	50	49	48
11/09/08	55	52	51	49	51	49
11/10/08	51	49	49	48	47	47
11/11/08	57	57	55	54	54	55
11/12/08	64	64	64	64	64	65
11/13/08	61	61	60	61	60	59
11/14/08	61	61	61	61	62	63
11/15/08	64	62	60	59	56	54
11/16/08	45	44	43	42	41	40
11/17/08	43	43	42	42	42	41
11/18/08	51	51	50	50	48	47
11/19/08	41	40	39	38	38	38
11/20/08	53	54	53	52	50	49
11/21/08	52	50	48	46	44	42
11/22/08	37	36	37	36	36	35
11/23/08	55	55	55	55	55	54
11/24/08	60	60	60	60	60	60
11/25/08	53	51	49	48	46	45
11/26/08	45	44	44	44	44	43
11/27/08	57	58	58	58	58	57
11/28/08	66	65	65	65	65	65
11/29/08	70	69	69	69	69	69
11/30/08	56	55	54	54	53	51
12/01/08	47	46	45	44	44	43
12/02/08	40	39	37	37	36	36
12/03/08	46	46	46	45	45	45
12/04/08	62	62	62	61	61	60
12/05/08	40	39	38	37	36	35
12/06/08	42	42	42	41	40	41
12/07/08	44	42	43	42	42	43
12/08/08	45	44	44	42	41	40

12/09/08	63	64	64	65	65	66
12/10/08	58	58	58	58	56	52
12/11/08	39	38	38	37	35	33
12/12/08	38	38	37	37	37	37
12/13/08	43	41	41	41	40	40
12/14/08	55	55	55	56	57	59
12/15/08	66	65	65	65	65	66
12/16/08	51	49	48	47	46	46
12/17/08	59	58	61	63	64	66
12/18/08	65	66	65	65	65	66
12/19/08	67	68	67	67	67	67
12/20/08	68	68	68	68	67	66
12/21/08	69	69	69	62	60	58
12/22/08	38	35	34	33	31	31
12/23/08	41	41	41	41	41	42
12/24/08	69	69	70	70	69	69
12/25/08	62	62	61	61	61	61
12/26/08	68	69	69	69	69	69
12/27/08	71	72	71	71	71	71
12/28/08	52	51	51	51	51	51
12/29/08	51	51	51	51	50	50
12/30/08	47	46	46	44	43	42
12/31/08	57	57	58	58	57	56

Annual Mean = 68.650 Maximum =

Standard Deviation = 13.808 Minimum =

Number of Observation = 8623 % of Obs.=

Monthly mean	51.349	58.681	62.501	69.006	76.329
# Obs	743	696	744	720	742
%obs	99.9	100.0	100.0	100.0	99.7

:enheit

6	7	8	9	10	11	12
44	44	45	46	48	50	52
33	33	34	35	37	39	40
24	25	27	31	34	37	39
39	40	41	44	48	55	58
55	55	57	60	64	69	69
61	60	62	65	71	73	75
61	62	65	69	72	74	77
68	68	70	72	74	76	78
56	53	52	55	56	58	61
68	69	70	71	73	74	74
46	46	48	51	54	56	58
42	44	49	54	58	60	62
49	49	50	54	56	59	60
38	39	44	49	52	55	57
46	47	51	55	58	60	61
47	47	46	45	46	46	48
46	47	48	49	51	53	53
44	43	44	46	48	51	
38	38	38	38	40	39	41
28	28	31	34	38	42	45
30	31	34	39	43	49	53
52	53	55	59	62	66	68
52	51	52	53	53	54	54
47	46	45	44	42	42	43
38	38	39	40	40	39	39
44	44	45	46	47	46	46
42	42	42	42	42	44	46
38	39	43	49	53	56	59
59	60	62	65	68	69	69
36	36	39	43	47	49	51
49	51	53	57	60	65	67
37	36	37	40	42	45	47
40	42	47	53	58	62	64
59	60	63	65	66	69	73
68	68	69	71	73	76	78
71	72	73	75	77	79	80
56	56	56	57	58	58	59
40	42	47	52	55	57	58
44	46	50	55	57	61	63
56	56	59	63	66	70	73
47	48	55	63	68	71	72
47	49	55	63	67	70	70
57	59	63	68	71	74	71
38	37	37	38	41	44	46
35	37	43	49	54	58	61
54	55	57	60	62	62	62
60	60	60	60	63	67	69
59	59	56	58	62	65	70
47	47	49	52	54	56	58
42	45	52	58	61	62	64
53	56	59	63	67	69	68
64	65	65	66	66	67	68
69	69	66	66	66	66	67

46	46	47	49	53	57	60
49	50	54	58	62	66	70
52	54	57	60	62	65	70
61	58	56	56	56	56	56
39	39	41	43	45	47	49
42	45	50	54	57	60	62
52	57	63	67	69	70	70
53	55	62	67	70	73	74
59	61	65	68	71	74	75
66	67	69	72	75	78	79
43	42	42	44	45	45	47
38	41	46	51	55	58	60
47	51	56	60	64	67	69
46	45	44	45	46	45	45
38	38	40	42	45	47	50
38	42	49	55	59	62	64
51	55	61	65	68	70	71
55	55	56	58	59	61	61
48	52	58	61	64	66	67
50	53	59	62	65	67	69
65	67	69	71	75	76	77
70	70	72	76	78	80	83
54	56	60	64	69	72	75
65	68	71	74	77	79	81
74	75	76	78	80	82	83
63	63	63	63	63	62	62
44	47	51	55	59	63	65
48	54	61	66	68	70	71
55	58	60	63	67	70	73
53	53	56	59	62	64	66
43	46	50	53	57	59	60
42	47	56	60	62	64	66
53	58	63	68	70	71	73
58	62	67	70	75	77	78
65	67	71	73	74	77	79
66	67	67	68	71	75	77
68	70	73	75	78	79	79
69	70	72	74	76	79	79
71	72	74	75	77	78	79
68	69	70	73	75	78	80
69	69	70	72	77	79	81
71	73	74	76	79	81	81
60	59	60	61	63	62	62
56	58	61	65	68	70	73
58	60	64	70	75	78	80
65	68	71	75	78	79	80
71	72	74	75	76	79	81
75	76	80	81	83	83	85
75	77	78	80	81	82	83
62	62	64	66	67	69	71
52	57	62	65	66	67	69
47	49	51	52	54	56	57
44	48	51	55	57	59	62
49	56	61	65	68	69	71
59	63	66	69	72	74	75
65	67	69	71	73	73	75
52	57	63	66	68	71	73
58	61	66	71	74	77	79

59	64	71	75	79	81	82
69	72	74	74	78	82	84
72	74	78	80	83	84	86
70	72	75	79	82	83	84
69	71	73	74	76	78	78
70	71	74	79	80	81	82
68	69	71	73	75	76	79
58	58	59	62	64	66	68
58	62	67	71	73	76	77
61	67	71	73	76	77	79
69	73	76	78	80	81	82
75	76	78	80	81	81	80
64	64	66	71	75	78	81
59	62	66	69	73	75	77
61	66	71	73	74	75	75
64	69	73	76	78	78	79
68	71	74	78	80	82	84
74	75	76	77	79	81	83
73	74	76	78	82	84	85
74	75	77	81	82	83	84
76	77	78	79	79	80	81
60	65	69	72	74	76	78
69	72	73	77	80	83	82
74	77	79	80	81	83	81
71	68	68	69	71	74	78
70	70	71	72	73	71	71
60	65	68	70	72	73	74
63	66	70	73	76	78	80
69	73	77	80	82	84	85
72	75	79	82	84	86	88
75	76	78	80	82	84	85
74	76	80	82	83	81	84
72	75	78	79	80	82	84
79	80	80	83	86	86	87
76	78	81	83	86	88	89
77	78	81	83	85	87	88
78	80	81	84	85	84	84
74	77	80	82	84	85	87
75	79	82	84	86	87	89
75	79	81	82	84	85	86
75	79	82	84	87	87	89
77	79	82	83	86	87	89
78	80	83	85	87	88	90
78	80	83	85	87	89	90
78	81	84	86	88	88	89
80	82	84	86	89	89	91
80	82	84	86	88	89	90
80	82	84	86	89	90	91
79	82	83	86	88	89	90
78	80	83	85	79	85	89
77	79	82	85	87	88	89
78	81	83	85	87	88	89
79	82	84	86	88	83	78
78	82	83	85	87	89	90
78	81	83	85	87	85	78
77	81	82	84	86	89	91
77	81	84	86	88	88	90
76	80	83	86	89	91	93

76	79	83	85	88	88	89
76	79	83	85	87	89	87
78	82	84	86	88	89	91
77	82	83	85	87	88	89
75	78	78	81	85	86	87
76	80	84	87	89	90	87
79	82	84	86	88	90	91
80	83	85	85	87	85	84
72	75	80	84	86	89	90
76	80	83	86	87	87	78
77	79	81	84	86	77	74
77	79	82	84	86	88	90
75	77	78	82	84	86	86
73	76	81	85	87	89	90
73	78	83	86	88	88	90
78	81	84	85	88	89	90
76	79	81	83	86	87	87
76	77	79	82	85	87	89
78	80	83	85	87	89	90
76	80	84	86	89	91	91
77	82	85	88	88	89	90
78	81	84	87	87	89	90
80	83	84	86	88	85	85
80	83	85	87	89	89	90
80	83	85	88	90	91	92
78	81	84	86	88	90	91
79	81	82	83	85	86	90
76	79	84	87		91	93
75	80	86	91	93	95	96
79	82	86	89	91	91	91
77	81	85	88	88	91	91
78	82	85	88	90	92	92
79	82	85	87	89	91	92
81	83	87	90	93	95	97
80	83	87	88	90	90	92
78	80	81	85	87	88	88
74	78	83	86	88	83	77
78	82	84	87	89	89	90
78	80	83	87	89	91	92
80	82	84	88	91	94	95
80	82	85	89	91	93	94
80	82	85	87	90	90	92
80	83	85	85	83	87	85
79	80	83	85	86	82	84
79	81	83	85	88	91	87
78	80	82	85	88	90	92
74	76	82	86	90	91	94
77	80	83	86	87	90	91
81	82	83	87	82	83	87
76	80	83	85	88	90	91
78	81	83	87	88	91	92
79	80	81	82	81	82	81
73	77	82	85	88	91	91
77	80	83	86	87	89	90
81	81	80	83	87	84	79
80	81	83	84	86	87	86
76	77	79	80	82	84	86
74	78	82	85	88	90	91

77	81	83	86	88	89	91
76	79	79	79	82	82	82
75	76	79	82	85	85	87
74	77	79	82	85	85	87
75	77	81	83	84	86	86
75	77	80	83	83	84	85
77	81	84	86	86	89	89
77	80	82	87	87	87	90
77	81	84	87	89	91	92
72	72	72	72	72	73	73
74	75	76	78	79	81	83
73	75	78	81	84	86	87
76	81	84	87	89	90	91
78	81	84	87	89	90	91
79	81	85	87	90	92	92
77	80	84	88	90	91	93
76	77	81	86	89	90	90
78	76	76	76	76		

76	80	83	87	89	91	91
74	77	81	85	87	88	89
75	78	82	86	89	90	91
77	80	83	84	87	88	89
76	79	82	82	84	86	87
83	83	83	85	85	85	86
81	82	83	85	86	87	86
73	73	74				
64	65	67	72	75	76	77
62	66	71	76	78	79	80
65	69	74	78	81	83	83
71	72	74	76	75	75	76
71	74	78	80	81	84	85
68	71	76	80	82	84	83
68	71	75	79	82	85	86
71	74	78	83	85	86	87
69	72	76	79	82	84	85
64	68	73	77	80	82	83
63	68	74	77	80	83	84
64	68	73	79	82	82	83
67	70	74	79	83	85	86
69	73	78	82	85	86	87
71	74	79	82	84	85	85
64	68	71	75	77	78	79
60	66	72	76	79	80	81
65	70	75	78	80	82	84
67	71	76	79	81	82	83
65	69	75	79	82	84	84
70	73	78	82	83	85	86
76	77	78	81	83	85	85
62	63	65	69	71	73	74
62	64	69	72	74	77	79
64	67	71	75	78	80	81
66	69	74	78	80	82	83

67	70	73	75	78	81	81
69	70	72	76	79	81	83
72	73	74	76	79	82	85
73	74	77	79	82	83	84
68	71	76	80	82	83	84
67	66	66	66	67	68	66
54	58	63	67	72	74	75
53	56	62	66	70	71	73
53	57	64	69	72	74	76
57	60	67	72	74	76	77
58	61	65	72	73	73	75
61	60	59	60	60	62	63
58	58	58	60	60	63	67
50	56	64	68	72	75	76
54	59	66	70	73	76	79
58	56	57	59	60	61	62
46	46	49	53	57		60
41	46	52	56	59	61	63
46	50	58	64	67	70	71
48	53	61	67	70	73	74
51	54	61	65	70	72	74
51	54	62	68	71	72	74
52	55	61	69	74	77	77
54	58	64	71	74	76	78
60	61	62	64	69	73	76
62	64	69	73	75	77	78
63	60	60	62	65	66	67
48	53	58	64	70	72	73
48	51	56	61	65	67	68
46	49	54	59	63	66	68
57	59	64	68	71	74	74
65	66	65	65	65	65	64
59	60	62	63	65	67	68
63	64	66	68	71	75	78
52	52	53	55	56	57	58
40	41	43	46	49	51	52
41	46	51	56	60	63	66
46	47	49	52	55	57	59
38	41	46	52	56	58	60
47	49	56	62	67	71	72
41	40	42	44	47	50	52
35	37	42	48	53	57	61
54	55	59	63	68	70	70
60	61	65	69	73	74	72
43	46	49	53	57	60	62
43	45	50	55	60	62	64
58	60	65	69	71	69	72
65	67	69	70	73	76	78
69	67	66	66	66	65	63
49	49	51	52	54	57	59
42	43	46	49	51	52	52
36	38	44	47	49	51	53
45	49	56	63	67	70	71
60	60	58	53	52	50	50
34	35	37	42	46	50	53
41	41	43	46	50	52	53
45	44	46	50	55	58	60
40	43	49	55	60	65	68

66	67	69	71	71	72	73
50	49	48	47	46	46	47
33	33	33	34	35	36	37
37	37	42	47	50	53	54
39	40	44	48	51	55	58
61	62	62	64	67	69	71
65	65	66	69	71	73	76
46	46	47	47	49	50	51
66	67	68	71	73	74	75
66	66	67	68	69	72	73
67	67	68	70	72	74	76
66	67	68	69	71	73	74
56	52	50	51	51	52	53
31	31	32	34	35	38	40
42	43	44	46	51	58	64
69	69	71	72	75	76	77
61	62	62	64	67	70	72
69	69	69	71	73	75	78
71	71	73	74	76	78	78
51	52	52	52	52	53	53
50	49	51	54	57	60	62
42	43	49	56	60	63	64
55	55	54	56	58	60	62

98

24

98.2

81.217	82.884	81.238	77.140	68.598	59.708	56.711
720	743	744	564	743	720	744
100.0	99.9	100.0	78.3	99.9	100.0	100.0

13	14	15	16	17	18	19
53	52	52	51	49	47	44
41	42	41	40	38	36	35
40	42	43	42	40	38	37
59	61	62	60	57	55	53
71	71	72	70	68	65	63
76	76	76	74	72	71	69
78	78	77	75	73	72	70
77	77	77	75	74	74	69
62	64	66	66	63	62	62
74	73	68	66	65	64	64
59	60	61	60	57	53	51
64	65	65	63	60	57	55
62	62	62	60	58	56	55
59	60	60	59	57	56	54
61	60	60	59	57	56	56
49	49	48	48	48	48	47
52	51	51	51	51	51	51
56	55	54	53	51	50	49
40	40	42	42	41	40	39
47	48	48	47	44	42	40
54	56	56	54	52	50	49
70	71	71	70	68	64	62
54	54	54	54	54	54	54
44	44	44	45	44	43	42
39	39	39	38	37	38	38
48	49	49	50	50	49	49
49	53	55	55	52	49	47
61	63	64	64	62	61	59
69	68	68	69	66	66	66
53	54	55	54	52	50	50
71	59	58	57	56	55	54
50	52	53	53	51	48	47
67	68	67	67	66	65	62
75	75	75	74	73	71	70
79	78	78	76	75	73	72
79	80	79	77	76	75	74
60	60	60	58	56	54	53
60	63	63	63	60	57	55
65	66	67	67	65	63	61
74	75	75	74	71	68	66
73	74	73	71	69	64	61
71	71	71	71	69	67	65
57	56	57	58	57	57	56
48	51	51	51	49	46	45
63	64	65	65	63	61	60
62	62	62	62	61	60	60
71	71	71	70	68	65	65
72	73	74	73	71	67	66
60	61	61	60	58	56	54
65	65	67	66	64	60	60
68	68	67	66	65	63	62
69	69	72	74	73	72	71
68	69	64	62	61	57	55

63	67	69	69	67	63	61
73	74	75	74	72	68	67
73	74	74	72	72	71	71
57	59	58	58	57	55	54
51	53	53	53	51	49	47
64	65	64	64	62	59	58
70	69	69	67	66	64	63
75	76	77	76	74	72	70
76	76	76	75	73	70	67
78	76	71	71	72	73	70
49	50	51	51	51	50	49
62	63	64	64	62	60	58
71	71	70	67	65	64	63
45	43	42	42	41	39	38
53	55	55	55	53	51	49
65	67	66	65	63	60	57
72	72	71	69	67	66	64
62	63	64	64	64	62	61
68	69	70	70	69	65	64
71	73	73	72	71	69	68
79	79	79	78	76	73	71
84	84	85	84	82	79	77
78	78	78	77	74	71	69
82	82	81	80	78	74	72
83	83	82	80	79	78	77
61	60	59	59	59	58	57
68	69	70	70	67	64	62
73	73	73	72	71	69	67
74	75	75	76	74	71	70
68	68	68	67	64	61	59
62	63	63	63	61	58	54
68	68	68	67	66	63	61
73	74	73	72	71	68	66
78	78	77	76	74	71	70
81	81	82	81	79	77	75
74	75	78	79	77	74	72
79	80	79	78	76	73	71
80	79	78	78	77	75	74
80	81	80	81	77	73	73
81	81	74	70	71	71	71
82	82	82	81	79	76	74
82	82	80	73	73	69	65
63	62	62	62	61	60	60
75	76	77	76	75	71	67
82	83	83	83	79	76	75
81	81	83	81	80	76	74
82	82	81	80	79	77	76
85	85	84	83	81	79	78
85	85	85	83	77	73	71
70	71	72	71	70	67	65
70	69	68	67	66	64	62
58	59	59	59	58	56	55
63	65	65	65	64	61	59
72	72	71	70	69	68	66
76	76	75	74	73	71	69
76	74	70	68	67	65	63
74	76	78	77	76	72	69
81	82	81	80	78	75	73

84	85	84	83	81	79	78
85	87	86	84	83	81	74
88	87	84	82	81	80	78
85	83	83	82	80	78	77
79	78	78	80	78	77	76
78	74	73	71	71	70	68
75	74	71	71	70	69	69
69	70	71	71	70	68	65
79	79	79	78	78	74	70
80	80	79	78	76	73	71
81	81	81	79	78	77	76
78	80	81	79	78	78	77
82	82	83	82	80	78	75
78	78	79	79	78	75	72
73	72	73	71	69	69	68
80	81	82	80	79	77	76
85	84	82	81	79	77	75
84	85	83	83	82	79	77
85	85	85	85	84	82	80
85	86	86	85	83	81	80
82	82	81	81	79	77	75
80	80	82	82	80	78	75
83	83	83	82	80	79	78
81	78			70	70	70
81	82	80	80	80	78	76
71	71	73	73	73	71	69
74	74	74	73	72	71	69
82	81	81	81	80	78	76
85	85	86	85	83	81	79
89	89	88	88	86	83	80
86	86	87	87	86	85	82
80	74	74	73	72	71	71
86	86	86	86	85	83	82
89	89	89	89	88	87	85
90	90	91	90	89	87	85
89	89	89	89	87	84	82
81	86	86	85	85	83	82
87	87	86	85	84	83	82
89	89	88	87	86	84	82
87	88	87	88	87	85	83
90	90	89	87	86	84	82
89	90	89	88	88	86	82
91	90	90	90	89	86	84
90	90	89	88	87	85	83
90	90	90	89	87	85	83
91	90	89	89	87	85	84
92	92	91	89	87	86	83
92	92	91	88	86	84	82
92	91	91	90	89	86	78
88	88	87	88	87	84	82
89	90	88	84	83	81	79
90	90	87	87	84	83	81
81	80	84	85	85	83	81
88	85	87	86	82	81	80
84	82	82	84	84	83	82
85	82	81	81	83	81	80
92	92	88	86	86	83	81
94	95	94	93	92	89	85

91	91	90	90	90	87	86
89	82	83	85	85	82	80
89	82	78	79	76	76	76
90	91	88	81	77	75	75
89	90	91	90	88	86	84
80	89	90	91	89	87	85
92	92	91	86	84	83	82
79	74	75	74	72	72	72
83	73	74	74	74	74	74
79	82	82	78	78	80	79
77	80	80	80	81	80	78
91	78	78	78	78	78	76
86	86	86	87	87	83	78
90	91	91	90	89	87	82
90	91	90	90	89	86	82
91	89	86	80	74	74	73
88	85	76	76	76	76	77
90	90	90	90	88	86	83
92	92	93	92	91	88	84
89	90	89	85	82	81	80
90	84	78	78	76	77	77
88	88	85	84	84	83	82
89	89	90	90	89	87	85
92	91	91	91	90	88	85
94	94	93	93	92	89	86
93	93	94	93	92	89	87
91	89	81	82	81	80	79
93	94	93	93	91	89	86
96	97	96	95	92	90	87
86	79	82	81	81	80	81
94	94	93	93	91	89	85
92	93	82	81	83	83	83
94	95	94	93	92	83	83
97	90	92	91	91	88	88
88	85	86	85	84	83	82
85	85	86	84	76	76	76
77	80	82	83	84	83	81
91	92	92	88	88	86	85
93	93	94	92	90	89	88
97	98	96	88	84	84	83
96	97	97	96	93	91	89
92	91	90	85	83	82	81
87	89	89	89	87	84	83
87	88	76	76	76	76	77
80	77	75	74	74	73	73
94	94	95	94	93	91	89
96	96	93	91	91	89	86
91	91	87	85	85	83	82
79	79	78	79	80	80	79
91	91	91	91	88	85	83
92	93	93	93	91	89	87
81	80	80	81	80	79	78
92	92	91	91	89	86	84
91	91	85	82	84	84	84
79	80	77	79	80	80	78
85	83	82	83	83	82	81
87	88	87	87	86	84	82
91	91	91	90	89	86	83

86	80	81	80	78	76	76
84	83	82	81	80	80	79
89	89	88	88	87	81	80
88	91	91	88	84	75	74
79	76	76	76	76	76	76
86	85	84	83	80	79	78
89	84	81	83	85	83	81
88	85	91	91	90	87	83
92	92	91	89	87	83	81
74	75	74	74	74	74	74
83	81	82	83	81	80	77
88	88	89	88	87	85	83
92	92	91	91	89	87	84
92	92	92	90	83	82	82
94	94	92	91	90	87	85
93	94	92	91	90	88	86
90	91	91	89	87	85	82

						84
92	90	76	77	76	76	76
91	90	89	86	81	81	82
92	90	86	88	86	84	82
91	90	89	87	86	85	84
87	86	85	85	85	84	83
87	88	86	85	84	83	83
82	76	76	77	76	76	75
79	78	77	75	74	73	72
77	79	79	77	75	73	71
81	81	81	80	78	74	73
85	84	83	81	80	78	77
78	79	78	79	78	77	76
82	76	75	74	74	73	73
85	82	82	80	75	75	73
87	88	87	85	83	80	79
86	88	84	83	82	80	78
86	85	84	83	80	77	76
84	84	83	82	80	76	74
85	86	85	84	82	78	75
85	85	85	84	81	79	77
87	86	86	84	82	79	78
87	87	87	86	84	82	80
86	86	86	85	82	81	79
80	80	80	78	76	74	72
82	83	83	81	78	76	73
83	84	84	82	80	77	76
84	85	84	83	81	79	78
85	85	84	83	80	78	77
86	86	87	86	82	80	79
75	74	76	77	76	75	75
76	76	76	74	72	70	69
81	81	82	80	78	75	73
83	83	82	82	79	76	73
84	83	84	82	80	78	76

80	81	80	80	78	76	75
85	86	85	82	80	78	78
87	86	85	83	80	78	77
84	84	84	83	81	79	78
85	86	86	84	82	81	80
66	67	68	68	67	67	66
77	77	76	74	71	69	66
74	75	74	73	69	66	64
77	78	78	76	73	69	67
78	79	78	77	73	69	67
76	74	73	72	71	70	70
64	64	64	64	62	60	59
70	73	74	72	69	64	63
77	77	77	75	73	67	64
81	81	81	78	73	69	67
63	63	62	61	59	57	56
61	61	61	60	57	56	55
65	65	65	64	59	57	55
72	73	73	70	66	62	60
75	76	75	73	69	65	62
76	75	75	73	69	67	65
75	75	75	73	69	64	61
79	79	78	76	72	68	66
78	79	78	75	71	69	67
77	78	77	75	73	71	68
77	73	72	72	71	70	69
66	67	67	66	63	60	58
74	74	73	71	67	63	60
69	70	69	67	64	61	60
68	67	66	64	62	60	58
75	76	76	74	73	71	69
64	64	65	64	64	63	63
69	70	71	69	65	63	62
78	77	77	74	71	69	69
58	58	57	55	53	52	51
54	55	55	53	52	51	49
67	68	68	65	60	57	55
61	61	60	58	55	53	51
62	64	64	62	58	56	54
73	74	74	71	67	64	62
54	54	54	51	49	46	44
63	63	62	60	58	56	56
71	72	71	70	67	64	63
71	71	66	65	64	65	65
63	64	63	60	56	53	52
66	68	67	65	63	61	60
73	74	75	73	72	71	69
79	78	76	74	73	72	70
61	60	60	59	58	58	58
59	59	57	55	52	51	50
52	52	51	49	49	47	45
55	56	56	54	52	51	50
72	72	71	69	67	65	65
49	48	47	46	46	46	45
54	55	54	53	49	47	46
55	55	55	53	50	49	47
61	62	62	60	56	53	51
69	70	69	66	63	62	61

75	75	74	74	74	73	73
46	45	44	43	43	42	42
38	40	42	45	45	43	40
56	57	57	55	52	49	46
59	59	58	56	54	53	52
72	72	72	70	66	65	65
75	76	76	74	72	69	65
54	56	57	58	58	58	58
77	77	77	76	73	71	69
75	77	76	75	73	71	70
77	77	77	76	74	73	71
75	75	74	73	71	70	69
55	54	51	49	47	45	44
41	42	42	41	40	41	41
67	68	69	71	70	69	69
78	76	69	69	68	69	69
73	75	75	74	73	71	69
79	80	78	78	76	74	73
78	78	77	76	75	73	72
52	51	52	52	52	52	53
64	65	65	63	60	57	56
65	67	66	66	63	61	60
62	63	62	60	56	54	51

20	21	22	23	Daily max
44	44	43	42	54
34	32	31	30	42
36	35	35	36	43
52	52	53	53	62
62	61	60	59	72
69	68	67	66	76
69	69	68	68	78
67	62	63	62	78
62	63	64	65	66
63	62	61	57	74
51	50	48	48	61
55	53	53	52	65
54	53	50	50	62
53	51	50	49	60
55	53	51	50	61
47	47	47	47	49
51	50	50	50	53
47	47	46	45	56
39	38	36	34	44
39	38	36	35	48
48	48	48	48	56
60	60	59	58	71
54	54	54	53	56
42	42	42	41	53
38	39	40	40	41
49	48	47	46	50
45	45	44	44	55
57	56	56	56	64
64	58	54	52	69
49	49	47	46	55
52	51	49	47	71
46	44	45	43	53
60	58	57	57	68
70	70	70	70	75
71	71	71	71	79
74	73	73	73	80
52	51	51	48	73
54	53	53	51	63
60	58	58	57	67
63	61	59	58	75
58	60	58	55	74
64	63	63	62	71
56	53	48	47	74
44	42	41	39	51
59	58	56	55	65
60	60	60	59	62
64	64	65	66	71
63	63	61	58	74
51	50	49	49	61
58	55	53	52	67
62	62	63	63	69
71	72	71	71	74
53	51	50	49	71

61	58	57	56	69
65	63	61	58	75
71	70	70	70	74
52	50	48	47	71
46	45	44	44	53
57	56	55	55	65
62	61	58	57	70
68	67	65	63	77
66	65	64	64	76
65	62	60	58	79
48	46	44	43	54
56	54	52	50	64
62	61	61	57	71
38	39	39	39	54
47	45	43	43	55
56	55	54	55	67
62	59	57	56	72
59	58	56	53	64
61	59	57	55	70
67	66	66	64	73
68	68	69	69	79
75	75	72	67	85
67	65	65	62	78
71	70	70	71	82
77	77	76	76	83
56	55	54	53	76
62	60	56	54	70
65	64	63	60	73
68	65	62	60	76
57	56	54	52	68
53	51	49	48	63
59	58	57	56	68
64	63	62	61	74
69	68	67	66	78
73	72	71	70	82
70	70	70	69	79
70	69	69	68	80
73	72	71	71	80
72	72	71	70	81
71	71	71	71	81
73	72	72	71	82
62	62	62	61	82
60	60	59	58	63
65	64	63	62	77
73	71	69	67	83
74	73	72	71	83
75	74	74	74	82
77	76	76	76	85
70	70	69	68	85
64	62	61	60	72
60	58	57	56	70
52	51	49	47	59
57	56	54	54	65
64	62	61	60	72
68	67	65	65	76
61	60	59	58	76
66	63	62	60	78
72	69	66	64	82

77	76	74	72	85
71	71	70	71	87
76	74	73	73	88
75	73	71	69	85
75	73	73	72	80
67	66	66	66	82
68	67	65	64	79
62	61	59	58	71
68	67	65	64	79
69	68	67	66	80
76	75	74	73	82
76	76	75	76	81
72	71	70	69	83
70	69	68	66	79
67	67	66	64	75
74	72	70	69	82
74	73	73	73	85
76	75	74	73	85
78	76	75	74	85
78	78	77	77	86
73	71	70	68	82
73	71	70	68	82
77	75	75	74	83
70	71	72	73	83
76	74	74	73	82
67	65	64	62	73
68	67	66	65	74
75	72	71	69	82
76	74	73	73	86
77	76	74	73	89
79	77	76	74	87
71	71	71	71	84
82	81	80	80	86
84	83	81	80	89
85	82	80	78	91
82	80	79	78	89
81	79	78	76	86
80	78	77	76	87
81	79	77	76	89
81	80	78	77	88
81	80	79	78	90
81	81	79	78	90
82	81	80	79	91
82	80	79	78	90
82	81	80	80	90
83	82	81	80	91
83	82	81	80	92
83	82	81	80	92
78	78	77	77	92
81	80	79	78	89
78	78	78	77	90
81	80	79	79	90
80	79	79	78	88
79	79	78	77	90
81	81	81	80	87
79	79	79	78	91
81	79	78	78	92
81	78	77	77	95

85	83	81	81	91
80	78	78	77	89
76	76	76	76	91
75	76	76	74	91
82	80	79	77	91
82	81	80	80	91
81	81	80	78	92
71	71	71	71	87
73	73	73	73	90
77	76	75	75	87
77	76	75	75	86
75	75	75	75	91
76	76	76	75	87
80	79	77	76	91
81	80	79	78	91
74	74	74	74	91
77	77	77	77	88
81	80	80	79	90
77	75	76	76	93
79	79	78	78	91
76	77	76	75	90
81	80	80	79	90
83	83	82	81	90
84	83	82	82	92
84	83	82	81	94
85	84	82	80	94
79	78	78	78	91
85	83	81	79	94
85	83	81	80	97
81	79	78	78	91
83	81	80	80	94
82	82	81	80	93
83	82	81	80	95
86	84	83	82	97
80	80	79	80	92
75	75	75	74	88
81	80	78	78	88
84	83	82	80	92
87	83	81	81	94
82	80	80	80	98
88	86	84	83	97
81	81	80	80	92
82	81	80	80	89
77	76	76	76	88
73	74	74	73	91
87	85	83	82	95
84	83	82	80	96
81	80	80	80	91
78	78	78	78	87
82	81	80	80	91
86	83	82	82	93
77	77	76	78	82
82	81	79	78	92
83	82	82	80	91
78	77	77	77	87
80	80	80	80	87
80	78	77	77	88
82	81	80	79	91

76	76	76	77	91
78	78	78	77	84
78	78	77	76	89
74	75	75	75	91
76	76	76	76	86
78	77	76	76	86
80	79	78	78	89
82	81	81	80	91
80	79	78	77	92
74	74	74	74	77
76	75	74	74	83
82	80	80	79	89
83	81	81	80	92
81	80	80	79	92
83	83	81	80	94
85	83	82	81	94
74	72	74	75	91
				78

83	82	80	80	84
76	76	76	75	92
82	81	80	79	91
81	80	80	79	92
83	81	81	81	91
84	84	83	83	87
82	82	82	82	88
76	76	76	76	87
71	70	69	68	79
70	69	67	67	79
72	71	70	69	81
75	74	73	73	85
76	75	74	73	79
72	71	70	70	85
73	72	71	71	85
77	76	75	74	88
77	75	75	74	88
74	73	71	70	86
73	71	69	67	84
72	71	70	69	86
76	73	73	70	85
77	76	75	74	87
78	77	75	73	87
77	75	74	73	86
71	70	68	66	80
72	71	70	69	83
74	72	71	71	84
76	75	72	71	85
76	75	73	72	85
78	76	76	76	87
74	74	73	72	85
69	68	67	67	76
72	70	69	68	82
72	71	71	69	83
75	73	71	70	84

74	73	71	70	81
77	76	74	73	86
76	76	75	74	87
76	75	75	73	84
78	77	77	76	86
65	64	62	61	73
64	62	62	61	77
62	60	58	57	75
65	64	63	62	78
66	64	63	63	79
69	69	70	69	76
58	58	57	57	69
60	58	55	54	74
62	61	60	59	77
67	67	66	66	81
55	52	50	49	67
53	51	51	49	61
54	52	51	50	65
57	56	54	52	73
60	58	56	55	76
64	62	60	56	76
59	57	56	55	75
64	62	60	59	79
65	63	63	62	79
67	66	65	64	78
68	68	68	67	78
56	54	53	52	67
58	57	61	60	74
58	56	54	52	70
58	57	56	56	68
66	66	65	64	76
63	63	63	62	66
62	61	61	61	71
68	67	67	65	78
50	48	47	46	64
47	46	44	43	55
54	53	53	53	68
48	46	44	43	61
54	54	54	53	64
62	62	58	54	74
43	41	40	38	54
55	55	55	55	63
62	61	60	60	72
63	60	57	55	74
50	49	47	46	64
59	58	58	58	68
68	66	66	66	75
70	69	69	69	79
57	57	57	57	70
50	49	48	48	59
43	43	43	42	52
49	48	47	47	56
64	63	63	62	72
45	43	41	41	62
46	44	44	43	55
45	44	44	44	55
51	49	49	47	62
61	61	61	61	70

72	71	65	58	75
41	40	40	40	58
41	39	38	37	45
44	43	43	43	57
53	53	54	55	59
65	65	65	66	72
60	56	54	53	76
58	59	60	60	60
67	65	66	65	77
69	67	68	68	77
69	69	68	68	77
69	69	69	69	75
43	42	41	40	69
41	41	41	41	42
69	68	68	69	71
67	64	63	62	78
69	69	68	67	75
73	71	71	71	80
72	69	55	53	78
51	51	51	51	53
54	53	51	49	65
61	60	59	58	67
49	47	45	43	63

APPENDIX F

Resume

February 27, 2010

Randy J. Robichaux

10409 Cochron Drive
McKinney, TX 75070
(972) 673-2073
randy.robichaux@denbury.com

Education

Sep-93 to May-94 **University of New Orleans**, New Orleans, LA
6 hours graduate credit for:
Applied Statistics
Regression Analysis
GPA (3.5)

Sep-88 to May-92 **Nicholls State University**, Thibodaux, LA
Degree: Bachelor of Science (May 22, 1992)
Major: Marine Biology
GPA (3.44)

Training/Certifications

- Registered Environmental Manager (National Registry of Environmental Professionals)-since 2004
- Certified Safety, Environmental and Emergency Manager (Office of Infrastructure Preparedness)-since 2008
- Level V Incident Command System
- EPA Inspector Training Course
- EPA Sewage Treatment Plant Diagnostic Course

Job Experience

Jun-07 to present ***Denbury Resources Inc.***
(HSE Manager)

- Responsible for implementing company-wide HSE programs including corporate office and operations in four states (AL, LA, MS, TX).
- Responsible for establishing and accomplishing DRI's HSE goals through successful implementation of HSE programs and working relationships with all company departments.
- Supervise a staff of 14 including HSE field operations, training and environmental regulatory departments.
- Led team to develop and implement new corporate HSE policy.
- Developed corporate training program.
- Responsible for managing budget and expenditures related to HSE capital and operating projects.
- Responsible for NEPA issues related to company projects.
- Assist field and staff management in understanding OSHA/EPA regulations and standards, including guidance on handling OSHA/EPA compliance, inspections, and citations.

- Act as ranking company representative in dealing with government agencies in environmental, safety, and health matters affecting the company.
- Track and review incident statistics including Workers Compensation and make recommendations for correction of problem areas.
- Verify compliance with health and safety regulations and ensure all necessary records are maintained and prepared according to established guidelines.
- Assess new developments in the environmental, health, and safety field which may have application to the company's operations.

Jan-06 to May-07 ***Denbury Resources Inc.***
(Regulatory Manager)

Primary duties:

- Supervise Safety and Environmental staff in the LA and SWMS Operations Area.
- Participate in the development and implementation of strategies, policies and procedures to ensure a safe and healthy work environment, environmental compliance, and minimize safety & environmental risks.
- Interact and advise employees on environmental procedures and policies.
- Communicate with federal, state and local regulatory agencies as a company representative concerning environmental compliance issues.
- Evaluate new and existing facilities to identify HSE concerns.

Aug-99 to Dec-05 ***Denbury Resources Inc.***
(Environmental Manager)

Primary duties:

- Identifying and developing solutions to potential safety & environmental hazards and noncompliance with DRI environmental policies and regulatory agency standards.
- Conduct required environmental tests, analysis, and observations.
- Plan and conduct evaluations of potentially hazardous conditions including exposure monitoring.
- Prepare reports for submission to supervisors, primary investigators and/or managers, which identify the potential safety & environmental hazards and/or program discrepancies, and provide recommendations for control and compliance.
- Interact and advise employees on environmental procedures and policies.
- Communicate with federal, state and local regulatory agencies as a company representative concerning environmental compliance issues.
- Respond to safety & environmental incidents, which may include emergency response to oil or hazardous substance releases, fires, injuries, and other mishaps.

- Participate in and/or lead accident/incident investigations
- Participate in the development and delivery of safety & environmental training for employees.
- Participate in meetings, workshops and conferences to keep abreast of emerging HSE issues and conduct and coordinate technical and professional training sessions for staff.

Oct-97 to Aug-99 ***Denbury Resources Inc.***
(Environmental Specialist)

Primary duties included:

- Participation in the development and implementation of strategies, policies and procedures to ensure environmental compliance and minimize environmental risk
- Conducting regular field environmental audits and drills in order to satisfy compliance with regulatory agencies and corporate policies
- Communicating with federal, state and local regulatory agencies as a company representative concerning environmental compliance
- Responding to spill and emergency events

Sep-95 to Oct-97 ***Louisiana Department of Environmental Quality***
(Environmental Quality Specialist II)

Duties include compliance inspections of both permitted and un-permitted facilities, enforcement activities regarding non-compliance, investigation of spills, complaints & fish kills, and periodic water quality monitoring. Also involved in special projects in the Bayou Lafourche Region including public speaking engagements, Natural Resource Damage Assessment (NRDA), NOAA Shellfish Challenge Program, and various Global Information System (GIS) projects.

Jun-92 to Aug-95 ***Louisiana Universities Marine Consortium (LUMCON)***
(Research Assistant/Associate)

Duties include phytoplankton identification and enumeration using epifluorescence microscopy, ordering supplies, collection and preparation of water samples, and preparing for and participating in oceanographic cruises. Supervisory responsibilities include helping and training students and employees.

Scientific Papers and Presentations

Dortch, Q., R. Robichaux, S. Pool, D. Milsted, G. Mire, N.N. Rabalais, T.M. Soniat, G.A. Fryxell, R.E. Turner, and M.L. Parsons. Abundance and Vertical Flux of *Pseudo-nitzschia* in the northern Gulf of Mexico. Marine Ecology Progress Series. Submitted 10/3/96.

Dortch, Q., R. Robichaux, M.L. Parsons, D. Gibson, W. Mendenhall, N.N. Rabalais, T.M. Soniat, R.E. Turner, G.A. Fryxell, and C. Scholin. Environmental Control of *Pseudo-nitzschia* spp. Abundance in the Northern Gulf of Mexico. May 27, 1996. NATO Advanced Study

Institute on the Physiological Ecology of Harmful Algal Blooms. Bermuda Biological Station.

Duet, L.M., Q. Dortch, N.N. Rabalais, and R. Robichaux. Distribution of *Beggiatoa* spp. along the Louisiana Continental Shelf. Gulf Estuarine Research Society annual meeting, Lafayette, LA. March 23-25, 1995.

Mire, G.A., R. Robichaux, T.M. Soniat, D. Gibson, and Q. Dortch. Temporal Variation in Phytoplankton and Environmental Variables Over Oyster Reefs in the Terrebonne Estuary. Gulf Estuarine Research Society annual meeting, Lafayette, LA March 23-25, 1995.

Robichaux, R. and Q. Dortch. Toxic and Noxious Algae in Louisiana and Texas Coastal Waters 1990-1993. Invited, August 10-11, 1994. Mortality Workshop, Galveston, TX.

Robichaux, R., Q. Dortch, G.A. Mire, N.N. Rabalais, T.M. Soniat, and M.R. Parsons. Occurrence of Toxic Algae in Louisiana Coastal Waters. Gulf Estuarine Research Society annual meeting, Beaumont, TX. April 7-9, 1994.

Robichaux, R. and T.M. Soniat. A Water Quality and Shell Activity Monitor for Oyster Depuration Systems. Invited, February 25, 1993. Louisiana Universities Marine Consortium (LUMCON), Cocodrie, LA.

Robichaux, R. and T.M. Soniat. A Water Quality and Shell Activity Monitor for Oyster Depuration Systems. January 7, 1993. Aquaculture Expo VI, New Orleans, LA.

Robichaux, R. and Q. Dortch. Occurrence of *Gymnodinium sanguineum* in Louisiana and Texas Coastal Waters 1989-1994. Contributions In Marine Science. Submitted.

Soniat, Thomas M., R. Robichaux, G.A. Mire, and Q. Dortch. Temporal Changes in Phytoplankton in a Louisiana Estuary: Trophic and Dystrophic Effects on the Eastern Oyster, *Crassostrea virginica*. Aquaculture '95. San Diego, CA. February, 1995.

APPENDIX G

Denbury Experience

Denbury Resources Inc. Corporate Responsibility Report - June 30, 2009

Table of Contents

Corporate Responsibility	3
Company Overview	5
Corporate Governance	6
Commitment to Equal Employment	7
Technology and Planning	8
The Green Pipeline	9
The Midwest Pipeline Feasibility Study	11
Health, Safety and Environment	12
Adding Environmental Value	16
Green Building Programs	18
Emissions Disclosure Estimations	19
Community Support	20
Research Programs	22

There is a saying in Texas about being "All hat, no cattle". In the world's most regulated industry, what matters more than what you say, is what you do. At Denbury, our people are our most important resource – because it is people that adapt to the changing oil and natural gas environment and make the Company what we are today.

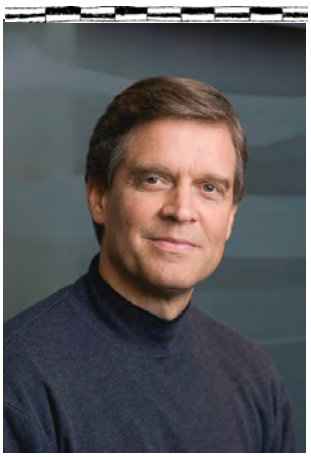
Our Corporate Responsibility report is more than a catalogue of what we do and how we do it. The report represents who we are and what we expect of one another as productive members of an organization. This report may be a first for our Company, but Denbury's values and commitment to how we do business has been the same for many years.

Over time, we have evolved into one of the leading carbon dioxide (CO_2) tertiary enhanced oil recovery (EOR) companies. What we have learned from our experiences in producing new reserves of American oil from old and depleted oil fields throughout the southern U.S. has been significant. Utilizing advanced technology, engineering ingenuity and geo-science to produce oil through the injection of CO_2 is being recognized today as one of the best opportunities to make carbon capture and sequestration (CCS) a reality in the near term.

Today, Denbury is providing government policy makers, the academic and scientific communities, and national environmental advocates a greater understanding of the potential America's old oil fields have for CCS of industrial CO_2. Our objective is to grow our business by expanding our use of CO_2, a significant portion of which we anticipate will be man-made. By doing so, this will allow us to produce additional volumes of domestic oil, contributing to greater American energy independence. Executing our business plan, while maintaining the highest level of environmental stewardship, is our long-held policy and our goal.

This report is a snapshot of Denbury's objectives and achievements, and about how we are striving to improve in the areas of environmental stewardship, health and safety each and every year. We are committed to being good corporate citizens and recognize the important responsibility we have to our employees, shareholders, the environment and the communities in which we operate. We hope as you read our report you will see the character of the employees who are Denbury.

As Trace Adkins put it best, "All hat and no cattle ain't gonna get it done."



Phil Rykhoek
Chief Executive Officer

Ronald T. Evans
President &
Chief Operating Officer

Our Commitment to Excellence: Protecting the Environment, Our Employees and Contractors Health & Safety, and the Communities in Which We Operate

Denbury Resources Inc. is unique among U.S. domestic oil and gas companies in that its corporate strategy and focus is aimed at developing significant stranded reserves of American oil from old fields utilizing a process known as tertiary or CO_2 EOR. We currently use underground natural sources of CO_2 from our Jackson Dome Facility. CO_2 EOR operations not only increase domestic oil production, helping to reduce our nation's need for imported oil, but also provide a promising method to sequester large volumes of industrial CO_2 that would otherwise be vented into the atmosphere.

How we do this is important. That is why our commitment to health, safety and the environment is critical to achieving our business objectives. Our employees, the natural environment and how we impact the communities in which we operate come first and foremost as we move ahead with our planning and execution. We strive to make these obligations a part of Denbury's culture by focusing on training, preparedness and measuring our performance. Communication of our expectations and regular assessment of our performance targets are key tools to achieving results. In addition, we have sought to meet this goal by adding environmental value to numerous aspects of our operations. By improving the fields where we operate, the buildings we work in, undertaking recycling and renewable energy programs, community support and partnering in scientific research programs, we believe we build a better company and a higher standard for achievement.

Denbury recognizes that reduction of carbon emissions is an important issue, and we take the responsibility of protecting our environment seriously. An important step in addressing greenhouse gas (GHG) issues is developing procedures and methods to collect data critical for calculating emissions. Our Company is taking steps to measure and define our emissions by utilizing the API Compendium estimation tools to calculate GHG. We are also making progress by evaluating and implementing emissions reduction programs within the Company.

CO_2 EOR has the potential to store billions of metric tons of CO_2 and produce 39-48 billion barrels of American oil that are not recoverable today. This would partially offset oil supplies from foreign countries that represent over one-half of U.S. consumption. In the Gulf Coast, not including offshore basins, up to 7 billion barrels are recoverable with CO_2 EOR. (Carbon Neutral Oil Solution here). As policy makers search for ways to capture and sequester CO_2 from industrial sources, it is clear that utilizing depleted American oil fields is the best *proven* opportunity to safely make carbon capture and sequestration (CCS) a reality in the near term. (NRDC report here).

As recent federal government research quantifies the potential for storing "CO_2 utilizing EOR" (DOE/NETL 2/7/2008 study here; SECARB report here), Denbury is advancing its program of CO_2 pipeline development to expand its CO_2 transportation network capability to reach targeted oil fields. Denbury's business model is an excellent example of how to combine technology, economics, and science and take a proven and safe process to a new level. Next year's completion of the Green Pipeline, our $825 million, 320 mile expansion through Louisiana to Southeast Texas (Green Pipeline facts here), will allow us to transport natural and man made sources of CO_2 to depleted oil fields. We believe our private energy sector model will be the leader in this arena for years to come.

To this end, Denbury has initiated an ambitious feasibility study to build a 600-700 mile CO_2 pipeline from the industrial Midwest and connect it to Denbury's existing CO_2 pipeline infrastructure. The "Midwest Pipeline", preliminarily estimated at $1 billion or more, would allow the Company to expand operations and transport significant volumes of man-made CO_2 to southern oil fields. With the federal government encouraging innovative coal gasification projects through federal loan guarantee and economic stimulus programs, Denbury has entered into agreements with several project developers to purchase CO_2 from proposed gasification plants in the Midwest for transport to our southern U.S. operations. (Denbury press release here). To become a reality, many factors must come together favorably, including cost, regulatory, legal and permitting requirements and the potential consequences of pending federal climate legislation.

For more information and an introduction to our strategy see our corporate video (here).

Our Company

Based in Plano, Texas, Denbury is the largest oil and natural gas operator in Mississippi and owns the largest natural reserves of CO_2 used for tertiary oil recovery east of the Mississippi River. Denbury also operates properties in Texas, Louisiana and Alabama. The Company's goal is to increase the value of acquired properties through a combination of exploitation, drilling and proven engineering extraction practices, with its most significant emphasis relating to tertiary recovery operations.

Denbury is included in the S&P 500 Index and trades on the New York Stock Exchange under the symbol DNR.

Denbury Operations

Since we acquired our first CO_2 tertiary flood in Mississippi in 1999, we have gradually increased our emphasis on these types of operations. During this time, we have learned a considerable amount about tertiary operations and working with CO_2. Approximately 50% of our proved reserves as of December 31, 2008 are proved tertiary oil reserves. Over 50% of our forecasted 2009 production is expected to come from tertiary oil operations (on a BOE basis), and almost all of our 2009 capital expenditures are related to our current or future tertiary operations.

Generally, from East Texas to Florida, there are no known significant natural sources of CO_2 except our own (Jackson Dome). While naturally produced CO_2 drives our operations today, we are also pursuing anthropogenic (man-made) sources of CO_2 to use in future tertiary operations. We believe this will not only help us recover additional oil, but will provide an economical way to sequester large volumes of man-made CO_2. We own and operate 12 active CO_2 EOR projects and have acquired several additional old oil fields in our areas of operations with potential for tertiary recovery. Our plan is to acquire additional fields as we continue to expand our CO_2 pipeline infrastructure to transport CO_2.

Denbury Values

Hire the Best Staff

Our people are truly our most important asset. The past few years have reinforced how important our personnel are to our success and how qualified personnel shortages can be a limiting factor to rapid growth. Recently, we have been able to selectively add key personnel, and we continue to improve the training and experience of our valued operational staff.

Ethics and Integrity are Our Most Important Values

Company policy requires all employees to operate at the highest level of integrity. Our values are dependent upon the expectation that all business relationships are conducted in this manner. We do not tolerate unethical or dishonest behavior within our Company.

We are Focused on Our Primary Purpose

Denbury is a publicly traded company, and we know that our primary goal is to increase shareholder value. Our focus on achievement is based on results through careful planning and execution.

Model After the Team Concept and be a Team Player

Every decision at Denbury requires teamwork. It is at the team level where ideas are formed, decisions are discussed and solutions are presented. At Denbury, we pride ourselves on being a team-driven company as we work to enhance effectiveness, and ultimately our performance, including the way decisions are made at the top. We have an Investment Committee consisting of our four most senior executives. The Investment Committee makes or reviews all significant corporate decisions.

Be a Good Neighbor and Respect Our Environment

Denbury believes that a good relationship with landowners and within the communities where we operate is good business. We strive to go the extra mile to establish a solid working relationship with those individuals and in the areas where we conduct our operations. More than simply "doing the right thing", we listen to our constituents, and seek to anticipate issues so that we may offer solutions and options to resolve problems and minimize impacts.

Corporate Governance

The business, property and affairs of the Company are managed by the Chief Executive Officer under the direction of the Board of Directors. The Board has responsibility for establishing broad corporate policies and for overall performance and direction of the Company, but is not involved in day-to-day operations. Members of the Board are kept informed of the Company's business by participating in Board and Committee meetings, by reviewing analyses and reports sent to them regularly, and through discussions with the Chief Executive Officer and other officers of the corporation (Corporate Governance link here).

Guidelines

The Board has adopted corporate governance guidelines that address significant issues and set forth the procedures by which the Board carries out its responsibilities. Among the areas addressed by the guidelines are director qualifications and responsibilities, Board Committee responsibilities, selection and election of directors, director compensation and tenure, director orientation and continuing education, access to management and independent advisors, succession planning and management development, Board meetings, and Board and Committee performance evaluations. The Board's Nominating/Corporate Governance Committee is responsible for assessing and periodically reviewing the adequacy of these guidelines.

Denbury Resources Inc.

Subsidiaries

Denbury Gathering & Marketing, Inc.
Genesis Energy, LLC
Denbury Operating Company
Denbury Onshore, L.L.C.
Denbury Marine, L.L.C.
Tuscaloosa Royalty Fund L.L.C.
Denbury New Frontiers, L.L.C.
Denbury Green Pipeline – Texas, LLC

Code of Ethics

Denbury has established a Code of Ethics for its Chief Executive Officer and Senior Financial Officers (the "Code") to ensure the continuing integrity of financial reporting and to protect the interests of its shareholders and all those with which Denbury conducts business. The Code sets forth specific policies to guide the Company's Chief Executive Officer and Senior Financial Officers in the performance of their duties.

Denbury's Chief Executive Officer and Senior Financial Officers shall:

1) Act with honesty and integrity, avoiding actual or apparent conflicts in personal and professional relationships.

2) Provide full, fair, accurate, complete, objective, timely and understandable financial disclosures in internal reports as well as documents filed or submitted to the Securities and Exchange Commission, any other government agency or self-regulatory organization, or used in public communications.

3) Comply with applicable rules and regulations of federal, state and local governments, the Securities and Exchange Commission, the New York Stock Exchange, and other appropriate private and public regulatory agencies.

4) Be accountable for adherence to this Code and promptly report violations of this Code to Denbury's audit committee.

5) Maintain accurate financial record keeping.

6) Refrain from taking any action that fraudulently influences, coerces, manipulates, or misleads any independent public or certified accountant engaged in the performance of an audit of the financial statements of the Company for the purpose of rendering such financial statements materially misleading.

In addition, all Denbury employees must sign and comply with a Code of Business Conduct and Ethics. This sets forth the fundamental principles and key policies and procedures that govern the conduct of all officers, employees and directors of Denbury.

Equal Employment Opportunity and Non-Discrimination Policy

Equal employment opportunity benefits Denbury and its employees through the full utilization of all people. Denbury has and shall continue to recruit, hire, promote, train, transfer, discipline and make all personnel decisions without regard to race, color, religion, sex, age, disability or national origin, as well as any other category protected by applicable federal, state, or local laws. Discrimination based on any protected category is unlawful, and all persons involved in the operations of Denbury are prohibited from engaging in this type of conduct.

Company policy protects human dignity and will also protect the interests and safety of all employees and the organization. Harassment by anyone on the basis of race, color, sex, religion, national origin, ancestry, age, physical or mental disability, membership in a uniformed service, or any other protected status is strictly prohibited. It is Denbury's policy to provide its employees with a work environment that is free from all types of discrimination and harassment.

Compliance Hotline (800) 826-6762

Denbury upholds the highest standard of integrity as a company and has established an anonymous hotline for employees and business partners to report suspected unlawful, unethical conduct or criminal activity occurring within Denbury. The Company will not tolerate any form of retaliation for reports made in good faith to the hotline.

Denbury Employees

At Denbury, we know our true values are reflected in our people. We believe that our most important resource and our biggest competitive advantage is our roster of highly skilled and knowledgeable employees.

Our employees are encouraged to use their skills and creativity in their areas of expertise and thrive in an atmosphere of cooperation and respect. Our entire staff works in the spirit of teamwork and focus to develop innovative solutions that strive to exceed expectations.

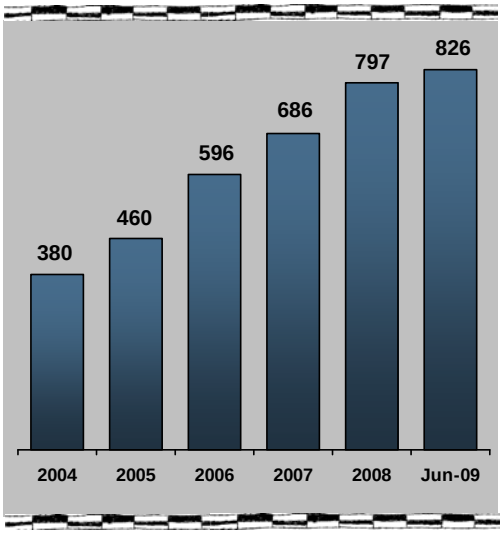
We believe in the employees expectation of an appropriate working environment, excellent work culture and competitive compensation. A culture of empowerment allows them the opportunity to practice and develop ideas for tomorrow and continue the success that is Denbury.

In short, our people work hard, enjoy their work and truly care about every aspect of our business - a synergistic relationship at its best.

Employee Count

From 2006 to June 30, 2009, we experienced a 28% increase in employee count as a testament to our thriving operations and our commitment to retaining and attracting key personnel.

As of June 30, 2009, we had 826 employees, 506 of whom were employed in field operations or field offices.



For Denbury, The Future is Now

Denbury is Already Achieving "Next Generation" Results

- The DOE/NETL report (here) estimating current CO_2 storage levels was based on projects using Water Alternating Gas (WAG) methods; Denbury uses 100% CO_2 (no water), injecting and storing almost double the CO_2 of WAG methods.
- Denbury's current CO_2 EOR projects inject from 0.52 to 0.64 metric tons of CO_2 for every recovered barrel of oil (which releases ~0.42 metric tons of CO_2), *storing* between 24% and *up to 52% more* CO_2 than the recovered oil will release when consumed.

Advancing U.S. Energy Independence

- CO_2 EOR can recover billions of barrels of identified oil from existing U.S. oilfields, and offers additional domestic production without additional exploration and development lead times.
- The environmental impact of every barrel of recovered U.S. oil could be offset by carbon capture and storage (CCS), versus no CO_2 reduction for imported oil.

Infrastructure for Future CCS Solutions

- Denbury's current and proposed CO_2 pipeline network will enable commercial-scale CCS during enhanced oil recovery and potentially in post-production utilization of underlying saline formations.
- CO_2 pipeline networks provide the basic infrastructure needed for development of carbon solutions for environmentally-sensitive industrial developments including innovative gasification projects that can produce transportation fuels, power, substitute natural gas, fertilizer and chemicals from plentiful U.S. natural resources.

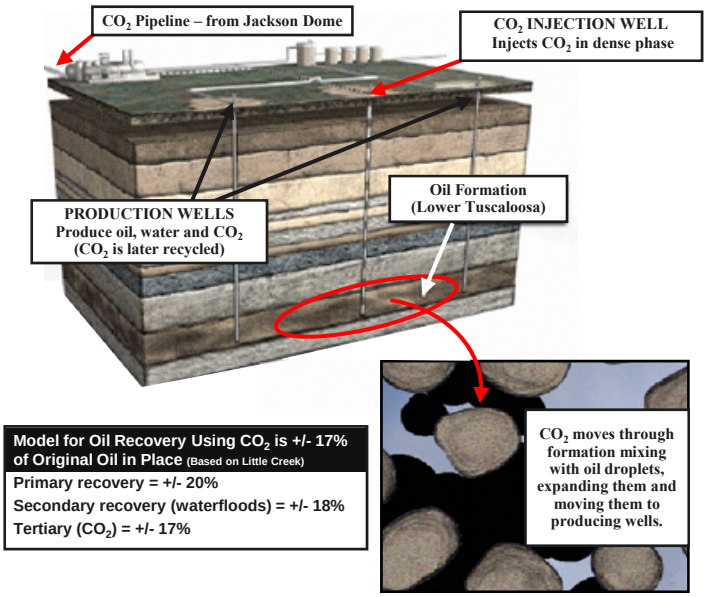
"The country has a significant, untapped win-win-win opportunity to stimulate our economy and reduce our dependence on imported oil while actually helping to protect wild places and reduce global warming pollution: a process known as carbon dioxide enhanced oil recovery (CO_2 EOR).

"To date, no significant documented environmental impacts from CO_2 injection, such as to groundwater sources, have been reported."

Source: National Resources Defense Council (NRDC)
Energy Facts – July 2008

A "Carbon Neutral" American Oil Solution

In most U.S. oilfields, about 33% of the original oil in place is recoverable through primary and secondary methods, increasing to 50-60% with CO_2 EOR.

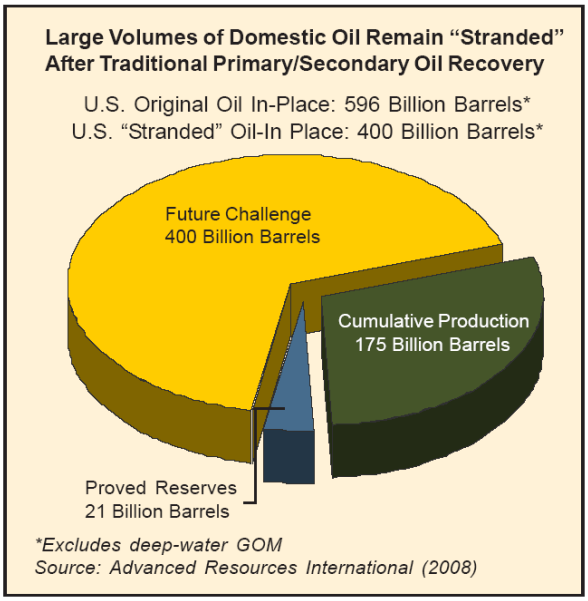


Model for Oil Recovery Using CO_2 is +/- 17% of Original Oil in Place (Based on Little Creek)
Primary recovery = +/- 20%
Secondary recovery (waterfloods) = +/- 18%
Tertiary (CO_2) = +/- 17%

The Gulf Coast Area (AL, SE TX, MS, LA)

Does not include offshore basins

- Estimated 44.4 billion barrels original oil in place
- Estimated 27.5 billion barrels are "stranded"
- Estimated up to 7 billion barrels are recoverable with CO_2 EOR



The Green Pipeline

Denbury is currently constructing a 24" pipeline from Donaldsonville, Louisiana to Hastings Field, south of Houston, Texas. The approximately 320-mile pipeline, estimated to cost a total of $825 million, is designed to transport both natural and man-made CO_2. The Green Pipeline will be one of the first pipelines designed to transport anthropogenic CO_2 in the Gulf Coast area.

Construction of the Green Pipeline

A reclaimed section of the Green Pipeline adjacent to US Hwy 190 east of Livonia, LA (approximately 30 miles WNW of Baton Rouge, LA)

Purpose of the Green Pipeline

The U.S. CO_2 pipeline network is extremely small when compared to the U.S. oil and gas pipeline system. Denbury is currently constructing the Green Pipeline to transport CO_2 from both natural and man-made sources to reenergize petroleum reservoirs. We have entered into purchase contracts with owners of potential sources of man-made CO_2 and are in various stages of discussions with several other entities. Assuming these plants are ultimately constructed, Denbury plans to use this CO_2 to recover oil that would not otherwise be produced. In addition to increased domestic oil production, our potential use of man-made CO_2 in our EOR operations, will help reduce the release of CO_2, a greenhouse gas, into the earth's atmosphere.

Benefits of Denbury's Strategy

- Our CO_2 EOR operations increase domestic oil production
- Creates jobs and improves the local economies in which we operate
- Provides a promising method to safely sequester industrial CO_2 emissions
- Helps reduce our nation's need for imported oil

Facts About the Pipeline

- Size: 24" diameter pipeline
- Length: Approximately 320 miles
- Volume: Designed to transport up to 800 million standard cubic feet per day of CO_2
- Design and Operations: The pipeline has been designed to operate under the rules and regulations of the Department of Transportation (DOT)
- Regulatory: Compliant with local, state and federal regulations; pre-pipeline construction involved approvals for wetland-delineation, habitat evaluations and culture resource studies, along with other environmental and safety statutes
- Targeted Completion Date: Louisiana to Galveston Bay in mid 2010; Galveston Bay to Hastings in late 2010

Wetland Conservation

Denbury has always taken the opportunity to avoid adverse impacts to ecologically and culturally sensitive areas. Construction methodologies and/or compensatory mitigation is provided to offset all unavoidable impacts, including replacing wetland acreage. Pipeline construction methods include alternative routing, reduction in construction width, installation of mats, push methods and horizontal directional drilling.

Routing is paramount to avoid sensitive sites and creates opportunities to utilize other ecologically sensitive construction methods. The reduction of right-of-way widths can be achieved through proper planning and by chipping woody vegetation, reducing impacts by as much as one third. The installation of mats within the working right-of-way reduces compaction and soil disturbance which facilitates post construction rehabilitation.

When conditions dictate, the "push method" of construction provides for further reduction of right-of-way width. This method of flooding the pipeline trench, fabricating the joints of pipe at a single location and pushing the pipe down the flooded ditch on floats as more pipe is attached, is capable of reducing impacts by over fifty percent.

The use of horizontal directional drilling can be used to completely avoid surface features and is a great option for archeological sites, narrow wetlands or site specific habitat concerns (i.e. denning or nesting areas). Additionally, properly installed erosion control devices are strategically positioned along the right-of-way, and these devices are maintained until the impacted area has fully recovered.

Denbury works closely under the guidelines of the U.S. Army Corps of Engineers and other federal, state and local regulators to ensure that the highest quality of compliance is achieved.

Installation of mats

Wetland Push

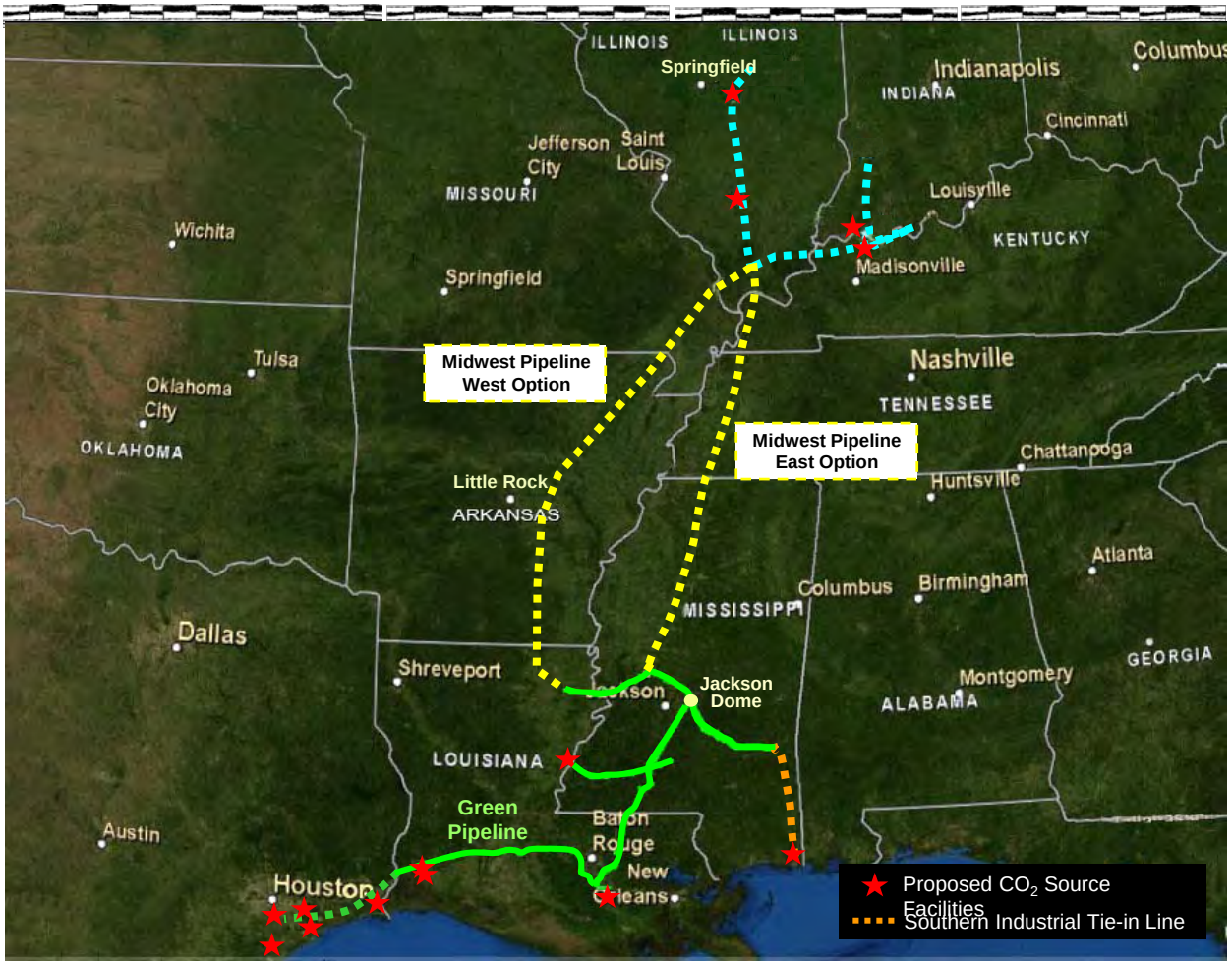
Horizontal Directional Drilling

The Midwest Pipeline Feasibility Study

Denbury initiated a study in early 2009 to evaluate the feasibility of a pipeline to transport man-made CO_2 from the Midwest U.S. south into Mississippi or Louisiana. If feasible, this project would involve 600 to 700 miles of pipeline to connect proposed gasification plants in the Midwest to Denbury's existing CO_2 pipeline network. This project alone would double the mileage of CO_2 pipelines currently owned and operated by Denbury. The study represents another significant step in Denbury's leading effort to establish the infrastructure necessary to capture man-made CO_2 in the U.S.

Key Project Developments

- Two Midwest gasification facilities, one in Indiana and one in Illinois, are advancing in the U.S. Department of Energy Loan Guarantee Program; Denbury holds CO_2 purchase contracts with both facilities
- The Illinois Department of Commerce and Economic Opportunity (DCEO) provided financial assistance to support portions of the feasibility study
- Multiple pipeline routes from the Midwest are being evaluated to ensure optimization of the environmental and landowner aspects of the project
- The pipeline design will be capable of transporting volumes up to 800 million cubic feet per day of captured man-made CO_2



Health, Safety, and the Environment

Operational Goals

Denbury is committed to continuously improving our Health, Safety and Environmental (HSE) performance by focusing on training, preparedness and has established a system of measurement to achieve superior results. Denbury has a long-standing HSE commitment to the highest standards for the health and safety of our employees, contractors, local communities, as well as the protection of the environment in which we live and work. To accomplish these goals, we believe Denbury must continuously improve the safety, well-being and development of our employees, implement the highest standards of environmental protection and ethical conduct, and work proactively to be a good corporate citizen by aligning our interests as a company with the interests in the communities in which we operate.

It is our policy to:

- Comply with all pertinent environmental and safety regulations and requirements;
- set HSE targets and goals annually to measure our performance, to achieve superior results and continually improve;
- monitor, revise and re-employ safety systems and environmental assessments on a regular basis;
- provide education and training to our employees in order for them to have the knowledge, skills, and understanding to perform their responsibilities and duties at the highest level

"Denbury has been operating over here for a number of years as an oil and gas operator. They have a very good compliance history with our rules and regulations. As the main oil and gas regulator in the state, that's what we look for in a company, a good corporate citizen. We believe they meet that definition."

Jim Welsh
Commissioner of Conservation
State of Louisiana
July 2009

HSE Key Performance Indicators

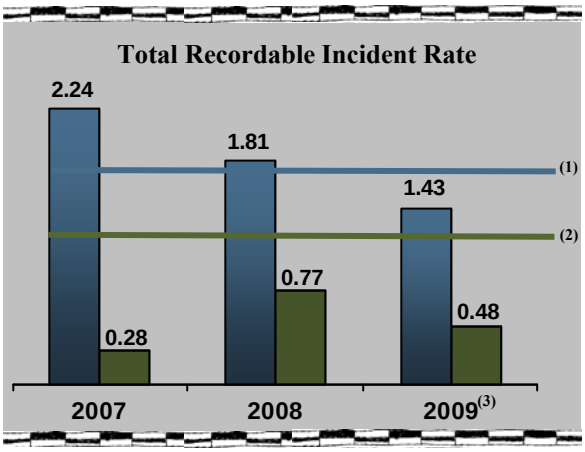
Denbury tracks four Key Performance Indicators (KPI) designed to track progress towards our Health, Safety and Environment goals. The KPI represent:

1. Safety (TRIR)
2. Spill Prevention
3. Training
4. Regulatory Compliance

These metrics are monitored continuously and communicated on a regular basis. Denbury also assesses these performance targets annually as part of our employee compensation package.

1. Safety

Through June 30, 2009, the Total Recordable Incident Rate (TRIR) for Denbury employees was the lowest measured in the last three years. This rate represents the number of Occupational Safety and Health Administration (OSHA) recordable incidents for every 200,000 hours worked. The most recently published Bureau of Labor Statistics data (2007) for the oil & gas extraction sector indicated an average of 1.70.

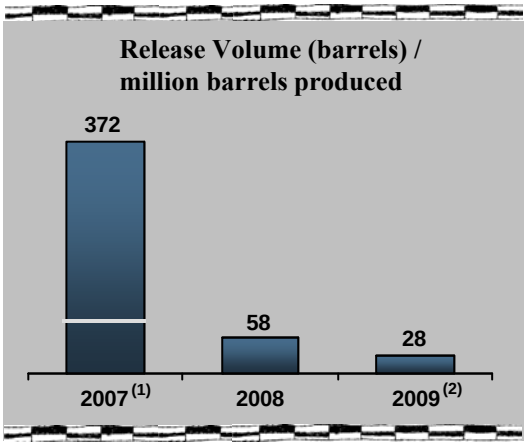


(1) 2007 BLS Industry Average (1.70) for TRIR
(2) 2007 BLS Industry Average (1.20) for lost time, restricted duty or job transfer
(3) Through June, 2009

Of these incidents, those that resulted in lost time, restricted duty, or job transfer, Denbury's rate was 0.48 compared to the latest Bureau of Labor Statistics (2007) industry average of 1.20.

2. Spill Prevention

Denbury's HSE policy is designed to reduce and prevent spills and releases in the fields in which we operate. As a direct result of new investments, improvements in our operating procedures, employee training and management supervision, Denbury's record of achievement in this area improved by 84 percent from 2007 to 2008 (32 percent excluding two large well control events at Eucutta and Smithdale Fields). We continue to see additional progress company-wide in 2009. In particular, Denbury's acquisition of the Citronelle Field in Alabama led to significant operational improvements on a property that had experienced numerous problems. The Alabama Oil & Gas Board recognized these efforts by awarding Denbury a Stewardship Award, the first of its kind to an oil and gas company by the Agency since its inception in 1945.



(1) 2007 figure includes a large accidental spill at Eucutta Field and a well control event at Smithdale Field which combined accounted for 285 bbls/mmbls produced

(2) Through June, 2009

Additionally, Denbury's professional response to the well-control event at Smithdale Field (noted above) was highlighted by EPA Region IV in a Regional Response Team meeting in February 2009. The Mississippi Department of Environmental Quality extended the invitation to Denbury to brief Federal On-Scene Coordinators, as well as emergency response officials from Region IV member states to showcase Denbury's response in this case study.

Stewardship Award - February 4, 2009

"In 2005, as operator of the Citronelle Field, Denbury developed a comprehensive plan to modernize and upgrade the operations and facilities in Citronelle Field. Denbury's plan included:

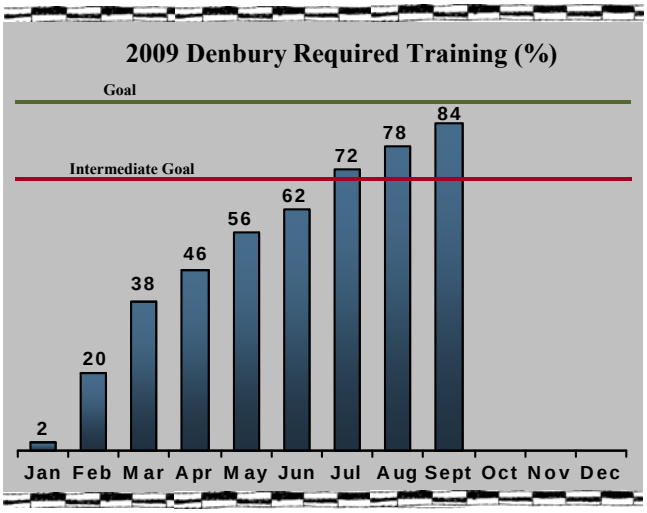
> Upgrading gathering lines, equipment, and tank battery facilities, plugging unneeded wellbores, removing unused gathering lines, testing and restoring mechanical integrity of wellbores, removing oil-contaminated soils, cleaning up tank battery sites using best management practices, remediating NORM materials, restoring inactive wells to a producing status, and maintaining full regulatory compliance for inactive wells with future utility

"By making a major financial commitment over and above that required for normal field operations, Denbury was able to accomplish this major undertaking by the end of 2008 while establishing itself as a responsible corporate citizen.

"The successful implementation of this project will undoubtedly extend the productive life of Alabama's largest oil field while protecting the public's health and safety, as well as protecting the environment. The project also serves as an excellent example of an effective partnership between a state regulatory agency and an operator that is dedicated to developing the State's oil and gas resources in a safe and prudent manner. This level of dedication and commitment by Denbury and its employees to 'go the extra mile' is greatly appreciated by the State Oil and Gas Board and its staff. The Stewardship Award presented to Denbury reflects and acknowledges our appreciation."

3. Employee Training

The success of any Health, Safety and Environment (HSE) program hinges upon an institutional commitment from our executive management and the awareness and the training of our employees. A comprehensive training program covering HSE, including job specific and productivity training, initiatives has recently been implemented company-wide. Training consists of computer-based, classroom, and field training to fully maximize technology to deliver the training program efficiently. The training program is designed to meet regulatory training requirements, provide job specific training, and enhance employee productivity and safety.



Required Training for Field Personnel

- Accident Prevention
- Asbestos Awareness
- Confined Space Entry
- Electrical Safety
- Fire
- Forklift Safety
- Hazard Communications
- Hazwoper Awareness
- Hearing Conservation
- Lockout/Tagout Authorization
- Personal Protective
- Respiratory Protection
- Safety Overview
- Small Spills
- Workplace Emergencies
- Workplace Violence

Denbury employees undergoing CPR Training

4. Regulatory Compliance

Denbury is subject to a variety of federal, state, and local HSE laws and regulations. We strive to achieve full compliance with regulatory requirements and minimize our operational "footprint" on the environment. Given the nature of acquiring older properties, we are often faced with the challenge of correcting existing adverse environmental issues while minimizing future impacts. In an effort to insure compliance, routine audits are conducted to identify and generate corrective actions.

Individual Emergency Response Plans

Denbury has a company-wide Emergency Response Plan to cover various types of emergencies including spill response, well control events, natural disasters, fire, and pandemics. Additionally, each field location has site specific emergency procedures for these events. Emergency Response Plans, Facility Response Plans, and Spill Prevention Control and Countermeasure Plans are employed at the field locations where applicable.

Heath, Safety, and Environmental Management

At Denbury, the Health, Safety, and Environmental Department is integrated into corporate and field operations. The HSE department's primary task is to manage issues once they arise and train and educate employees to reduce HSE related risks to the Company. As part of this management philosophy, the HSE department conducts routine documented audits that focus on compliance with federal, state, and local regulations, as well as Company policies and procedures. HSE initiatives are communicated to employees through new employee orientations, formal training programs, regularly scheduled safety meetings, and field visits by HSE staff.

Louisiana Black Bear – Listed as a Threatened Species under the Endangered Species Act (1992)

Protecting natural habitat requires proper planning and execution in our development plan. Denbury addresses wildlife protection, soil quality, plant species and other natural values as a part of our development, reclamation and remediation efforts.

Wetland Mitigation

Denbury takes great effort to minimize impacts to the environment. When constructing new projects, the following mitigation sequence is followed:

Avoid…Minimize…Restore…Compensate

This process starts in the very early stages of planning a project. Site selection, routing, and mitigation is included as an integral part of any project's alternative analysis. In some cases, compensatory mitigation is required. Over the last two years, Denbury has committed to preserving or restoring over 1,400 acres of wetland habitats related to various construction projects.

Pearl River Wildlife Conservation

Ross Barnett Reservoir (Northeast of Jackson, MS)

Denbury contributed $350,000 to The Foundation for Mississippi Wildlife, Fisheries and Parks in support of the Pearl River Wildlife Management Area's (PRWMA) Turcotte Wildlife Center. The donation will be used towards the construction of a training facility for State Wildlife officers as well as State provided hunting, fishing and general wildlife education for youth, especially handicapped youth groups, visiting the Turcotte Center.

Denbury also contributed approximately $150,000 to construct three handicap accessible cabins used for hunting. A 35-acre plot of scrub land surrounding the cabins was cleared and replanted with over 4,000 oak trees to enhance the wildlife habitat, and the access road leading to the cabins was greatly improved.

Denbury Beaver Pond

Denbury has donated $10,000 to transform an existing beaver pond into an extensive educational nature retreat within the Pearl and Leaf Rivers Rails-to-Trails Recreational District in Hattiesburg, MS.

Adding Environmental Value to U.S. Oil Fields

Older, depleted U.S. oil fields that we acquire often suffer from mechanical or environmental conditions that we remedy as part of our enhanced oil recovery operations. Denbury's program to rejuvenate these fields and increase oil production from marginal oil fields begins by initiating a comprehensive environmental assessment and remediation program that addresses environmental issues, equips the field with updated technology, and results in a more environmentally benign operation that is cleaner and "greener" than what existed before.

Areas of improvement that typically receive attention include: mechanical review of wellbores and surface production facilities; pressure testing of existing casing and the replacement of old tubing; installation of new wellhead equipment; installation of emission reduction equipment; installation of sound barriers, silencers and landscaping; replacement of old production flow lines with new flow lines; in some cases adding remote telemetry technology for communication and data gathering thus reducing traffic; review and address all areas of state mandated regulatory compliance.

These actions, taken together, ensures identification of any age-related problems associated with an older facility, while adding improvements through new equipment and technology to modernize the facility and prepare it for CO_2 injection.

Reactivating and increasing oil production in marginal oil fields results in increased revenue to the mineral owners, additional severance, ad valorem and sales tax revenues to state and local governments, and job growth that benefits local economies. CO_2 EOR is capital intensive and thus large sums of revenue are injected into the local and state economy.

Environmental Remediation Projects

Since 2006, Denbury has completed 31 remediation projects on various properties. Over $5 million has been spent on these projects, and Denbury dedicates part of its capital budget towards similar remediation projects each year.

These projects include waste removal, soil remediation, tank battery removal and other remediation actions to improve the older oil field facilities we have acquired.

Lockhart Crossing Field - Louisiana

Environmental and Public Enhancements

The Lockhart Crossing CO_2 EOR Facility is Denbury's "Greenest" thus far

Denbury contributes to being a good neighbor by installing noise silencers and sound barriers, building fences, improving irrigation, and planting trees at Lockhart Crossing Field

Denbury installed environmental controls including a Vapor Recovery Unit (VRU)

Cranfield Field - Mississippi

The Cranfield Facility was constructed on the same site where an old facility originally lay. Approximately 6,000 tons of concrete and 200 tons of steel rebar pipe was removed and then recycled at this location. The concrete was used for road stabilization and as surface material for the new facility.

Original concrete mound

Concrete Crusher

Rebar pipe being separated and recycled

Cranfield Facility today

Barnett Shale Salt Water Disposal Project

Denbury's Barnett Shale operations currently produce approximately 12,300 barrels of salt water per day that is untreatable for human or agricultural use and requires multiple truck trips for hauling and disposal. The Company is in the process of drilling a salt water disposal well that would take 3,000 bbls saltwater/day and inject it into the Ellenberger formation, a deep salt aquifer that is over 7,000 feet below the earth's surface. The benefit of deep injection will eliminate 23 truck loads of water being hauled away each day and the associated exhaust and fuel use. Other similar deep salt water injection wells are being considered to further reduce hauling activity.

Waste Heat Recovery

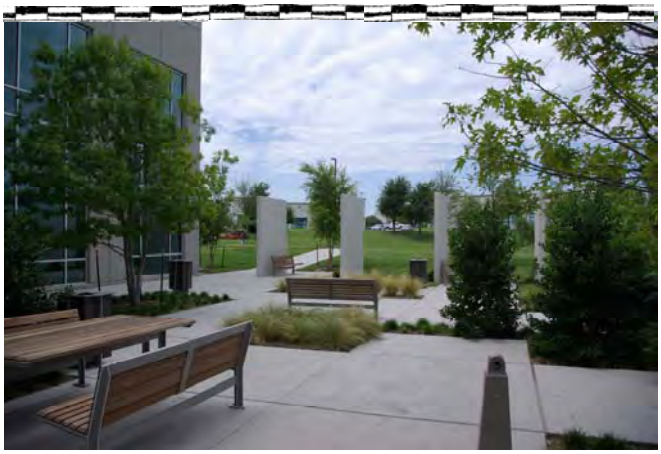
In a CO_2 flood, it is necessary to compress the CO_2 for re-injection into the formation. The compression process generates a significant amount of heat. Denbury captures the heat from the compression process to assist in the seperation of CO_2 from water and oil. Using this waste heat eliminates the need to purchase and use natural gas for our process heat requirements, thereby significantly reducing our carbon footprint.

The compression process causes the CO_2 to reach temperatures of 200 ^{o}F. After each stage of compression, the CO_2 is run through heat exchangers to heat water to 160 ^{o}F. The heated water is circulated through another heat exchanger to heat the oil, water and CO_2 to 90 ^{o}F coming from the field, which results in improved separation of the CO_2 from the oil and water for recycling. The photos below show heat exchangers in use at Denbury facilities.

Waste Heat Recovery is currently in use at Soso, Martinville, Eucutta, Heidelberg, Tinsley, Lockhart Crossing and Cranfield Fields.

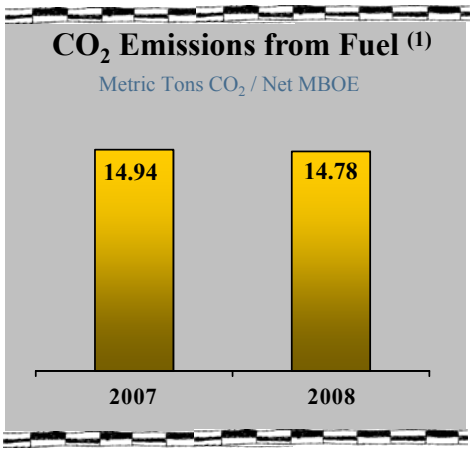
Plano, Texas – Corporate Headquarters

The expansion of our corporate offices in Plano, Texas, was completed in 2008. Our new building is LEED (Leadership in Energy and Environmental Design) certified, the national standard for an environmentally responsible and a healthy place to work.

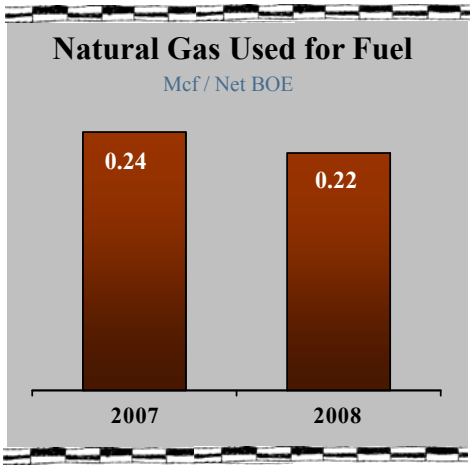


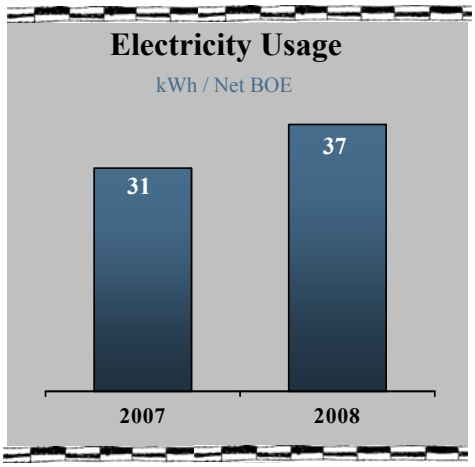
Heidelberg, Mississippi – Field Office

Heating and cooling of our Heidelberg Field office, located in Jasper County, south central Mississippi, was designed and engineered using a ground-source geothermal heat pump system. This system uses the earth as a source of heat in the winter and a source of cooling in the summer. Ground-source heat pumps have high thermal efficiencies and produce zero direct emissions. Many consider ground-source heat pumps the most energy efficient, environmentally clean, and cost effective air conditioning systems available. All supply and return air ducts are separately filtered, maintaining a higher degree of indoor air quality.



(1) The CO_2 emissions from fuel is estimated based on fuel combustion. Denbury is currently conducting a more comprehensive greenhouse gas inventory following the API Compendium for estimating greenhouse gases. A more detailed summary of this emissions inventory will be forthcoming in the next report (June 30, 2010).





Summerland Field – Mississippi

Denbury Hosting Geothermal Technology Study

Denbury is participating in a study of the effectiveness of generating electricity from geothermal heat supplied by produced hot water. Most U.S. domestic oil wells produce significant quantities of unusable water associated with oil production. In this test, Gulf Coast Green Energy will install demonstration technology on one of Denbury's wells to produce 50 KW of electricity from 4,000 barrels of produced water per day that is approximately 200 °F when it reaches the surface. The machine works by using the geothermal heat from the water to drive a small generator via a turbo expander. If the idea is successful, it would save approximately $3,600 per month in electricity purchases and would pay for the installation and cost of the machine in three years.

Iberia Field - Louisiana

Solar Powered Injection Pumps

Denbury's Iberia Field has been selected as a trial site to test a new line of solar powered pumps built by Wellmark Company LLC. The pumps are used in a corrosion prevention process at the wellhead. This Solar System replaces natural gas fueled pumps thus reducing emissions (saving approximately 274 mcf/year per pump). The pump efficiency and overall effectiveness will be monitored during the trial period. This solar option provides an environmentally friendly benefit and operating cost reduction.

Charitable Contributions

Our employees are encouraged to give generously to charitable organizations and educational institutions of their choice with Denbury supporting their efforts through a matching gifts program.

Denbury and its employees have recently participated in various fundraising programs such as donations to the Salvation Army Christmas Angels, North Texas Food Bank and Susan B. Anthony Golf Tournament.

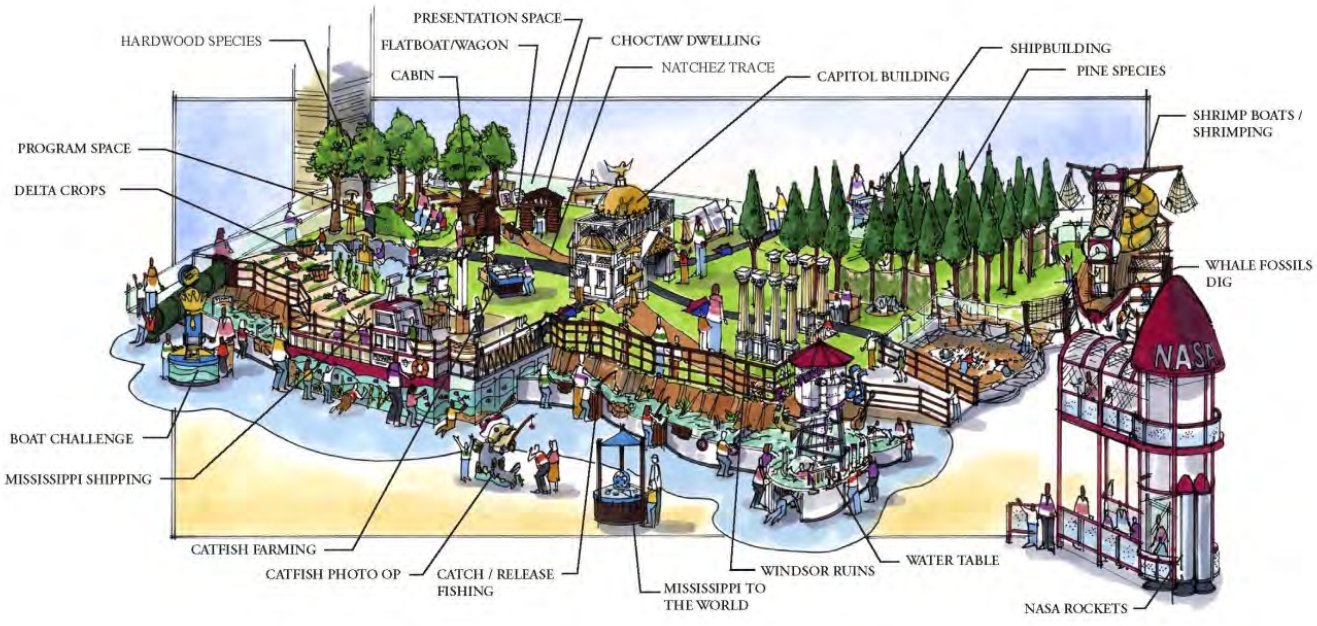
Mississippi Children's Museum

The Mississippi Children's Museum, operational in 2010, will be located in Jackson, MS. The Museum's feature exhibit is the Mississippi climbing exhibit which includes an underground exhibit with various interactive geological experiences including the underground volcano that is believed to be the source of CO_2 at Jackson Dome. The Museum's board has raised almost $22 million of the $24.5 million budget. Denbury has committed to match charitable donations on behalf of its interest owners, vendors and business partners in Mississippi up to $125,000 with a goal of generating $250,000 in donations to the Museum from our efforts.

www.mississippichildrensmuseum.com

In addition to the above mentioned contributions, Denbury and its employees contributed more than $385,000 to over 100 charitable organizations and educational institutions in 2008.

Illustration of Mississippi Children's Museum



Volunteer Activities

Mississippi Multiple Sclerosis (MS) Society Bike Tour

Denbury has been a sponsor of the MS150 Bike Tour in Mississippi for the past five years, two of which were as title sponsor. In 2008, Denbury, its employees and business partners, raised approximately $155,000 during the October MS Bike Tour in Mississippi. We had 25 Denbury employees join the ride and 15 Denbury volunteers support the two day tour.

In 2009, Denbury will continue its matching charitable grant program for employees who wish to give personal funds to the MS Society or through the MS 150 Bike tour. To further our commitment to support multiple sclerosis research activity, Denbury has made a $25,000 corporate contribution to the University of Mississippi Medical Center's "Multiple Sclerosis Endowment Fund". This fund provides research funding and support for doctors and students attending the University of Mississippi Medical Center.

Education

An educational assistance program is provided by Denbury to help employees obtain additional education or training to increase their competence in their present job and to prepare for advancement within Denbury. For regular, full-time employees with one or more years of employment at Denbury, the Company will reimburse 80% of the cost of tuition, enrollment fees, and books for courses which employees take at a recognized college or university.

Internship Program

Each year, Denbury selects college students from various universities to participate in our CO_2 EOR program. Our goal is to share CO_2 EOR operational knowledge as well as our culture and work environment with student interns with the objective of attracting and employing qualified candidates at Denbury upon graduation. This summer, Denbury assigned 13 interns (six of which are international students) represented by five universities to projects relating to petroleum operations, reservoir engineering, geology, accounting, supply chain management and human resources. Each student was teamed with a mentor and given the opportunity to take a trip to the field to see CO_2 EOR operations first hand. Upon the completion of their assignment, the interns gave a presentation to their respective departments describing the details of their assignment, ultimate results and suggestions for improvement.

COLORADO SCHOOL OF MINES
EARTH • ENERGY • ENVIRONMENT

LSU

TEXAS TECH UNIVERSITY

Colorado School of Mines Project

Denbury's Delhi Field was selected as the next two-year research program for the Colorado School of Mines Reservoir Characterization Project. The RCP is an independently sponsored research consortium which fosters industry and university interaction to provide cost effective, collaborative research. This project will train students for employment in the oil and gas industry as well as help Denbury in optimizing and managing CO_2 floods for years to come.

Department of Energy Projects

Little Creek Field - Mississippi

DOE # DE-PS26-05NT15600-2B

Using bacteria to produce more oil after traditional drilling methods have been exhausted is the subject of a research project involving Denbury and Mississippi State University. The $1.5 million grant to test a technique called Microbial Permeability Profile Modification helps make existing bacteria grow which plug up flow channels thus re-directing CO_2 to other areas of the reservoir to recover additional volumes of oil. This technique provides nutrients by alternating concentrated phosphate and nitrate injections with normal CO_2 injections.

Soso Field - Mississippi

DOE # DE-FC26-04NT15536

Louisiana State University and Denbury are involved in a DOE sponsored reservoir study to quantify bypassed oil in a CO_2 flood using carbon-oxygen and pulsed neutron logs. The goal of the project is to determine true oil saturation in a CO_2 flooded zone. Near wellbore oil saturation determination in a CO_2 flood requires that the evaluation technique differentiate oil from CO_2 in the reservoir especially when CO_2 is miscible with the oil. This technique can be used on wells where no baseline cased-hole logs have been run.

Cranfield Field - Mississippi

DOE # DE-FC26-05NT42590

The University of Texas and the Bureau of Economic Geology (BEG) are involved with Denbury in an 18 month project of sustained injection of CO_2 at a rate of 1 million metric tons per year focusing on high volume injection into salt water intervals below the oil-water contact. The project intends to measure sweep efficiency, quantify the relationship between injection rate and pressure and document that the CO_2 is retained within the target zone with no risk of leakage to groundwater or atmosphere. (BEG link here)

This work is being performed by the BEG Gulf Coast Carbon Center (GCCC) in conjunction with the Southeast Regional Carbon Sequestration Partnership (SECARB) with support from the DOE. In addition to the above, sponsoring organizations include Denbury Resources, Sandia Technologies LLC, Schlumberger Carbon Services, Lawrence Berkeley National Lab, Lawrence Livermore National Labs and Promore, the University of Mississippi and Mississippi State University.

Drilling rig in position at F-2, Cranfield Field, Mississippi.
Source: Bureau of Economic Geology

Department of Energy Projects

Citronelle Field - Alabama

"CO_2 Enhanced Oil Recovery in the Rodessa Formation"
DOE # DE-FC26-06NT43029

This project is a cooperative agreement with the DOE National Energy Technology Laboratory (NETL) to evaluate the potential for CO_2 EOR and CO_2 sequestration in Citronelle Oil Field. The entire project consists of three stages, each lasting 20 months. Stage I (Jan 1, 2007 thru Aug 31, 2008) has been completed. It consisted of selection of the test site, a detailed geological study, determination of the oil/CO_2 minimum miscibility pressure, a CO_2 simulation, and establishment of background conditions at the site. Stage II (Sept 1, 2008 thru April 30, 2010) is in progress. It consists of the first CO_2 injection of 7,500 tons, and associated measuring and monitoring. Stage III (May 1, 2010 thru Dec 31, 2011) will consist of the second CO_2 injection of 7,500 tons, and associated measuring and monitoring.

Sponsoring organizations, in addition to the DOE, are Alabama A&M University, Denbury Resources, the Geological Survey of Alabama, Southern Company Services, Inc, the University of Alabama, the University of Alabama at Birmingham, and the University of North Carolina at Charlotte.

"The oil and gas industry has over 35 years of continuously developing experience in transporting and injecting CO_2 for enhanced oil recovery (EOR). While constantly evolving, the technology operating experience, and regulatory requirements that have been developed for EOR are extensive. In the United States alone, the oil and gas industry operates over 13,000 CO_2 EOR wells, over 3,500 miles of high pressure CO_2 pipelines, has injected over 600 million tons of CO_2 (11 trillion standard cubic feet) and produces about 245,000 barrels of oil per day from CO_2 EOR projects."

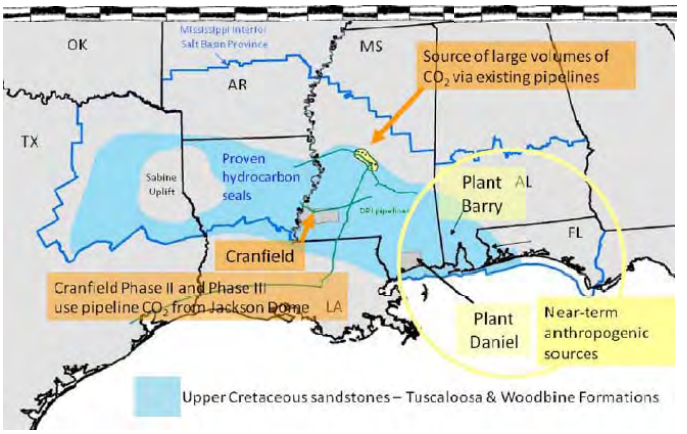
Prepared for the American Petroleum Institute (API)
Summary of Carbon Dioxide Enhanced Oil Recovery (CO_2 EOR) Injection Well Technology
James P. Meyer PhD
September 2007

Citronelle Field - Alabama

Proposed "SECARB Phase III Anthropogenic Test"

Denbury is participating in the early planning stages of a project to inject CO_2 into a saline formation and to monitor CO_2 containment. The Southern Company will design, build and operate a carbon capture and separation unit at Alabama Power Company's Plant Barry, near Bucks, Alabama, which is approximately 12 miles from the Southeast Citronelle Unit. The project will be capable of capturing approximately 125,000 metric tons of anthropogenic CO_2 per year. A pipeline will be constructed from Plant Barry to Denbury's Southeast Citronelle Unit, and the CO_2 will be injected into saline Paluxy sandstones at depths of approximately 10,000 feet. These sandstones are separated from the deeper Rodessa oil reservoir by the impermeable Ferry Lake Anhydrite. One new injection well and one new monitoring well are planned. Injection will continue for four years at a rate of 125,000 tons per year. After cessation of injection, the sequestered CO_2 will be monitored for an additional four years in order to determine how well the CO_2 has been contained.

The Southeast Regional Carbon Sequestration Partnership (SECARB), The Southern Company, Denbury Resources, the Alabama Geological Survey, Advanced Resources International Inc, Electric Power Research Institute (EPRI), and the University of Alabama at Birmingham are potential partners in this proposed Phase III anthropogenic CO_2 sequestration test in cooperation with the DOE National Energy Technology Laboratory.



Source: Southeast Regional Carbon Sequestration Partnership (SECARB)

ENVIRONMENTAL INFORMATION VOLUME

For

Denbury Onshore, LLC
CO_2 Sequestration Monitoring, Verification, and Accounting
Hastings Field, Texas

By

Steve Walden Consulting

&

RDB Environmental Consulting

March 1, 2010

TABLE OF CONTENTS

1.0 SUMMARY 1

2.0 PROPOSED PROJECT AND ITS ALTERNATIVES 2
2.1 Proposed Project 2
2.2 Alternatives to Proposed Action 13
2.2.1 "No Action" Alternative 13
2.2.2 Different MVA Site Alternatives 14
2.2.3 Alternate MVA Technologies 14

3.0 EXISTING ENVIRONMENT 14
3.1 Land Use 14
3.2 Atmospheric Conditions/Air Quality 16
3.3 Hydrologic Conditions/Water Quality 17
3.4 Geologic/Soil Conditions 22
3.5 Vegetation and Wildlife Conditions 23
3.6 Socioeconomic Conditions 26
3.7 Historic/Cultural Resources 26
3.8 Visual Resources 28
3.9 Health and Safety Factors 28

4.0 ENVIRONMENTAL IMPACTS OF THE WORK TO BE PERFORMED 28
4.1 Land Use 29
4.2 Air Quality Impacts 29
4.3 Hydrological Conditions/Water Quality 29
4.4 Geologic/Soil Conditions 30
4.5 Vegetation and Wildlife Resources 30
4.6 Socioeconomic Conditions 31
4.7 Historic/Cultural Resources 31
4.8 Visual Resources 31
4.9 Health and Safety Factors 31
4.10 Solid and Hazardous Wastes 32
4.11 Impacts on Regional or Local Plans 32
4.12 Mitigation Measures 33

5.0 POTENTIAL LIABILITY TO DOE OF EXISITNG CONDITIONS AT THE SITE(S). 33

6.0 ABILITY TO MEET COMPLIANCE REQUIREMENTS AT THE SITE(S). 33

7.0 EXPERIENCE AND APPROACH TO THE IDENTIFICATION AND RESOLUTION OF ENVIRONMENTAL ISSUES. 34

8.0 REFERENCES 35

LIST OF ATTACHMENTS 39

Attachment 3.1.1 - Denbury Onshore, LLC Pipeline Distribution Maps

Attachment 3.2.1 - Air Quality Monitoring Data

Attachment 3.3.1- Listing of Public Water System Wells

Attachment 3.4.1- Detailed Soil Type Descriptions

Attachment 3.5.1- Listing of State and Federal Rare, Threatened, and Endangered Species

Attachment 7.1- Qualifications of Key Team Members

ENVIRONMENTAL INFORMATION VOLUME
March 1, 2010

Denbury Onshore LLC
CO_2 Sequestration Monitoring, Verification, and Accounting
Hastings Field, Texas

1.0 SUMMARY

This section shall contain a succinct summary of the proposed project and its potential environmental, safety, health, and socioeconomic impacts. A brief description of any construction and operation activities, including the duration and schedule shall also be provided. The summary shall focus on both beneficial and detrimental impacts, as well as any major risks associated with constructing, operating, maintaining, and dismantling/disposing of the proposed test facility, if applicable.

This Environmental Information Volume (EIV) has been prepared to compile information required by the National Environmental Policy Act (NEPA) to evaluate the potential for adverse environmental, ecological, cultural, and socioeconomic impacts of the proposed Denbury monitoring, verification, and accounting (MVA) activities in the Hastings Field, Brazoria County, Texas. The proposed action is seeking U.S. Department of Energy (DOE) funding to conduct scientific research MVA activities to determine the effectiveness of enhanced oil recovery (EOR) for long-term geologic storage of anthropogenic carbon dioxide (CO_2).

The research MVA activities will supplement privately-funded, on-going monitoring activities conducted in conjunction with Denbury's commercial EOR operations. While the overall extent of the Hastings Oil Field is approximately 25 square miles, the research MVA activities will only be performed on a site that is less than 4 square miles located between Alvin and Pearland, Texas on State Highway 35. Only the research MVA activities are subject to NEPA review and will be considered in this EIV. The following MVA activities will be conducted:

- ***Well Integrity Testing*** – Logging of existing idle production wells and testing of plugged and abandoned (P&A) well to detect CO_2 migration through non-sealing well bores.
- ***Flood Conformance Testing*** – Augmentation of measurements to observe and model movement of CO_2 in subsurface formations during the EOR flood operations.
- ***Above-Zone Monitoring*** – Monitoring of pressures and geochemical parameters in the formations above the confining layer to detect CO_2 migration beyond the injection zone.

Research MVA activities will be conducted on a periodic or continual basis during active commercial EOR flood operations from 2012 through 2015.

In most cases, MVA activities will be conducted in or around existing Denbury idle or plugged and abandoned (P&A) wells. Any new wells drilled for groundwater monitoring or soil-gas testing will be shallow and require only temporary placement and use of drilling equipment. Seismic profiles will be conducted with minimal surface disturbance and/or downhole equipment in existing wells. Above-zone testing will be conducted in selected idle wells that will be plugged back to above the confining layer to minimize potential impacts. If new wells are required, drilling will be performed at existing well pads, if at all possible. As a result of these

measures, potential environmental, ecological, and cultural impacts will be minimized or eliminated. Socioeconomic impacts of the MVA activities will be insignificant. However, significant benefits to the local economy may result from the increased production from the EOR activities at the Hasting Oil Field and its potential as a long-term anthropogenic CO_2 storage repository.

2.0 PROPOSED PROJECT AND ITS ALTERNATIVES

2.1 Proposed Project

This section shall discuss the objectives of the proposed project, and shall describe the proposed site, system, and/or process. It shall also describe the work to be performed, the schedule, associated requirements (e.g., land, natural resources), and any changes that will be necessary to the existing site, system, or process. The description shall include a project site plan and topographic map of the area. Any offsite facility requirements shall also be identified in this section.

The concentration of CO_2 in the atmosphere has increased 17.4 percent over the past 60 years (Keeling and Whorf, 2002). The Intergovernmental Panel on Climate Change (2001) has concluded that these changes result principally from accumulation of anthropogenic CO_2 emitted to the atmosphere as a result of changing land use patterns and combustion of fossil fuels, such as coal, oil, and natural gas, to produce energy. Predictions of global energy use in the next century suggest that anthropogenic carbon emissions will continue to increase, resulting in continued rising atmospheric concentrations of CO_2 unless major changes are made in the way we produce and use energy (U.S. Department of Energy, 1999, p 1-1).

Uncertainty remains in predicting the effects of this change in composition of the atmosphere. However, there is significant risk that continued increase in atmospheric concentrations could force changes in global climate, which may have a variety of serious consequences (see U.S. Climate Change Science Program / U.S. Global Change Research [2003] http://www.usgcrp.gov/usgcrp/nacc/education/default.htm for regional summaries or the Intergovernmental Panel on Climate Change http://www.ipcc.ch/ [2003]).

DOE has prepared several documents that consider U.S. energy policy and the options that can be evaluated in response to concerns over the impact of anthropogenic CO_2 releases on climate change. The National Energy Policy Development Group (2001) considered a broad spectrum of energy issues, and in chapter 3 (Protecting America's Environment) states that "Industry and the federal government are researching various new technologies that will reduce greenhouse gas emissions or sequester those emissions, in geologic formations, oceans, and elsewhere." The U.S. Department of Energy (1999) document "Carbon Sequestration" provides a detailed assessment of the role of carbon sequestration in reducing anthropogenic CO_2 emissions. Three categories of technologically driven solutions are proposed: (1) energy conservation and efficiency; (2) substituting lower carbon or carbon-free energy sources for current sources, for example switching to renewable energy sources, nuclear power, and low-carbon fuels; and (3) carbon sequestration, which removes CO_2 from combustion emissions and stores it directly within a geological formation or in the deep ocean or in directly by enhanced uptake by soils, vegetation, and the oceans.

The purpose of the proposed action is to test the application of carbon sequestration within a geologic formation concurrent with EOR. Specifically, additional research-oriented monitoring, verification, and accounting (MVA) activities will be conducted on CO_2-based EOR operations by Denbury Onshore LLC at a site in the Hastings Oil Field to further demonstrate the safety and effectiveness of long-term geologic storage of anthropogenic CO_2. While on-going monitoring will include both commercial and research monitoring activities, only the research MVA activities will be federally funded and subject to NEPA review. Commercial monitoring is linked to effective "best practices" procedures for an effective EOR CO_2 flood and to meet current regulatory requirements. The commercial EOR flood and related monitoring will occur independent of federal funding and thus are not be considered in the impact analysis of this EIV.

While the overall extent of the Hastings Oil Field consists of approximately 25 square miles of rural farmlands, suburban areas and residential neighborhoods, the proposed project area is less than 4 square miles located between Alvin and Pearland, Texas on State Highway 35. The Hastings Oil Field has been in production since 1934, thus reducing the likelihood that neighboring communities would see this proposed enhanced monitoring action as anything but helpful. Denbury is currently drilling and/or reworking a large number of wells in the Hastings Field that will be used for injection of CO_2, production of oil and gas, testing, water production, and brine disposal. All activities related to the commercial operations at the Hastings project site will be permitted by the Texas Railroad Commission and implemented for Denbury's EOR operations. Again, EOR activities and associated monitoring will be completed by Denbury regardless of the implementation of the research MVA activities.

In addition to Denbury's offer of data from their regulatory and best practices monitoring, they have also agreed to a) back plug selected wells for above-zone monitoring, b) the use of selected idle wells for supplemental logging and testing, and c) allow access to specific surface locations sites in the Hastings Field for drilling and testing of groundwater and soil-gas wells and seismic tests. Hence this MVA project offers a tremendous opportunity to highly leverage ongoing commercial activities.

The following figures are maps of the location and significant features in and around the project area:

- **Figure 2.1** - Topographic Map
- **Figure 2.2** - Aerial View (Google Map)
- **Figure 2.3** - Site Plan (with locations of existing active, inactive, plugged & abandoned, and temporarily abandoned wells)

The research MVA program will focus on areas of uncertainty in retention of CO_2 fluids in the injection zone. As these oil fields have retained oil and gas for geologic time, they have demonstrated that effective natural seals exist to support long-term retention of a significant CO_2 column.

The research MVA objectives will focus on potential migration pathways to reduce the uncertainties regarding the retention of fluids in the injection zone. Potential pathways include ***(1) non-sealing well completions; (2) vertical migration up faults when reservoir pressure exceeds original pressure; and 3) off-structure or out-of-compartment migration of CO_2 or***

brine as a result of elevated pressure into areas not controlled as part of the flood.

Figure 2.1
Topographic Map of Hastings MVA Project Area
Brazoria County, Texas

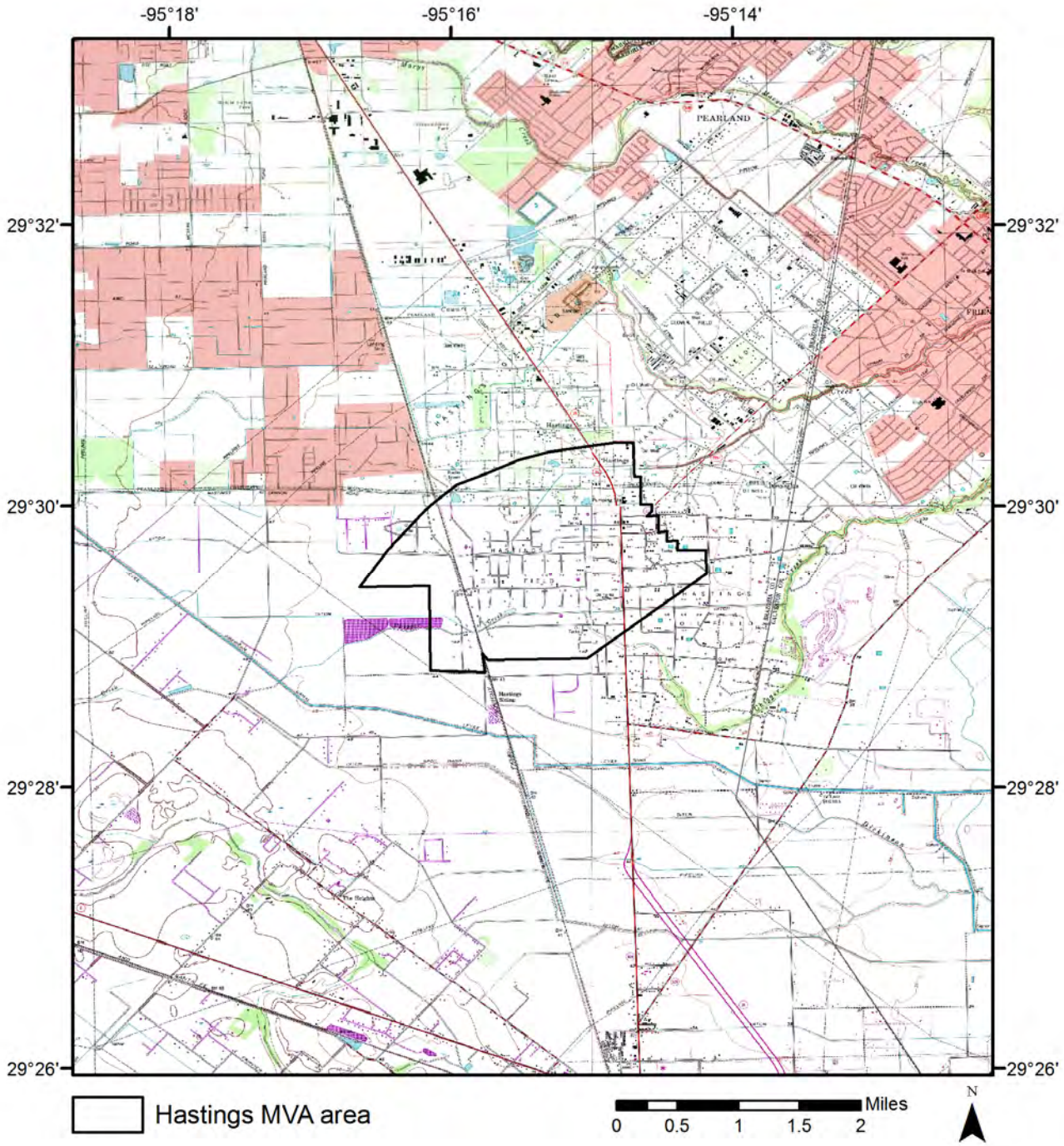


Figure 2.2
Aerial (Google Earth) Map of Hastings MVA Project Area
Brazoria County, Texas

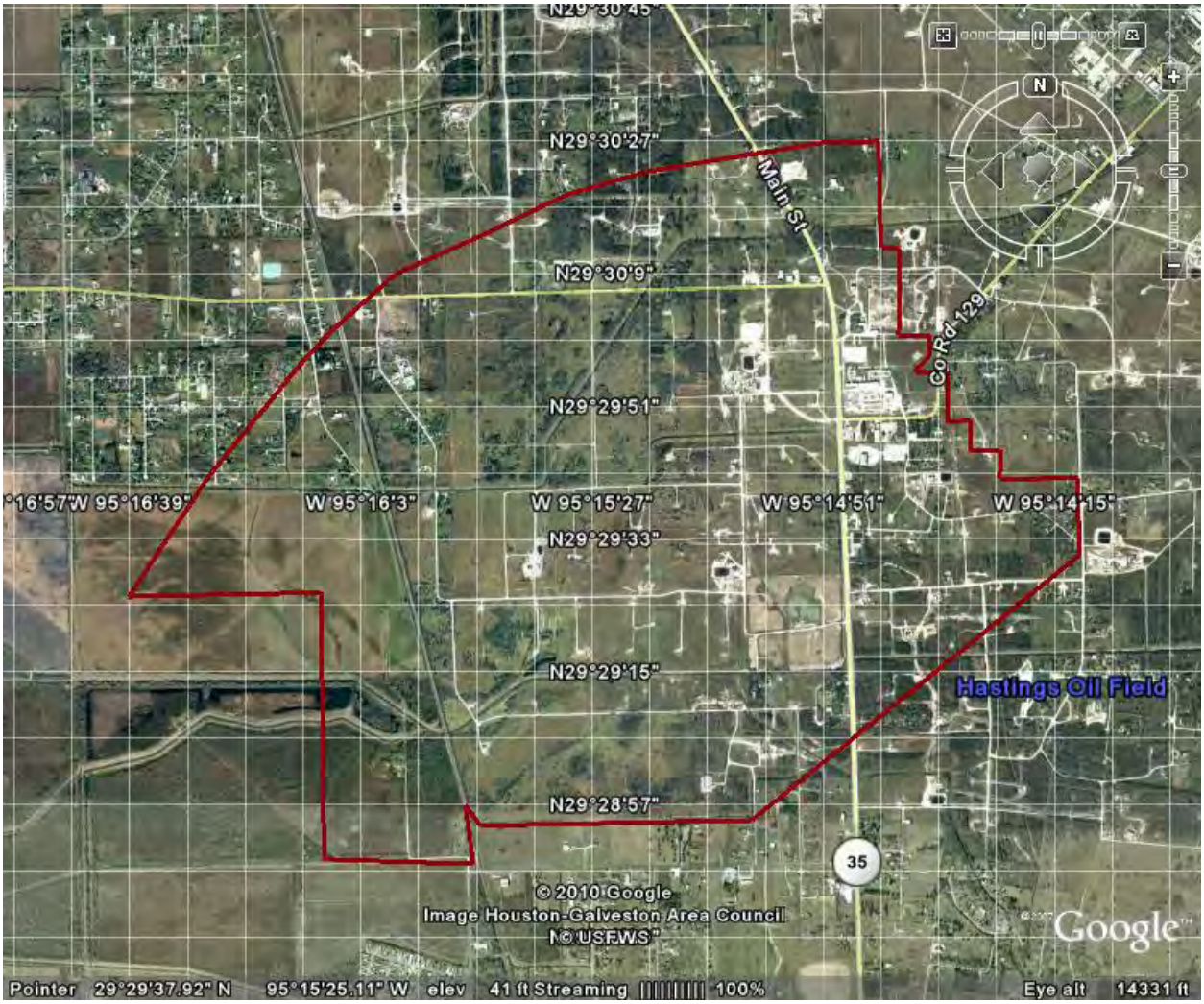
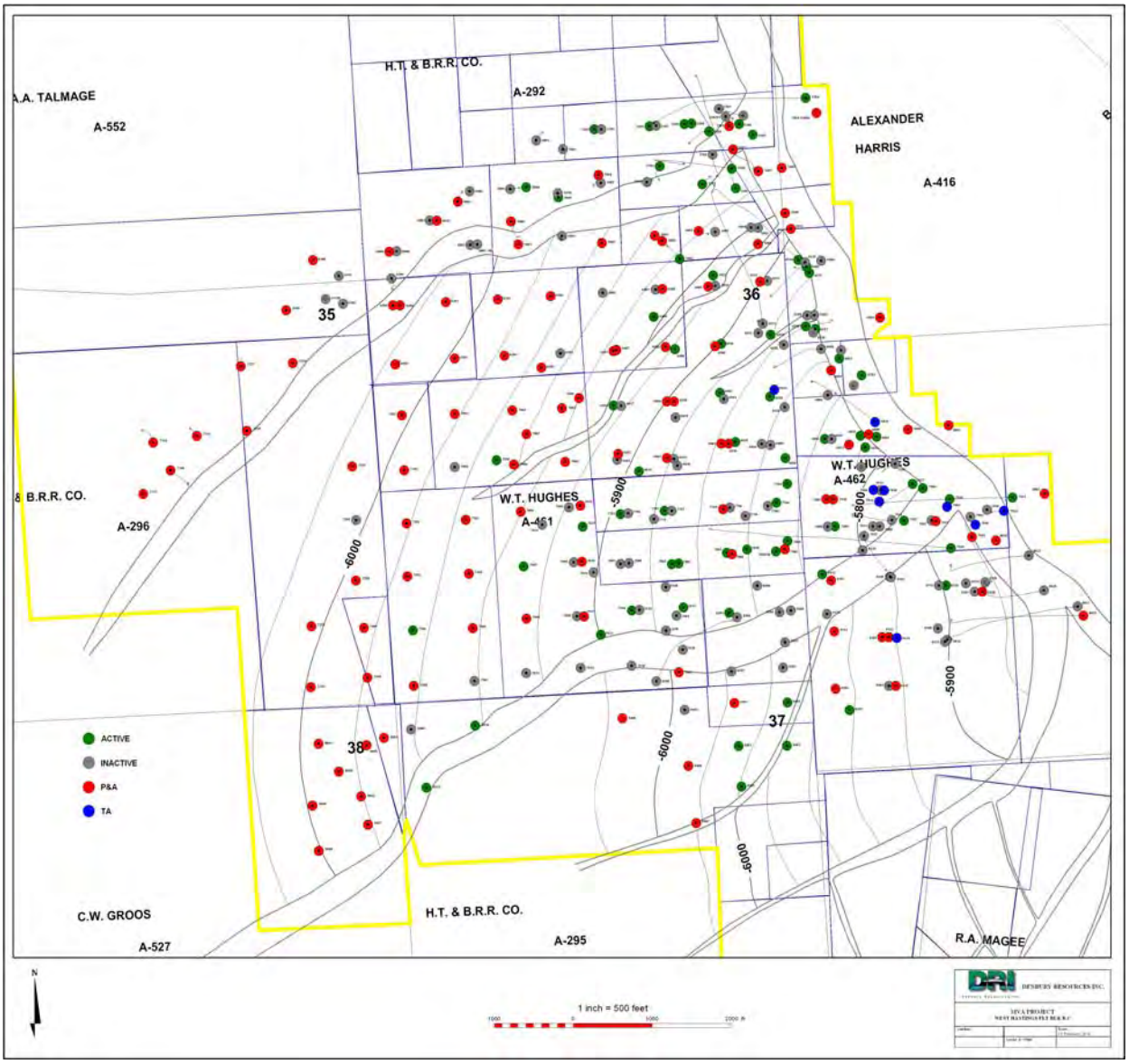


Figure 2.3
Site Plan of Hastings MVA Project Area
Brazoria County, Texas



The following MVA program has been designed to verify and assess the likelihood that the injected CO_2 is permanently stored.

Well Integrity Testing

The research MVA activities will supplement the commercial well integrity program and test the effectiveness of the commercial EOR activities in preventing CO_2 migration through non-sealing active and plugged and abandoned (P&A) wells. Activities include:

1) Logging of Idle Wells – A select number (2 – 10) idle wells within the project area will be subject to additional wireline wellbore integrity logs (temperature, noise, CBL, USIT, RAT) or other techniques to verify adequate performance. To be completed in 2014-2015.

2) Soil Gas/Casing Head Gas Testing of P&A Wells – Soil gas monitoring using numerous shallow (20 ft) small diameter boreholes below the active soil zone will be conducted near a select number (2 – 10) of P&A wells within the project area. To be completed in 2012-2015.

3) Groundwater Testing of P&A Wells – Groundwater monitoring will be conducted in existing or new shallow (100 ft depth) freshwater wells near a select number (3 – 10) of P&A wells within the project area and several in up-gradient and down-gradient (off pattern) locations. To be completed in 2012-2015.

4) Tracer Testing of P&A Wells – Denbury is evaluating the possible use of Awardee's proprietary technology in the area of tracer testing as method of tracking injected CO_2. In the event that Denbury decides to include such tracer testing in the MVA, tracers may be added to the injected CO_2 and monitored in soil gas and groundwater wells. To be completed in 2014-2015.

Flood Conformance Testing

The research MVA activities will augment the measurement of the injection zone through several different techniques to model and observe the movement of CO_2 in the subsurface formations during the flood operation. Activities include:

1) Reservoir Modeling – Available data from Denbury will be used to develop a reservoir simulation that will model the plume size. The model will be evaluated and calibrated using observed monitored data. Completion dates are not yet specified.

2) Vertical Seismic Profile (VSP) – Annual VSP surveys will be conducted of the project site. This technique uses seismic receivers temporarily located in existing boreholes and on the surface. Three 3D VSPs are proposed to document the maximum lateral extent of the plume. To be completed in 2013-2015.

3) Gravity Monitoring – Surface and borehole gravity monitoring will be conducted approximately 3-4 times per year. Several hundred permanent monuments (up to 500 12-inch round concrete monuments buried 2 feet in the ground) will be installed for surface equipment which will be deployed for 2 – 20 minutes at each site. Additionally, wire line trucks will be

used to lower monitoring equipment down several of Denbury's existing boreholes to monitor subsurface conditions. To be completed in 2013-2015.

4) Bottom Hole Pressure Testing – Real-time bottom hole pressure measurements will be conducted in selected existing wells and/or in one or more future injectors wells drilled by Denbury in off-structure areas. To be completed in 2014-2015.

5) Tracer Testing of Production Wells – Denbury is evaluating the possible use of Awardee's proprietary technology in the area of tracer testing as method of tracking injected CO_2. In the event that Denbury decides to include such tracer testing in the MVA, active oil production wells will be monitored to detect tracers added to the injected CO_2 to further document plume movement. Completion dates are not yet specified.

6) Geochemical Testing of Production Wells – Active oil production wells will be monitored to detect natural geochemical tracers. Completion dates are not yet specified.

Above-Zone Monitoring

The research MVA activities will measure the pressure profiles and geochemistry of the zone above the injection zone to detect indications that CO_2 is migrating past the confining layer as a result of the flood operation. Activities include:

1) Current Pressure Profile – A profile of the current pressures above the injection zone will be established in a selected number (2 – 4) of new wells being drilled by Denbury for future injection or production or in existing wells that are perforated at an appropriate interval. To be completed in 2013.

2) Pressure Testing – On-going monitoring of the pressures above the injection zone will be performed in a select number (2 – 8) of idle wells that have been plugged back and converted into monitoring wells by perforation at the appropriate interval. To be completed in 2013.

3) Geochemical Testing – On-going sampling of geochemical parameters above the injection zone will be performed in a select number the wells to be used for above zone pressure testing. Sampling will be conducted if pressure anomalies are observed. To be completed in 2013.

Table 2.1 shows the commercial monitoring activities performed by Denbury and those performed as part of the research MVA program for the Hastings MVA project:

Table 2.1
Monitoring Activities at Hasting EOR Project

Denbury Commercial Monitoring Activities	*Research MVA Activities
Integrity Testing	
Normal well review and remediation as needed prior to flood	Additional surveillance of idle wells via logging
Normal well surveillance and remediation procedure for active wells	Surveillance of P&A wells via soil gas/casing head gas
Normal well surveillance and remediation	Surveillance of P&A wells via Seeper trace**

Denbury Commercial Monitoring Activities	*Research MVA Activities
procedure for P&A wells (volumetric balance)	
Learning from experience in block A, and from well remediation in B&C	Surveillance of P&A wells (groundwater monitoring plan via shallow (100 ft) freshwater wells, up-gradient & down-gradient)
Additional surveillance of idle wells via logging	
Surveillance of P&A wells via soil gas/casing head gas	
Surveillance of P&A wells (Available or planned Denbury-owned water wells)	
Surveillance of P&A wells (If no wells available, drill and complete 100 ft water sampling wells, plan and depth to groundwater)	
Flood Conformance	
Reservoir characterization	DOE style reservoir modeling to confirm plume size
Normal Denbury approach to monitoring flood, including daily pressure at well head, injection profiles, monitoring producer fluids at least monthly at test plant.	Augmented measures of conformance - Annual VSP plan for blocks B&C
Normal Denbury approach to mitigation, e.g. if a well will not take the planned rate, acidize, reperforate, or inject at a higher rate in other parts of pattern.	Augmented measures of conformance - Surface & borehole gravity monitoring 3-4 times per year, Gravity plan for B&C
	Augmented measures of conformance - repeat 3-D seismic profiling.
	Augmented measures of conformance - Real time tubing pressure/increased intermittent memory gauge pressure.
	Augmented measures of conformance - Introduced tracers collected at wellhead
	Augmented measures of conformance - Natural geochemical tracers collected at wellhead
	Match predictive model to observed monitoring data
Above-Zone Monitoring	
Identify idle or reentered wells that could be sacrificed	
	Establish current pressure profile via DST/perforate existing wells (Identify new drills at which DST could be applied. Consider pressure above Miocene water disposal zone as proof of containment)
	Plug back idle/reenter wells in selected above-zone interval to create monitoring wells
	Place instruments in plugged back idle/reenter wells in selected above zone (Detailed plan for pressure monitoring in idle perforated wells)
	Conduct geo chemical sampling of plugged back idle/reenter wells in selected above-zone (Detailed

Denbury Commercial Monitoring Activities	*Research MVA Activities
	plan for geochem ical sampling of above-zone monitoring wells; follow up if pressure ano maly observed)
Fault Monitoring	
Characterization of main fault; conduct well logging program in idle wells in B&C	
Logging program for fluid/temperature change at main fault intersection	
Perforate fault zone in one or more wells and monitor pressure	

* Actions conducted for the MVA activities that exceed the activities already expected to occur as a result of Denbury's commercial EOR operations at the Hastings Field.

** Denbury is evaluating the possible use of Awardee's proprietary technology in the area of tracer testing as method of tracking injected CO_2. In the event that Denbury decides to include such tracer testing in the MVA, tracers may be added to the injected CO_2 and monitored in soil gas and groundwater wells.

Table 2.2 provides an overview of the project sche dule of the MVA activities f or the Hastings MVA project.

Table 2.2
Hastings MVA Test Schedule

Date(s)	Major Milestones
Well Integrity Testing	
2014-2015	Additional surveillance of idle wells via logging
2012-2015	Surveillance of P&A wells via soil gas/casing head gas
2014-2015	Surveillance of P&A wells via Seeper trace*
2012-2015	Surveillance of P&A wells (groundwater monitoring plan via shallow (100 ft) freshwater wells, up-gradient & down-gradient)
Flood Conformance	
TBD	DOE style reservoir modeling to confirm plume size
2013-2015	Augmented measures of conformance - Annual VSP plan for blocks B&C
2013-2015	Augmented measures of conformance - Surface & borehole gravity monitoring 3-4 times per year, Gravity plan for B&C
2013-2015	Augmented measures of conformance - Repeat 3-D seismic profiling.
TBD	Augmented measures of conformance - Real time tubing pressure BHP/increased intermittent memory gauge pressure.
TBD	Augmented measures of conformance - Introduced PFT tracers collected at wellhead
TBD	Augmented measures of conformance - Natural geochemical tracers collected at wellhead
2012-2015	Match predictive model to observed monitoring data
Above-Zone Monitoring	
2013	Establish current pressure profile via DST/perforate existing wells (Identify new drills at which DST could be applied. Consider pressure above Miocene water disposal zone as proof of containment)
2013	Plug back idle/reenter wells in sel ected above-zone interval to create

	monitoring wells
2013	Place instruments in plugged back idle/reenter wells in selected above zone (Detailed plan for pressure monitoring in idle perforated wells)
2013	Conduct geochemical sampling of plugged back idle/reenter wells in selected above-zone (Detailed plan for geochemical sampling of above-zone monitoring wells; follow up if pressure anomaly observed)

* Denbury is evaluating the possible use of Awardee's proprietary technology in the area of tracer testing as method of tracking injected CO_2. In the event that Denbury decides to include such tracer testing in the MVA, tracers may be added to the injected CO_2 and monitored in soil gas and groundwater wells.

Although most of the activities related to the research MVA program will be conducted at the Hastings project site, some analytical work, modeling, and other evaluations of the data will be performed at research partners' facilities, such as the Bureau of Economic Geology at the University of Texas at Austin.

DOE's Need for Action

"The vision for the road map is to possess the scientific understanding of carbon sequestration and develop to the point of deployment those options that insure environmentally acceptable sequestration to reduce anthropogenic CO_2 emissions and/or atmospheric concentrations. The goal is to have the potential to sequester a significant fraction of the 1 Gt/year in 2025 and 4 Gt/year in 2050" (U.S. Department of Energy, 1999, p.1-1).

One option that has the potential to achieve DOE's goal is sequestration of CO_2 in geologic formations, such as oil and gas fields, coal beds, and porous brine-bearing formations (U.S. Department of Energy, 1999, p.5-1). Decades of reservoir characterization experience gained by U.S. industries in understanding the performance of the subsurface in containing gases and fluids help make geologic sequestration an attractive option. The ability of the subsurface to store oil and gas for geologically significant periods is well known, lending credibility to the concept that injected CO_2, which will be buoyant like oil and natural gas in most geological environments, could be sequestered for long periods (Hitchon, 1996). Technologies for introducing gas and fluids to the subsurface are also mature. For decades, oil producers have injected CO_2 into oil reservoirs to act as a solvent and to enhance oil recovery (EOR), a process known as CO_2 EOR. In many parts of the U.S., surface water is protected from contamination by disposal of waste fluids into the subsurface. A permitting process, Underground Injection Control (UIC), assures the public that the disposal occurs in deep subsurface formations that are below and hydrologically isolated from potable water. CO_2 is already being sequestered geologically offshore beneath the North Sea, where approximately one million tonnes of CO_2 are stripped from natural gas and reinjected into the subsurface annually to prevent release to the atmosphere (U.S. Department of Energy, 1999, p. 5-2).

Although the processes of geologic sequestration are relatively well known, additional research is needed to fill gaps in our scientific understanding of carbon sequestration to demonstrate permanent storage for the protection of human health and the environment, to reduce costs, and to facilitate the full-scale deployment of this technology. Extensive laboratory and modeling studies have been completed to assess how CO_2 geologic sequestration would work in the subsurface (for example, Hitchon, 1996; U.S. Department of Energy, 1999). Comparing

predictions from bench scale tests and numerical models with field results is necessary to validate the models and demonstrate that scientific understanding is correct.

The current absence of data sufficient to account for CO_2 fate in the complex EOR system leaves a gap in scientific understanding. It is generally assumed, but has never been demonstrated, that migration of CO_2 from the injection zone is small, relative to the other fates.

Potential fates of CO_2 injected for EOR that need to be studied include the following:

- sorbed in the oil,
- held by capillary forces in pore space,
- trapped by buoyancy forces in stratigraphic or structural compartments,
- dissolved in pore water,
- produced and reused, or
- migrate from the injection zone through the soils and/or penetrations.

To address these gaps in scientific understanding, we are proposing a field experiment in a high-porosity, high-permeability formation similar to those that could eventually be used to sequester large volumes of CO_2. This project will be onshore, so that it can be closely monitored to determine whether the CO_2 remains within the injection zone and so that scientific understanding can be maximized. The research MVA will (1) demonstrate that health and safety and environmental risks are minimized, (2) obtain results quickly so that experience can be used in moving to production fields in other parts of the world, and (3) minimize costs during this phase before stakeholders are ready for full scale deployment. The test location will provide an opportunity for matching numerical model results with field observations under conditions of high volume injection at a scale similar to what would be done if CO2 from a large anthropogenic source (such as a power plant) was captured and sequestered.

2.2 *Alternatives to Proposed Action*

A complete description of likely alternatives to the project, including a "no action" alternative, shall be provided. The description shall address technology-specific aspects of the action, such as process design configurations, and site-specific considerations, such as alternative waste disposal sites, etc.

2.2.1 "No Action" Alternative

"No action" (meaning that the proposed MVA project is not implemented) would mean that the significant commercial EOR development in the Hastings Field would still take place yet exclude the critical research elements needed to document the fate and ultimately the long term storage capability for CO_2. Existing commercial EOR data collection leaves a gap in scientific understanding of the fate of injected CO_2. Hence without the research MVA implementation, the increased understanding of subsurface fate and behavior of CO_2 in a large scale EOR setting of high permeability formation would not be gained, nor could an example of successful and safe sequestration be offered to the public and decision makers. "No action" would also turn away from a highly leveraged demonstration of long term EOR sequestration of CO_2 which has the peripheral benefits of concurrently developing safe, domestically produced oil for our nation. Delays in acquiring this missing information on the fate of CO_2 in a representative EOR environment would result in implementation delays of this possible "low cost" strategy to safely

sequester CO_2. Additionally this strategy is likely the fastest strategy to deploy and expand the sequestration of anthropogenic CO_2 sources. Hence "no action" will delay meaningful sequestration efforts thereby jeopardizing goals of rapid action on climate change issues. A 3-year delay in initiating large-scale sequestration efforts would increase CO_2 emissions by approximately 5% and atmospheric concentrations of CO_2 would increase by as much as 6 ppm before any stabilization effort would be started.

2.2.2 Different MVA Site Alternatives

Six fields were proposed and evaluated from which Hastings was selected. Hastings was highly desirable because of the following positive attributes not present at the other considered fields:

1) It is proximate to several potential anthropogenic CO_2 sources, significantly reducing pipeline costs,
2) The field is in the early development stages for EOR. With an EOR development schedule closely aligned with Phase 2, only Hastings can be suitably monitored for baseline data before CO_2 injections begin. Alternate fields have existing EOR CO_2 injection and might offer a muddled data set related to clear understanding of the fate of the project's injected CO_2,
3) Hastings has a close match between the volume needed for field development and availability of captured CO_2. Hence only Hastings can simulate a future scenario with EOR based solely on anthropogenic CO_2.

2.2.3 Alternate MVA Technologies

No reasonably reliable alternate MVA technologies are presently available.

3.0 EXISTING ENVIRONMENT

This section shall discuss the existing environment at the project location(s). The principal proposer and all proposed subcontractors shall discuss the following:

3.1 Land Use

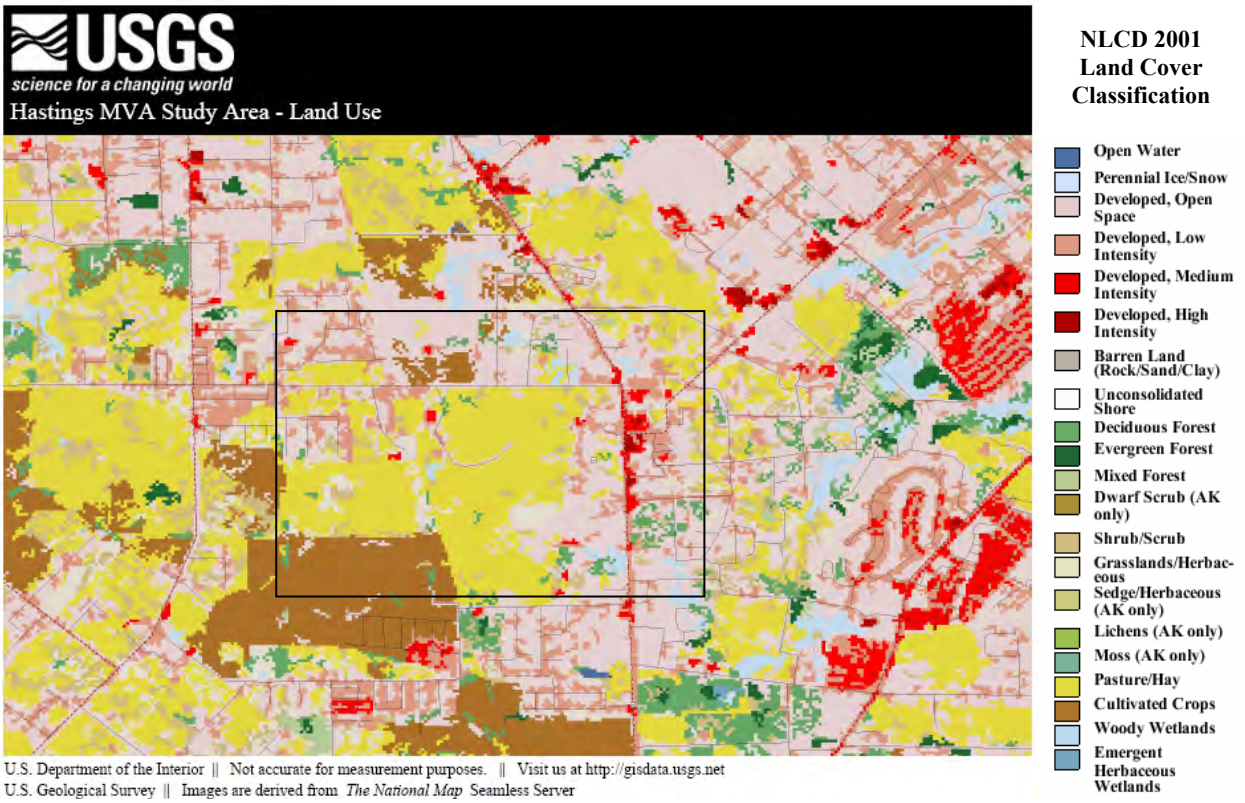
This section shall provide a description of the affected land area and its dimensions; a discussion of current land usage (e.g., farming, industrial, etc.); characterization of any existing landforms (i.e., waterfalls, runoff areas, etc.); and descriptions of nearby pipelines and transmission lines, as well as transportation access (by rail, road, barge, etc.).

While the overall extent of the Hastings Oil Field consists of approximately 25 square miles of rural farmlands, suburban areas and residential neighborhoods, the proposed project area is less than 4 square miles located between Alvin and Pearland, Texas on State Highway 35. The Hastings Oil Field was discovered in 1934, and oil production continues to be a primary land use in the area (TSHA, 2010a). The project area contains approximately 80 active, 100 inactive, and 110 plugged and abandoned (P&A) wells, as well as a number of temporarily abandoned (TA) wells (**Figure 2.3**).

According to the 2001 USGS Land Use Survey (**Figure 3.1.1**), a large portion of the area is dedicated to pasture hay and cultivated corps. The majority of the remaining area is in open

space and low intensity development. Pockets of medium intensity and high intensity development are located in the area, primarily along and just east of State Highway 35. Only small, scattered areas of deciduous forests and shrub/scrub areas remain. Cowart Creek is located in the northeastern section of the area and Chigger Creek flows through the southern edge. Both streams are small tributaries of Clear Creek approximately 3.5 miles to the east of the site.

Figure 3.1.1
2001 USGS Land Use



State Highway 35 runs north-south through the eastern portion of the project area, and County Road 128 (Hastings Cannon Road) runs east-west along the northern portion of the project area. Numerous smaller county and private roads provide access to the site. A spur of the Burlington Northern (Atchison Topeka and Santa Fe) Railroad also intersects the project area to the west. A large high-power transmission line is located just southwest of the project site.

An extensive network of large oil and gas pipelines exists in this part of the North Gulf Texas coastal area and many run within a few miles of the project area. Denbury has identified pipelines owned and operated by the following companies in the West Hastings Field: BP Pipelines, Conoco Phillips, Enterprise Products, Exxon Mobil GGS, Kinder Morgan Tejas, Texas Eastern Transmission, TexCal Energy, and several others. A large network of smaller gathering pipelines also services the existing well sites in the Hastings Oil Field. High pressure and low

pressure gas collection lines, production water and salt water lines, and power lines service the area, as well. **Attachment 3.1.1** includes maps provided by Denbury Onshore, LLC that show the type and location of this network.

3.2 Atmospheric Conditions/Air Quality

This section shall identify the air quality control regions where the project is located; and describe the local climate and existing air quality conditions in the immediate vicinity of the proposed site.

The Hasting MVA project area is located in the Texas Coastal Plains, a humid subtropical area near the Gulf of Mexico. Humidity is high, especially during the summer when morning humidity values average over 90% and afternoon values exceed 60%. Prevailing winds are from the south and southeast, except in January when polar cold fronts cause strong north winds to occur. The proximity to the Gulf of Mexico moderates temperatures and results in abundant rainfall, which is evenly distributed throughout the year. Annual precipitation totals range between 30 and 60 inches about 75% of the time, with thunderstorms being the major contributor. The following **Table 3.2.1** summarizes average climatic data for the National Weather Service station in Alvin, Texas (NCDC, 2010).

Table 3.2.1
NOAA Southern Regional Climate Center
National Climatic Data Center (NCDC) Climate Normals
Alvin, Texas

Normals [1971 - 2000]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Avg. Precipitation (inches)	4.76	2.91	3.11	3.22	4.92	5.35	4.78	3.84	7.12	3.93	4.43	3.36	51.73
Mean Temperature (Deg. F.)	52.7	55.9	62.5	68.5	75.5	80.7	82.7	82.7	78.7	70.6	62.2	54.9	69.0
Avg. High Temperature (Deg. F.)	62.2	65.7	72.0	77.3	83.6	88.8	91.2	91.6	87.7	80.8	72.2	64.7	78.2
Avg. Low Temperature (Deg. F.)	43.1	46.1	53.0	59.6	67.3	72.5	74.2	73.8	69.6	60.4	52.1	45.1	59.7

The Hastings MVA project site is located in the Houston-Galveston Metropolitan Statistical Area which is one of the most intensely monitored air quality regions in the nation with monitoring locations operated by the Texas Commission on Environmental Quality, as well as a number of local and private organizations. The entire metropolitan area, including Brazoria County, is currently listed as nonattainment for the 8-hour National Ambient Air Quality Standard (NAAQS) for ozone, but is in attainment for all other criteria pollutants identified in the Clean Air Act (CAA), including Sulfur Oxide (SOX), Particulate Matter (PM-10 & PM-2.5), Carbon Monoxide (CO), Nitrogen Dioxide (NO2), and Lead.

The nearest air quality monitoring station to the Hastings MVA project area is at the Clear Brook High School in Friendswood approximately 5.5 miles to the northeast (TCEQ, 2010a). It

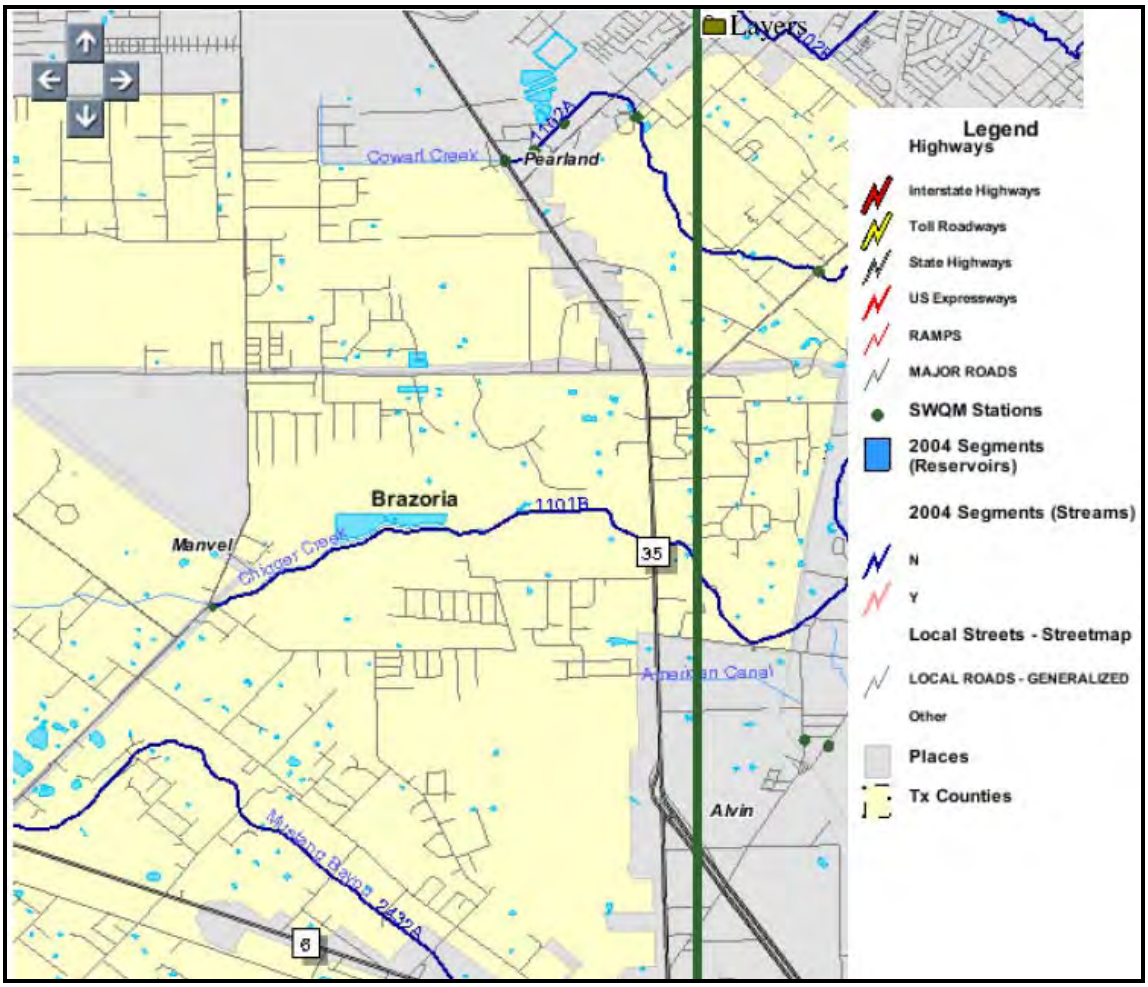
collects data on ozone and a suite of meteorological parameters. Between the years of 2006 - 2009, the station recorded several exceedances of the NAAQS for ozone. Other monitoring sites near the project area include the Manvel Croix Park station approximately 8.5 miles west-northwest of the site and the Mustang Bayou station approximately 13.0 miles south-southeast of the site. These sites monitor for various nitrous oxides, as well as ozone and meteorological parameters. **Attachment 3.2.1** includes descriptions of these monitoring stations, hourly ozone monitoring data, including high and second-high values, and ozone compliance values for 2006-2009.

3.3 Hydrologic Conditions/Water Quality

This section shall identify any watersheds and downstream drainage, surface and groundwater quality (nearby aquifers and the depth of groundwater) in the project area, existing floodplains, unique aquatic habitats, recreational areas, public water supplies; describe any constraints on water availability imposed by treaties, court decree, state and Federal water laws; and identify existing wastewater treatment and/or disposal facilities.

Watershed: The Hastings MVA project area is located on relatively flat coastal plain. Two streams, Cowart Creek and Chigger Creek, are located within the project area and flow toward the east as tributaries to Clear Creek (**Figure 3.3.1**). Clear Creek flows into Clear Lake which ultimately connects to Galveston Bay.

Figure 3.3.1
Hastings MVA Project Area – TCEQ Surface Water Body Viewer



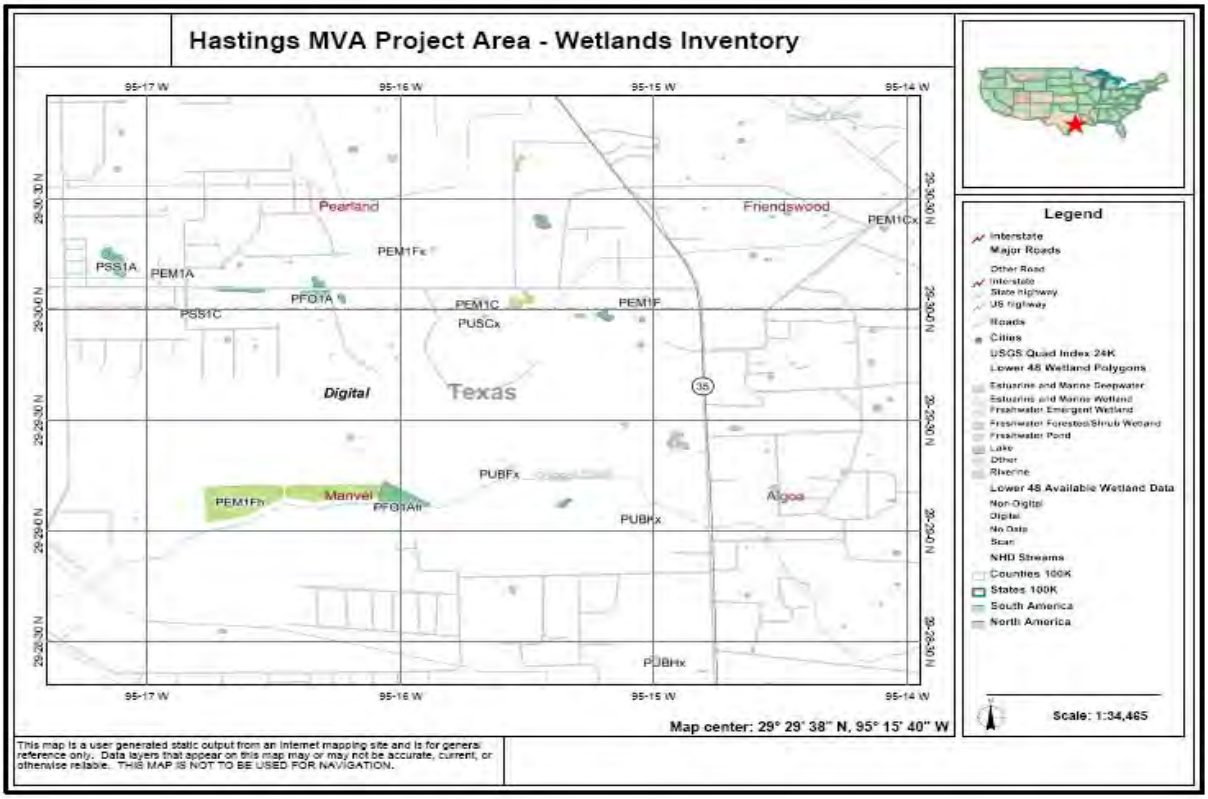
Surface Water Quality: The TCEQ periodically monitors water quality in these streams and has detected impairments for bacteria concentrations in the following segments (TCEQ, 2010b):

- Chigger Creek (Segment ID 1101B) from the confluence of Clear Creek Tidal to the Brazos River Authority Canal near CR 143 in Galveston County – first listed in 2002.
- Cowart Creek (Segment ID 1102A) intermittent stream with perennial pools from the confluence with Clear Creek in Galveston County to SH 35 in Brazoria County – first listed in 2002.

State plans to address these impairments, known as Total Maximum Daily Load (TMDL) plans, have been initiated by the TCEQ. No other impairments have been noted.

Wetlands: Several small, isolated wetlands have been identified in the U.S. Fish and Wildlife Service National Wetland Inventory (USFWS, 2010) within the Hastings MVA project area, including freshwater ponds, emergent wetlands, and forested/shrub wetlands (**Figure 3.3.2**).

Figure 3.3.2

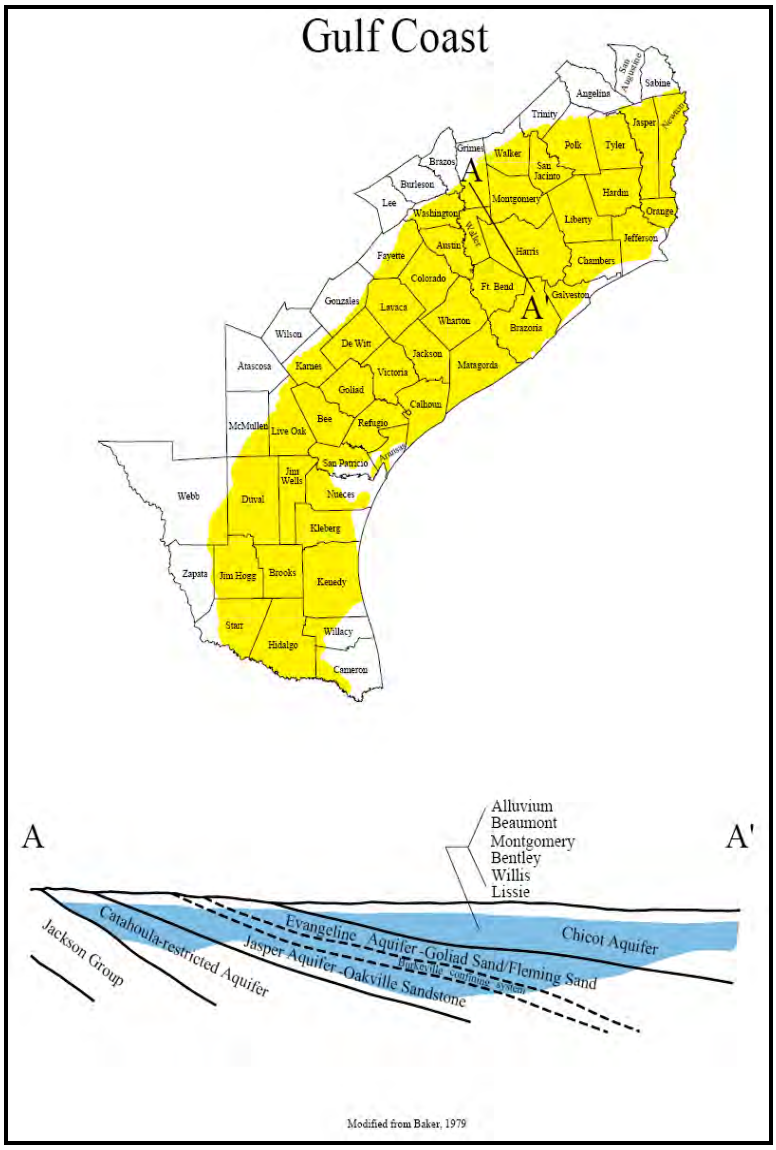


Floodplains: The Federal Emergency Management Agency (FEMA) has surveyed the floodplains in the project area and developed detailed Flood Insurance Rate Maps (FEMA, 2010). Areas identified as Special Flood Hazard Areas Inundated by 100-year Floods (Zones A, AE, and AO) occur within short distances of Chigger and Cowart Creeks. Some areas identified as subject to 500-year floods (Zone X) are also indicated on the maps. These areas extend from 100 feet to up to 2,000 feet across the drainage areas of these creeks.

Aquatic Habitats: No unique aquatic habitats or recreational areas exist within the boundaries or in the proximity of the project area.

Groundwater: The Gulf Coast aquifer system forms a wide belt along the Gulf of Mexico from Florida to Mexico. In Texas, the aquifer provides water to all or parts of 54 counties and extends from the Rio Grande northeastward to the Louisiana-Texas border (**Figure 3.3.3**). Municipal and irrigation uses account for 90 percent of the total pumpage from the aquifer (Baker, 1979).

Figure 3.3.3
Gulf Coast Aquifer Complex



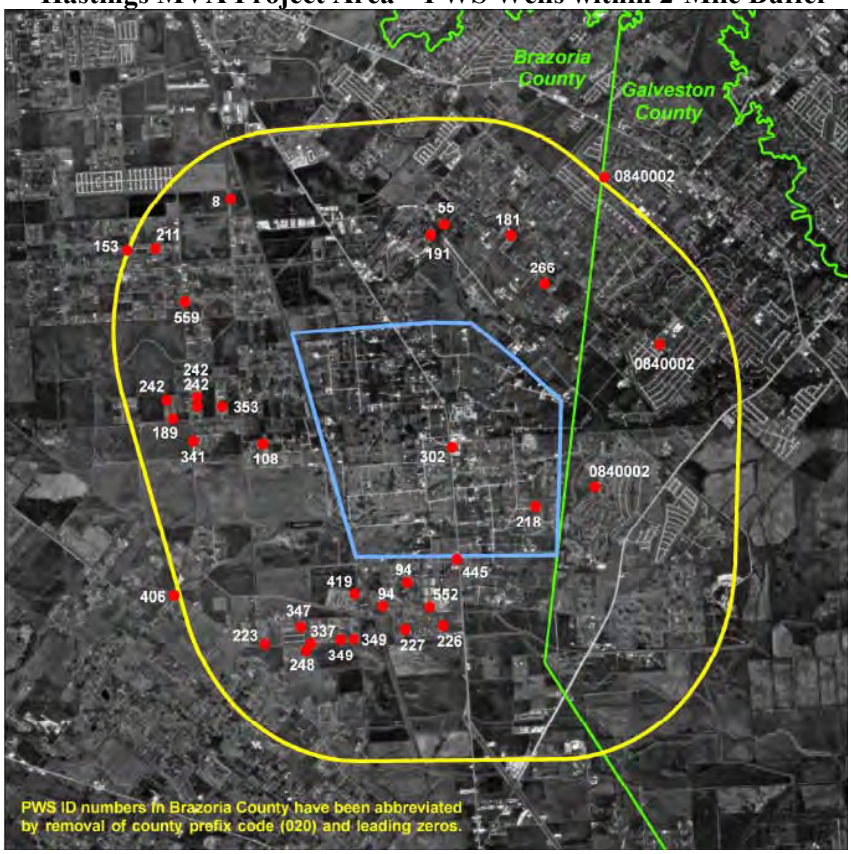
The aquifer consists of complex interbedded clays, silts, sands, and gravels of Cenozoic age, which are hydrologically connected to form a large, leaky artesian aquifer system (Baker, 1979). This system comprises four major components consisting of the following generally recognized water-producing formations. The deepest is the Catahoula, which contains ground water near the outcrop in relatively restricted sand layers. Above the Catahoula is the Jasper aquifer, primarily contained within the Oakville Sandstone. The Burkeville confining layer separates the Jasper from the overlying Evangeline aquifer, which is contained within the Fleming and Goliad sands. The Chicot aquifer, or upper component of the Gulf Coast aquifer system, consists of the Lissie, Willis, Bentley, Montgomery, and Beaumont formations, and overlying alluvial deposits.

In Brazoria County only the Evangeline and the Chicot Aquifers are present. Brazoria County water well construction depths range from 60 feet to 1,400 feet and groundwater quality is generally good with total dissolved solids ranging from 480-950 mg/l. Thirty-four operational, demand, or emergency-use wells belonging to 28 public water systems are located within 2 miles

Aquifer and range in depth from 100-674 feet (average 409 ft, median 375 ft).

Figure 3.3.4 is a map of the general project area including a two mile buffer zone indicating the location of each of the nearby wells. **Attachment 3.3.1** lists the wells and depth of each of these wells.

Figure 3.3.4
Hastings MVA Project Area – PWS Wells within 2-Mile Buffer

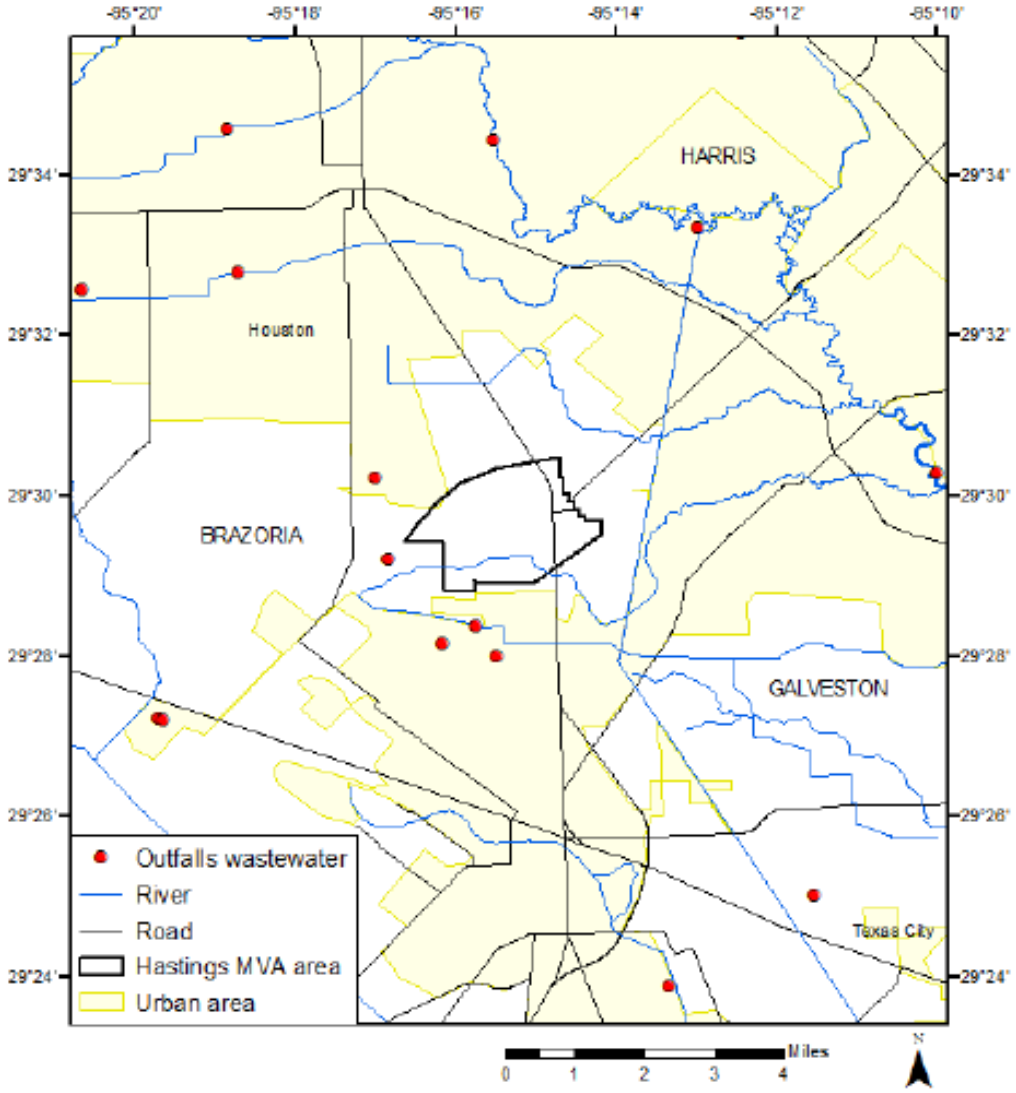


The Brazoria County Groundwater Conservation District (BCGCD) was created by Texas statute to maintain and protect the groundwater resources of Brazoria County (BCGCD, 2008). The BCGCD was confirmed by county voters in November 2005 and proactively addresses groundwater issues by working with groundwater users to manage and plan for groundwater use. According to BCGCD rules, all monitoring wells similar to those to be used for MVA activities are exempted from registration and permitting.

Wastewater Treatment: The following wastewater treatment facilities are located in the proximity of the Hastings MVA project area: City of Alvin, City of Hillcrest Village, Brazoria County MUD 24, K.C. Utilities Inc., Meadowland Utility Corp., Foretaire Estates, City of Pearland (3 facilities), Keeshan & Bost Chemical Co. Inc., and Texas-American Water Company (2 facilities). **Figure 3.3.5** shows the locations of wastewater discharges near the project area.

Figure 3.3.5

Hastings MVA Project Area – Wastewater Discharges



3.4 Geologic/Soil Conditions

This section shall describe the topographic stability (e.g., formations and/or faulting), the productivity of soil, any unique soil species, and the soil's susceptibility to erosion.

Brazoria County lies largely in the northern portion of the Gulf coastal plain, a 40- to 50-mile-wide swath along the Texas Gulf Coast. Typically, elevation rises approximately one foot per mile inland. Underpinning the upper coastal land surface are unconsolidated clays, clay shales, and poorly-cemented sands extending to depths of several miles. The region's geology developed from stream deposits from the erosion of the Rocky Mountains. These sediments consist of a series of sands and clays deposited on decaying organic matter that, over time, was transformed into oil and natural gas. Beneath these tiers is a water-deposited layer of halite, a rock salt. The porous layers were compressed over time and forced upward. As it pushed upward, the salt dragged surrounding sediments into dome shapes, often trapping oil and gas that seeped from the surrounding porous sands.

A major subsurface fault exists within the area that runs from northwest to southeast almost exactly on a line followed by Texas Highway 35 between Pearland and Alvin and was used in 1958 to divide the Hastings West and Hastings East Fields. No other significant topographic features exist within the area.

Three major soil types were identified in National Cooperative Soil Survey by the Natural Resources Conservation Service (NRCS) of the U.S. Department of Agriculture (NRCS, 2010). These include Bernard clay loam, Bernard-Edna complex, and Lake Charles clay (**Figure 3.4.1**). All of these soil types are characterized by slopes of from 0 – 1 percent and somewhat poorly to moderate drainage class indicating very limited susceptibility to erosion. **Attachment 3.4.1** includes detailed soil type descriptions.

Figure 3.4.1
Hastings MVA Project Area – NRCS Soil Types

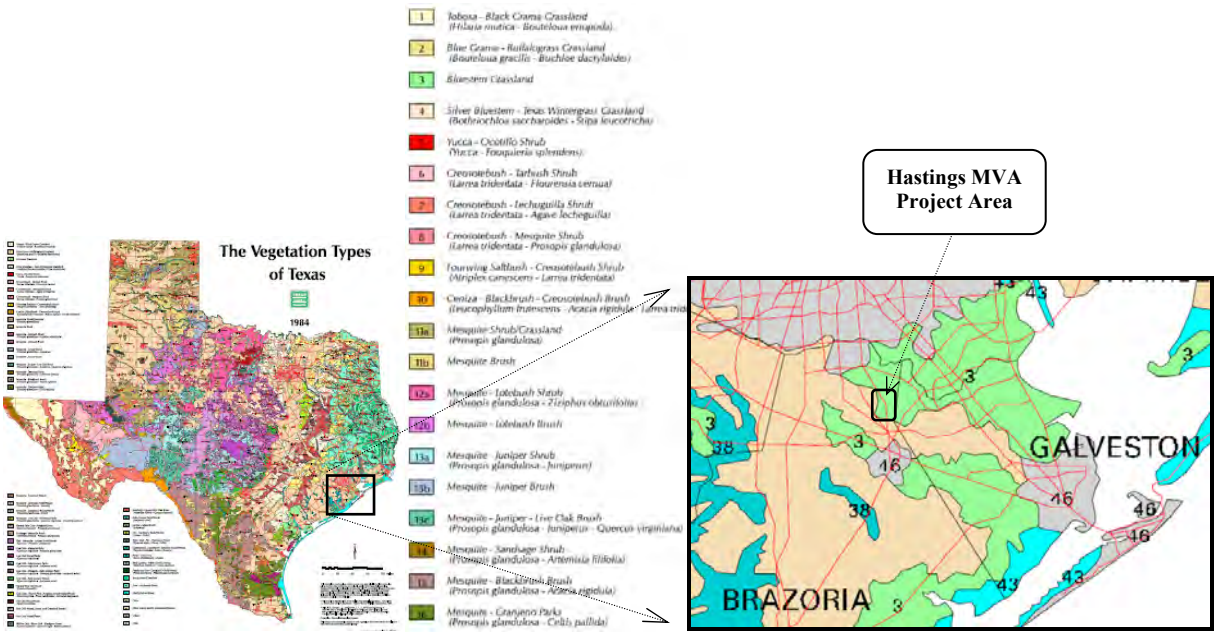
3.5 Vegetation and Wildlife Conditions

This section shall describe any indigenous flora and fauna, state and federally-listed endangered or threatened species and their habitats, and sensitive habitats such as wetlands, floodplains, or other ecologically sensitive terrain.

The Texas Parks and Wildlife Department (TPWD) includes Brazoria County in the Coastal Prairies of Oak-Prairie Wildlife District (TPWD, 2010a). In pre-settlement times, this tallgrass prairie extended to approximately 9 million acres, of which 6.5 million were in Texas. Today, much of the prairie has been converted to improved pasture or rice, sugarcane, forage, and grain crops and less than one percent remains.

The Hastings MVA project area is part of the Bluestem Grassland (**Figure 3.5.1**) with nearly 1,000 plant species have been identified, including bushy bluestem, slender bluestem, little bluestem, silver bluestem, three-awn, buffalograss, bermudagrass, brownseed paspalum, single-spike paspalum, smutgrass, sacahuista, windmillgrass, southern dewberry, live oak, mesquite, huisache, baccharis, Macartney rose.

Figure 3.5.1
Hastings MVA Project Area – Vegetation Types



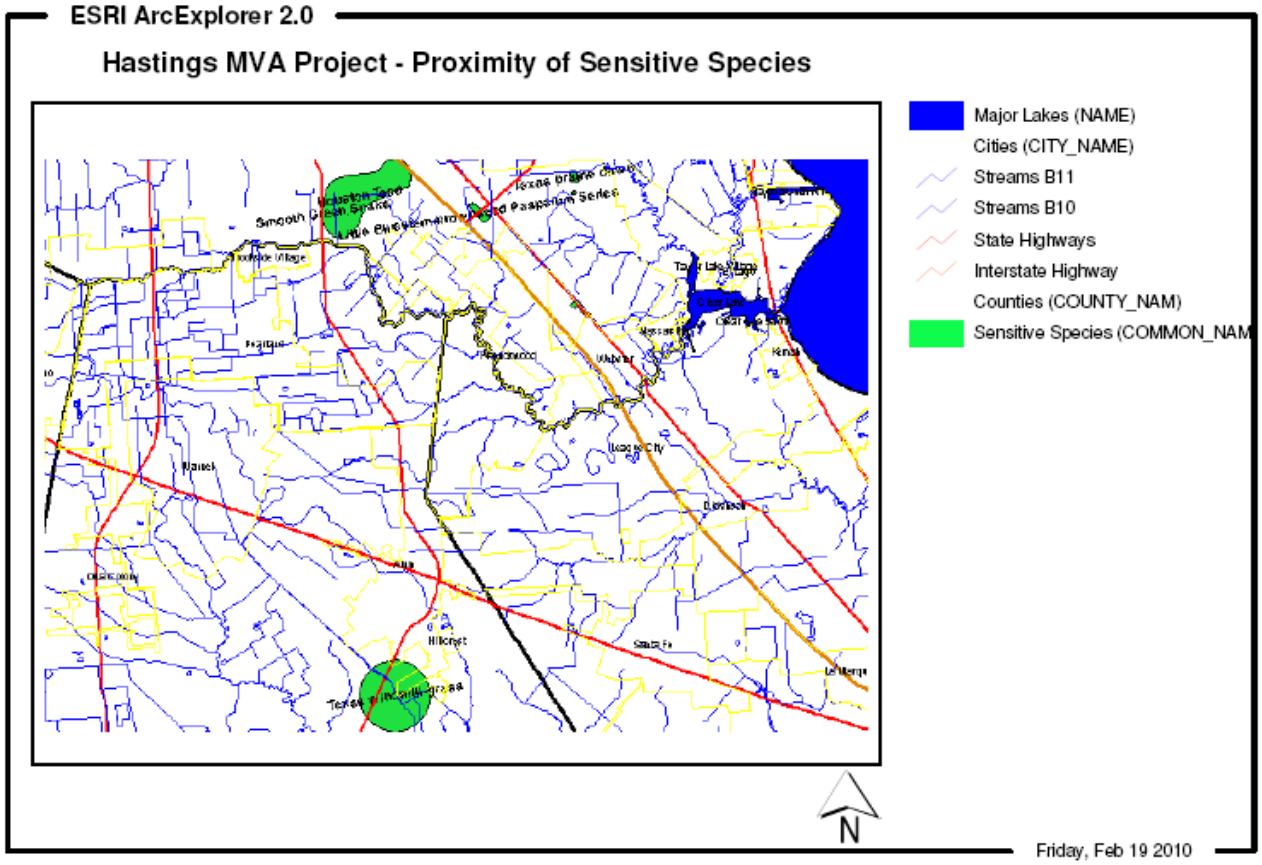
A wide range of waterfowl and other forms of wildlife also occur in the Coastal Prairie with more red-tailed hawk, northern harriers, white ibis, and white-faced ibis than any other region in the United States. A number of rare species exist in Brazoria County including 18 birds (e.g. Brown Pelican, Whooping Crane), 3 fish (e.g. Smalltooth Sawfish), 6 mammals (e.g. Jaguarundi, Ocelot, Red Wolf), 5 mollusks (e.g. False Spike Mussel), 10 reptiles (e.g. Alligator Snapping Turtle, Texas Horned Lizard), and 5 plants (Texas Windmill-grass). **Attachment 3.5.1** provides a complete listing of state and federal rare, threatened, and endangered species observed in Brazoria County.

The TPWD Wildlife Diversity Program provided data from the Texas Natural Diversity Database (TXNDD) for the USGS topographic quadrangles in near the Hastings MVA project site (**Figure 3.5.3**) and identified the approximate locations of observed federal and state listed

threatened, endangered, and rare species (TPWD, 2010c). None have been observed in or within 5 miles of the project area. (Note: These data cannot provide definitive statement as to the presence, absence, or condition of special species, natural communities, or other significant features in any area. Nor can these data substitute for on-site evaluation by qualified biologists.) The following are the nearest reported occurrences:

- Houston Toad – 7 miles north in Harris County
- Smooth Green Snake – 7 miles north in Harris County
- Little Bluestem-Brownseed Paspalum Series – 6 miles north in Harris County
- Texas Prairie Dawn – 11 miles northeast in Harris County
- Texas Windmill Grass – 6 miles northeast in Harris County
- Texas Windmill Grass – 7 miles south in Brazoria County

Figure 3.5.3
Hastings MVA Project Area – TPWD Proximity of Sensitive Species



Numerous, small, isolated wetlands have been identified in the U.S. Fish and Wildlife Service National Wetland Inventory within the Hastings MVA project area, including freshwater ponds, emergent wetlands, and forested/shrub wetlands. Small areas of floodplain also occur along and adjacent to Cowart Creek and Chigger Creek within the project area. However, none of these wetlands, floodplains, or any other terrain represent sensitive habitats for endangered, threatened, or rare species.

3.6 Socioeconomic Conditions

This section shall discuss the population in the project area, and shall describe the employment and labor mix.

According to the U.S. Census Bureau (2010), the population of Brazoria County in 2006-2008 was 293,000 with 142,000 (49%) females and 150,000 (51%) males. The estimated per capita income was approximately $27,260.

The Socioeconomic Modeling Group at Houston-Galveston Area Council (H-GAC, 2010) collects data on the population and economy of the region and maintains databases with data from many federal and state sources. The **Table 3.6.1** provides estimated 2008 employment and labor statistics for Brazoria County and the major population centers near the Hastings MVA project area.

Table 3.6.1
Employment and Labor Statistics for the
Hasting MVA Project Area

	Brazoria County	Alvin	Pearland	Friendswood
Civilian Labor Force	**143,941**	**11,205**	**40,891**	**19,079**
Civilian employed population 16 years and over	**137,268**	**10,342**	**39,441**	**18,464**
OCCUPATION				
Management, professional, and related occupations	50,074	2,961	19,819	9,680
Service occupations	18,738	1,405	3,513	2,040
Sales and office occupations	32,124	2,165	10,285	4,207
Farming, fishing, and forestry occupations	616	0	26	0
Construction, extraction, maintenance and repair occupations	18,188	1,761	2,405	1,172
Production, transportation, and material moving occupations	17,528	2,050	3,393	1,365
INDUSTRY				
Agriculture, forestry, fishing and hunting, and mining	3,863	231	1,212	282
Construction	15,004	1,154	1,742	1,055
Manufacturing	20,063	1,518	4,114	2,520
Wholesale trade	4,698	466	2,031	433
Retail trade	13,749	1,470	4,272	1,255
Transportation and warehousing, and utilities	6,828	553	2,313	1,313
Information	2,338	428	824	501
Finance and insurance, and real estate and rental and leasing	7,113	507	2,528	1,698
Professional, scientific, and management, and administrative and waste management services	14,684	906	5,180	2,305
Educational services, and health care and social assistance	26,284	1,764	9,431	4,260
Arts, entertainment, and recreation, and accommodation, and food services	8,820	785	2,036	1,157
Other services, except public administration	7,271	499	1,776	926

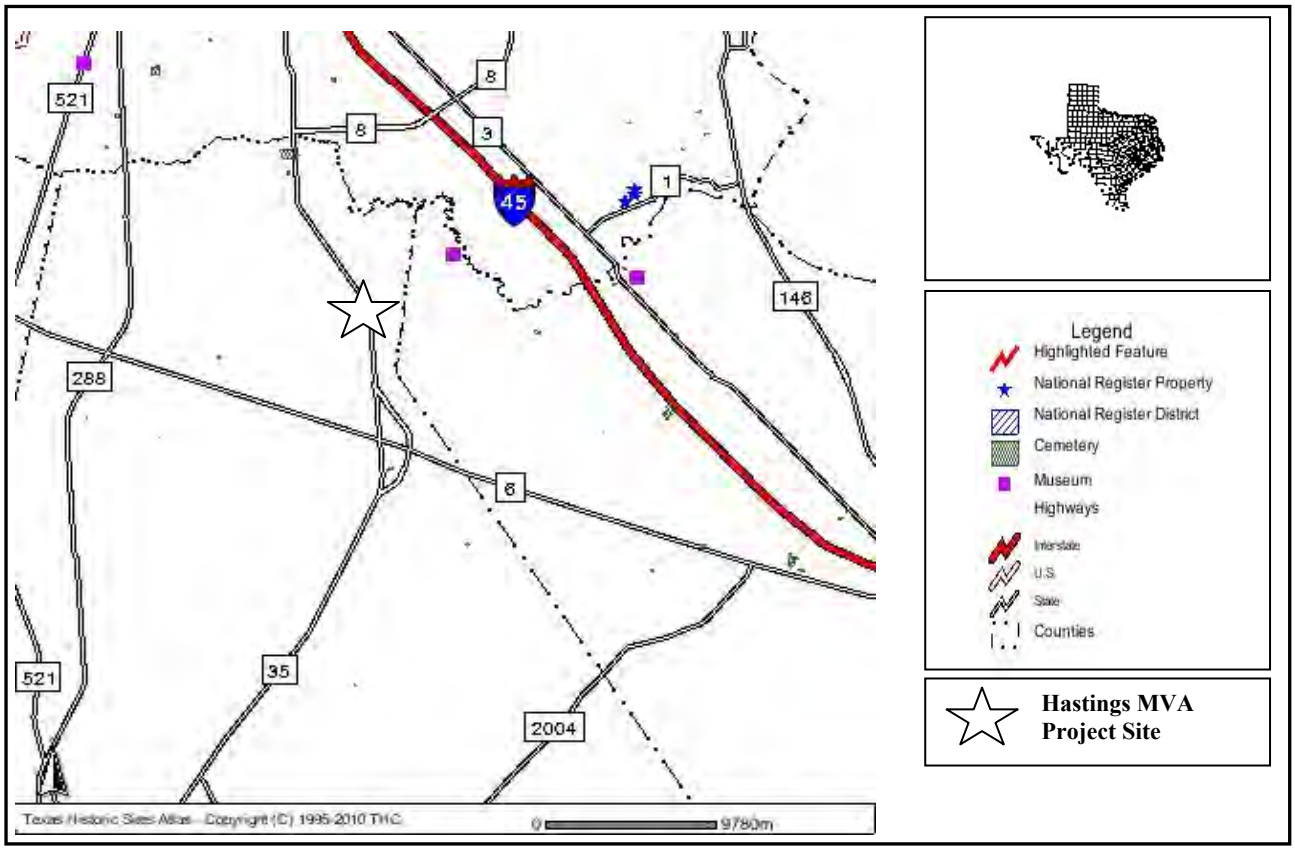
3.7 Historic/Cultural Resources

The section shall describe any historic and/or cultural places in the project area, as well as archeological sites.

Although Brazoria County has a rich historical heritage and has played a major role in Texas history, no sites of historical or cultural significance have been documented in the Hasting MVA project area. The nearest locations listed on the National Registry of Historic Sites are at the National Aeronautics and Space Administration (NASA) complex in Harris County approximately 10 miles northeast of the site. (THC, 2010) Major archeological studies have been reported in Brazoria County at the Levi Jordan and the Varner-Hogg Plantations, the 1897 Brazoria County Courthouse, and Lake Jackson, but all of those are from 25 – 35 miles southwest of the project area (TSHA, 2010b). Most recently, prehistoric human remains were discovered in the San Bernard National Wildlife Refuge approximately 45 miles to the southwest.

Several cemeteries are located in the proximity of the Hastings MVA project area including the Friends Church Cemetery (3.6 miles), Old Pearland Cemetery (3.5 miles), Confederate Cemetery (5.4 miles), Manvel Cemetery (5.6 miles), and South Park Cemetery (6.6 miles). The Frank J. Brown Heritage Museum is also located approximately 3.6 miles from the site in Friendswood, Texas (THC, 2010). **Attachment 3.7.1** shows historical locations near the project site. The Texas Historical Commission has been contacted to confirm the locations of any existing or potential historical or archeological sites near the Hastings project site, and an official response is pending.

Figure 3.7.1
Hastings MVA Project Area – Proximity of Historic Sites



The Environmental Protection Agency (EPA) Region 6 Office of Environmental Justice and Tribal Affairs (EPA, 2010) and the Alabama Coushatta Indian Tribe (ACIT, 2010) were contacted regarding potential Native American tribal interests in or near the Hastings MVA project area. No sites were identified and an official response is pending.

3.8 Visual Resources

This section shall describe any scenic vistas or existing aesthetic landscaping in the project area.

The Hastings MVA project area is characterized by relatively flat coastal plain topography with no significant scenic vistas or outstanding aesthetic landscaping. Most of the project area has been converted to pasture hay and cultivated crops, oil and gas production, or low to moderate density development.

No parks or other recreational areas are located within the project area. The nearest public park, Friendswood Sports Park, is located approximately 1.4 miles southeast of the area. Several other small community parks are located from 2.5 – 4.0 miles away. The nearest major recreational areas are Brazos Bend State Park, 17 miles west-northwest, and Brazoria National Wildlife Refuge, 18 miles south.

3.9 Health and Safety Factors

This section shall discuss current emissions (toxic and non-toxic), effluents, and noise levels at the project area.

All current environmental releases from activities in the Hastings MVA project area are generally associated with Denbury's privately-funded, commercial oil exploration and production operations. Air emissions are limited to temporary diesel emissions from drilling equipment during well development as part of Denbury's on-going commercial operations in the area. Total emissions (NOx, CO, VOC, etc.) will be well below levels considered to be major emission sources.

Produced wastewater generated from the drilling is captured from the wells, transported by truck, and re-injected into permitted Class II wells operated by Denbury at the Hasting Field. Drilling mud and associated wastes also generated during drilling operations are landfarmed on site in accordance with Texas Railroad Commission regulations (Texas Administrative Code Title 16, Rule 3.8). No other solid or hazardous wastes are produced.

Transient noise from diesel engines (80 Db) is generally only audible in the immediate proximity to an active drilling operation and is not at levels that could be considered a nuisance.

4.0 ENVIRONMENTAL IMPACTS OF THE WORK TO BE PERFORMED

This section of the Environmental Volume shall describe the anticipated environmental impacts from the project. It shall describe all impacts and consequences of the project (at the selected site[s] and the alternative site[s], if appropriate). The existing environment (described in Section A.3) shall be evaluated in terms of the potential impacts from any construction, operation/testing, and disposition activities. Any mitigative measures that will address these impacts shall also be identified.

The description shall address the environmental categories listed below. Please ensure that all direct, indirect, short-term, and long-term impacts resulting from project activities are identified clearly.

4.1 Land Use

This section shall describe land use impacts from any construction and operation activities; waste disposal problems (for non-toxic, toxic, and/or hazardous substances); and effluent discharges requiring the development of settling ponds.

Denbury is currently drilling and/or reworking a large number of wells in the Hastings Field that will be used for injection of CO_2, production of oil and gas, testing, water production, and brine disposal. All activities related to the commercial operations at the Hastings project site will be permitted by the Texas Railroad Commission and used for EOR operations being conducted by Denbury. EOR operations and commercial monitoring activities will be conducted by Denbury regardless of the implementation of the research MVA activities.

All research MVA activities will be consistent with the current oil and gas production land use within the Hastings Oil Field. MVA activities will be conducted in existing idle wells within the project area or will require only minor, temporary drilling of shallow groundwater and soil-gas testing boreholes. If new wells are required, existing well pads will be used, if possible, to reduce or eliminate changes in land use.

4.2 Air Quality Impacts

This section shall discuss projections in air quality changes; estimated process emissions (e.g., stack emissions); construction emissions from land disturbance or the operation of machinery/equipment, solid waste disposal operations, coal handling, etc.; and the source, emission rate, duration, and frequency of all emissions.

Air pollutant releases will be limited to temporary diesel emissions from drilling equipment during well development as part of Denbury's on-going commercial operations in the area and drilling of the groundwater and soil-gas monitoring wells. No emissions will result from monitoring or testing operations during the MVA activities.

4.3 Hydrological Conditions/Water Quality

This section shall describe any changes in groundwater/surface water quality and quantity, stream diversion resulting from construction, runoff from storage piles (source, discharge rate, discharge frequency and duration), leachates from waste disposal sites; and wastewater treatment and discharges.

The possibility of the migration of CO_2 into the groundwater in the Hastings location is extremely remote due to the extensive configuration of geologic seals that separate the deep injection formations from shallow local aquifers and the surface. Furthermore, penetration-related pathways are greatly reduced by extensive plug and abandonment records and testing and the use of new well construction standards. The commercial and research MVA activities conducted as part of this project are targeted to detect subsurface movement or migration through existing P&A wells that could result in impacts to groundwater. Back plugging of idle wells for above-surface monitoring will be conducted in accordance with industry practices and regulations to prevent migration and will be monitored to demonstrate that no migration occurs. Thus, the risks of direct impacts to water quality will be greatly reduced as a result of the MVA activities.

The fresh and saline dewatering of all of the wells that may be required of the MVA activities related to this project will be minimal or will be generated from Denbury's commercial EOR operations even if the MVA project is not conducted. This wastewater will be captured from the wells, transported by truck, and re-injected into permitted Class II wells operated by Denbury at the Hastings Field.

Drilling operations related to the MVA project will have no discharges and will not require National Pollutant Discharge Elimination System (NPDES) permitting. Construction activities associated with oil and gas exploration, production, processing and treatment, and transmission facilities are generally exempt from NPDES construction requirements. Denbury applies construction best management practices in order to minimize the discharge of pollutants in storm water runoff.

4.4 Geologic/Soil Conditions

This section shall describe any subsidence that might be caused by construction; any possible erosion, stream diversion, floodplain and wetland intrusion, and any increases or decreases in soil permeability and filtration.

The research MVA activities associated with this project do not involve the removal or injection of any materials that will result in subsidence, changes in subsurface conditions, runoff, or other significant effluent release. Minor drilling operations will be temporary and result in no permanent change in geologic or soil conditions.

One perennial stream, Chigger Creek, and one intermittent stream, Cowart Creek, intersect the project area, and a few isolated wetlands are observed in the area. No drilling activities related to the MVA activities will impact these potential flood-prone or wetland areas. Other monitoring activities, such as seismic profile and well integrity testing will have no permanent impacts.

4.5 Vegetation and Wildlife Resources

This section shall describe any impacts to indigenous flora and fauna, state and federally-listed endangered species and their habitats, and sensitive habitats such as wetlands, floodplains, or other ecologically sensitive terrain.

The back plugging of idle wells, the drilling of groundwater and soil-gas testing boreholes near P&A wells, and the placement of concrete monuments for periodic seismic testing during MVA activities will require only minimal disturbance within the project area and will result in no permanent changes that would impact indigenous or listed species or their habitats.

The drilling of shallow groundwater monitoring wells will likely use small, temporary, truck-mounted equipment that will result in insignificant impacts. No additional impact on terrestrial or aquatic species or habitats will result from the logging or monitoring of exiting idle wells or other MVA activities. The VSP and repeat seismic survey will use similar minimal invasive procedures, with truck-mounted drill rig or similar conveyance. The planned monitoring or tracer injection operations have no surface impacts.

4.6 Socioeconomic Conditions

This section shall describe any increases/decreases in labor requirements or changes in labor mix.

The addition of the MVA activities to on-going Denbury EOR operations will result in no change in the labor force, employment, population, ethnic or cultural diversity, educational system, medical or emergency services, utility infrastructure, retail or wholesale markets, or other factors that would impact the socioeconomic characteristics of the area. The MVA activities will generally be temporary and require specialized personnel. The back plugging of existing wells and the drilling of shallow groundwater and soil-gas testing boreholes will be conducted by existing Denbury personnel or temporarily contracted companies that already service the oil and gas operations in the area.

Significant benefits to the local economy may result from the increased production from the EOR activities at the Hasting Oil Field and its potential use as a long-term CO_2 storage repository.

4.7 Historic/Cultural Resources

This section shall describe any disturbance to historical or archeological sites caused by construction, interference with Native American tribal or other religious practices or sites; impacts on local community character.

No locations listed on the National Registry Sites or other significant historical or archeological sites are located in or within 5 miles of the project area. No Native American or tribal interests have been identified. Although several local churches and cemeteries are located in the proximity of the project area, they should not be impacted by the MVA activities which will be a small, temporary aspect of the much larger commercial EOR operations and consistent with the common oil and gas practices in the local community.

4.8 Visual Resources

This section shall describe any impacts to scenic vistas or existing aesthetic landscaping.

No significant scenic vistas or outstanding aesthetic landscaping exist within the relatively flat coastal plain topography which has mostly been converted to pasture hay and cultivated crops, oil and gas production, or low to moderate density development. The MVA activities which will be very localized and temporary are consistent with existing and planned commercial oil and gas production operations in the area. No parks or other recreational areas that could be impacted by the MVA activities are located within the project area. The nearest public park, Friendswood Sports Park, is located approximately 1.4 miles southeast of the area. Several other small community parks are located from 2.5 – 4.0 miles away. The nearest major recreational areas are Brazos Bend State Park, 17 miles west-northwest, and Brazoria National Wildlife Refuge, 18 miles south.

4.9 Health and Safety Factors

This section shall discuss occupational hazards of project activities; exposure to toxic/hazardous substances; and increases in ambient noise, odor, and heat.

The potential health and safety hazards that may be present during MVA activities are consistent with those encountered in the oil and gas production industry. Denbury operations comply with all regulatory requirements of the Occupational Health and Safety Administration. Best management practices are implemented during all drilling, injection, monitoring, and other activities to avoid unnecessary hazards.
http://www.osha.gov/SLTC/oilgaswelldrilling/index.html

Transient noise from diesel engines (80 Db) during drilling operations should generally only be audible in the immediate proximity to an active drilling operation and is not at levels that could be considered a hazard with the use of appropriate industrial protection measures.

4.10 Solid and Hazardous Wastes

This section shall describe any and all waste material that is generated from project activities. This description shall include the source/type of any and all wastes produced (e.g., fly ash, bottom ash, scrubber sludge, etc.), and the approximate weight, density, and volume of the waste, and its method of disposal, location, and any permitting requirements necessary.

Minimal quantities of drilling mud and associated wastes generated during shallow water well drilling operations will be landfarmed on site in accordance with Texas Railroad Commission regulations (Texas Administrative Code Title 16, Rule 3.8). No other solid or hazardous waste will be produced during monitoring operations.

4.11 Impacts on Regional or Local Plans

This section shall describe any impacts to regional or local plans for fuel, water resources, solid waste, land, air quality, and labor force; commitment of resources and opportunities to reuse and recycle resources (wastes, water).

Brazoria County is included in the Houston-Galveston ozone nonattainment area and subject to the Texas State Implementation Plan (SIP) that imposes requirements on new and existing sources of ozone precursor emissions. Although a small amount of diesel emissions will be generated during drilling operations, they are considered to be below deminimus levels and are not included under any current control strategies. No other air emissions covered by the SIP will be emitted during MVA activities.

Two streams that intersect the Hasting project area, Chigger Creek and Cowart Creek, are listed as impaired for bacteria and are subject to current or planned Texas Maximum Daily Load (TMDL) plans to reduce contributing source contamination. Bacteria impairments primarily result from discharge from domestic wastewater and nonpoint source runoff from agricultural areas. None of the MVA activities will result in discharges to these water bodies and do not include activities that would cause bacterial contamination.

Denbury Resources has a **Waste Management / Minimization Plan** to provide guidance concerning the proper management and minimization of each type of waste stream generated by Denbury Onshore, LLC. An excerpt from that plan reads:

> *"Waste management includes the proper handling, accumulation, storage, transportation, and disposal of the waste generated. This section is designed to provide*

protection for the environment and comply with environmental laws and regulations regarding proper waste handling. The primary goal of this section is the reduction of generated waste at the source wherever possible. In the event source reduction is not feasible, recycling options will be the secondary goal. Denbury's mission is to eliminate the wastes requiring treatment and/or disposal to the best of its ability. "

"This section has been designed to assist field personnel and should provide the information needed to effectively practice waste minimization (i.e., source reduction and recycling) and management (i.e., treatment and disposal)."

No other regional or local plans exist in the project area.

4.12 Mitigation Measures

All MVA activities will be conducted in accordance with best operating practices, waste minimization, and other policies utilized by Denbury during normal oil exploration, development, and production operations to comply with all applicable regulations and minimize potential impacts. Existing idle or active wells being used as part of Denbury's existing commercial activities will be used for research MVA activities, if possible, to reduce the need for additional well completions. Existing water wells in the area will also be examined to determine if they can be used for groundwater monitoring to reduce or eliminate the need for additional well drilling. If new wells are required, existing pads will be used, if possible.

All MVA activities will be temporary and impacted areas will be protected, maintained, and restored in accordance with best practices for similar oil field operations.

5.0 POTENTIAL LIABILITY TO DOE OF EXISTING CONDITIONS AT THE SITE(S).

This section shall discuss any potential conditions for exposing the DOE to previous liability. It should detail any previous research, development, construction, and/or demonstration testing that could potentially have impacts on the existing project site(s) and therefore, the proposed project.

The Hastings Field is a mature oil & gas field. The field has changed ownership several times, but the primary operation of the field was to explore for, develop, and produce oil and natural gas. Numerous well bores were drilled and several production facilities were constructed throughout the life of the field in accordance with regulations of the Texas Railroad Commission. Any existing conditions would be typical for a mature and historically productive oil & natural gas field. Research activities which are integrated into existing commercial operations will result in minimal impact to the environment and community but will return maximum amounts of scientific data needed to assess the feasibility of geologic sequestration.

6.0 ABILITY TO MEET COMPLIANCE REQUIREMENTS AT THE SITE(S).

This section shall identify all of the environmental laws and regulations (Federal, state, and local) for which compliance would be necessary. It should include, but should not be limited to the Resource Conservation and Recovery Act, the Comprehensive Environmental Response, Compensation, and Liability Act, Toxic Substance Control Act, Water Pollution

Control Act, Clean Air Act, and Occupational Safety and Health Act. Any necessary permits, manifest, etc., shall be discussed.

The proposer's strategy for meeting all compliance requirements shall be discussed in detail. Identify the best available control technology and feasible practices for compliance with Federal air, land use, and water quality statutes. In addition, whether the proposed site is in attainment or non-attainment with current standards shall be discussed.

The Hastings MVA activities will not result in the use, production, or release of any chemicals or substances regulated under the Resource Conservation and Recovery Act; the Comprehensive Environmental Response, Compensation, and Liability Act; the Toxic Substance Control Act; or the Water Pollution Control Act. The Hastings project site is located in a Clean Air Act ozone nonattainment area; however, no permit or other regulatory requirements will be required for the types and quantities air pollutant emissions that will occur from the small, temporary drilling of monitoring wells or any other actions required for research MVA activities.

Denbury may be required to obtain a permit from the Texas Railroad Commission under Texas Administrative Code, Title 16, Chapter 3, to drill, deepen, reenter, or plug back any well to be used for MVA purposes. Wells used for injecting fluids, including wastewater, must obtain a Class II Underground Injection Control (UIC) permit from the Texas Railroad Commission. None of the MVA activities require injection that must be authorized under the UIC program.

Groundwater monitoring wells included in the research MVA activities are not required to be authorized under the UIC program. However, all water wells must be drilled by operators licensed by the Texas Department of Licensing and Regulation under Texas Administrative Code, Title 12, Chapter 1901.

Denbury complies with all requirements of the Occupational Safety and Health Act applicable to oil and gas exploration, development, and production.

7.0 EXPERIENCE AND APPROACH TO THE IDENTIFICATION AND RESOLUTION OF ENVIRONMENTAL ISSUES.

This section of the Environmental Volume shall consist of a discussion of the following areas:

1. All directly related education/experience of key project members in each of the following areas:

*** Air quality management**

*** Surface water and ground water management**

*** Solid and liquid waste management and disposal practices**

*** Noise, land use, ecological resources, archaeological, cultural, and historical resources management**

*** Environmental permit applications, amendments, and renewals**

The primary responsible official for regulatory compliance and permitting for the MVA will be Denbury's chief regulatory compliance officer, Linda Gruver (**Attachment 7.1**). Ms. Gruver has over 27 years of experience in maintaining regulatory compliance with large scale EOR and other oil and gas enterprises. She manages and monitors all aspects of regulatory compliance, both state and federal, for thousands of wells located in Texas, Louisiana and Mississippi.

Additionally, Ms. Gruver has two regulatory compliance professionals on staff to assist with Denbury's proactive oversight of compliance issues. Given the small scale of permitting and regulatory issues created by this MVA project (see Section 6 above) it is highly unlikely that Denbury's compliance team will encounter anything outside of their routine permitting and oversight duties.

Augmenting the regulatory capability of the Denbury team will be the MVA's lead researcher, Susan Hovorka, Ph.D. (**Attachment 7.1**). Dr. Hovorka has successfully overseen the permitting and research on numerous DOE funded CO_2 sequestration projects (Frio Brine experiment, SECARB Phase II, and SECARB Phase III Early Test). These projects are directly correlated to the MVA in Hastings and thus create well matched experience for the environmental and regulatory issues that will be encountered.

2. The offeror's experience in addressing and resolving environmental concerns during the performance of past projects of similar size and complexity including the obtaining of necessary permits.

See 7.1 above

3. Any of the offeror's existing written environmental policies, procedures, or plans currently in place and considered essential to the conduct of the offeror's commercial business operation.

See Part 1, Section 4.0

8.0 REFERENCES

Alabama Coushatta Indian Tribe (ACIT), 2010, personal communications with Bryant Celestine, Tribal Historian, February 12, 2010.

Baker, E.T., Jr., 1979, Stratigraphic and hydrogeologic framework of part of the Coastal Plain of Texas: TDWR Rept. 236, 43 p.

Brazoria County Groundwater Conservation District (BCGCD), 2008, Rules adopted May 8, 2008, http://bcgroundwater.org/documents/BCGCD%20RULES%20&%20REGS%20_as%20amended%205-8-08_.pdf.

Federal Emergency Management Agency (FEMA), 2010, Map Service Center, http://msc.fema.gov/webapp/wcs/stores/servlet/FemaWelcomeView?storeId=10001&catalogId=10001&langId=-1, (accessed February 18, 2010).

Houston-Galveston Area Council (H-GAC), 2010, Socioeconomic Modeling Group, Regional Data and GIS Services, http://www.h-gac.com/rds/census/default.aspx, (accessed February 21, 2010).

Hitchon, Brian, ed., 1996, Aquifer disposal of carbon dioxide: hydrodynamic and mineral trapping—proof of concept: Sherwood Park, Alberta, Canada, Geoscience Publishing Ltd..

Intergovernmental Panel on Climate Change, 2001, Climate change 2001: working group I: the scientific basis, Chapter 3 The Carbon Cycle and Atmospheric Carbon Dioxide, http://www.grida.no/climate/ipcc_tar/wg1/095.htm.

Keeling, C.D., and W horf, T.P., 2002, Atm ospheric CO_2 reco rds fro m sites in the SIO air sampling network, *in* Trends: a compendium of data on global change: Oak Ridge, TN, U.S. Departm ent of Energy, Oak Ridge National L aboratory, Carbon Dioxide Information Analysis Center, http://cdiac.esd.ornl.gov/trends/co2/sio-mlo.htm.

National Climatic Data Center (NCDC), 2010, U.S. Department of Commerce, http://www.ncdc.noaa.gov/oa/ncdc.html (accessed February 15, 2010).

National Energy Policy Development Group, 2001, http://www.fe.doe.gov/general/energypolicy/chapter3.pdf.

Natural Resources Conservation Service (NRCS), 2010, U.S. Department of Agriculture, National Cooperative Soil Survey, http://websoilsurvey.nrcs.usda.gov/app/, (accessed February 15, 2010).

Texas Commission on Environmental Quality (TCEQ), 2010a, Yearly Summary Report by Site, http://www.tceq.state.tx.us/cgi-bin/compliance/monops/select_year.pl?region12.gif, (accessed February 17, 2010).

Texas Commission on Environmental Quality (TCEQ), 2010b, Texas Integrated Report for Clean Water Act Sections 305(b) and 303(d), http://www.tceq.state.tx.us/compliance/monitoring/water/quality/data/wqm/305_303.html#fy2008 (accessed February 18, 2010).

Texas Commission on Environmental Quality (TCEQ), 2010c, Water Utilities Map Viewer, http://gis3.tceq.state.tx.us/iWudSpatialEx/Controller/?ccn=&zipCode, (accessed February 24, 2010).

Texas Historical Commission (THC), 2010, Texas Historic Sites Atlas, http://atlas.thc.state.tx.us/, (accessed February 22, 2010).

Texas Parks and Wildlife Department (TPWD), 2010a, Wildlife Division, Wildlife Management Districts, http://www.tpwd.state.tx.us/landwater/land/habitats/oak_prairie/, (accessed February 20, 2010).

Texas Parks and Wildlife Department (TPWD), 2010b, Rare, Threatened and Endangered Species by County, http://www.tpwd.state.tx.us/landwater/land/maps/gis/ris/endangered_species/, Last Updated: February 2, 2010.

Texas Parks and Wildlife Department (TPWD), 2010c, Texas Natural Diversity Database (TXNDD), GIS files provided on February 19, 2010, personal contact with Ms. Dorinda Scott.

Texas State Historical Association (TSHA), 2010a, *Handbook of Texas Online*, s.v., http://www.tshaonline.org/handbook/online/articles/HH/doh1.html (accessed February 12, 2010).

Texas State Historical Association (TSHA), 2010b, The Handbook of Texas Online, http://www.tshaonline.org/, (accessed February 22, 2010).

U.S. Census Bureau, 2010, 2006-2008 American Community Survey, Fact Sheet, Brazoria County, Texas
http://factfinder.census.gov/servlet/ACSSAFFFacts?_event=Search&geo_id=&_geoContext=&_street=&_county=Brazoria+County&_cityTown=Brazoria+County&_state=04000US48&_zip=&_lang=en&_sse=on&pctxt=fph&pgsl=010 (accessed February 25, 2010).

U.S. Climate Change Science Program / U.S. Global Change Research, 2003, U.S. national assessment of the potential consequences of climate variability and change educational resources, http://www.usgcrp.gov/usgcrp/nacc/education/default.htm.

U.S. Department of Energy, 1999, Carbon Sequestration—Research and Development, http://www.fe.doe.gov/coal_power/sequestration/reports/rd/index.shtml.

U.S. Environmental Protection Agency (EPA), 2010, Region 6 Office of Environmental Justice and Tribal Affairs, Dallas, Texas, personal communications with Jay Harris, GAP Project Officer and Tribal Liaison, February 12, 2010.

U.S. Fish & Wildlife Service (USFWS), 2010, National Wetland Inventory Mapper http://www.fws.gov/wetlands/Data/Mapper.html, (accessed February 18, 2010).

LIST OF ATTACHMENTS

Attachment 3.1.1

Hastings MVA Project Area
Denbury Onshore, LLC Pipeline Distribution Maps
- West Hastings RRC Pipeline Map
  - Brazoria County, Texas
- HP Gas Lift Lines
- Low Pressure Gas Collection Lines
- Production Water Lines & Saltwater Transfer Lines
- TexCal Energy Power Distribution Map

Attachment 3.2.1

Hastings MVA Project Area
Air Quality Monitoring Data
- Description of Closest Monitoring Sites and Hourly Ozone Data for 2009
  - Clear Brook High School (C570)
  - Manvel Croix Park (C84)
  - Mustang Bayou (C619)

Fourth Highest Annual Ozone Values for Monitors in
Houston-Galveston-Brazoria Nonattainment Area, 2007-2009

Attachment 3.3.1

Hastings MVA Project Area
Listing of Public Water System Wells

Attachment 3.4.1

Hastings MVA Project Area
Detailed Soil Type Descriptions
- Bernard Clay Loam
- Bernard-Edna Complex
- Lake Charles Clay

Attachment 3.5.1

Hastings MVA Project Area
Listing of State and Federal Rare, Threatened, and Endangered Species
In Brazoria County

Attachment 7.1

Hastings MVA Project
Qualifications of Key Team Members
- Linda Gruver, Denbury Onshore, LLC
- Susan Hovorka, Ph.D., Bureau of Economic Geology, University of Texas at Austin

Attachment 3.1.1
Hastings MVA Project Area
Denbury Onshore, LLC Pipeline Distribution Maps

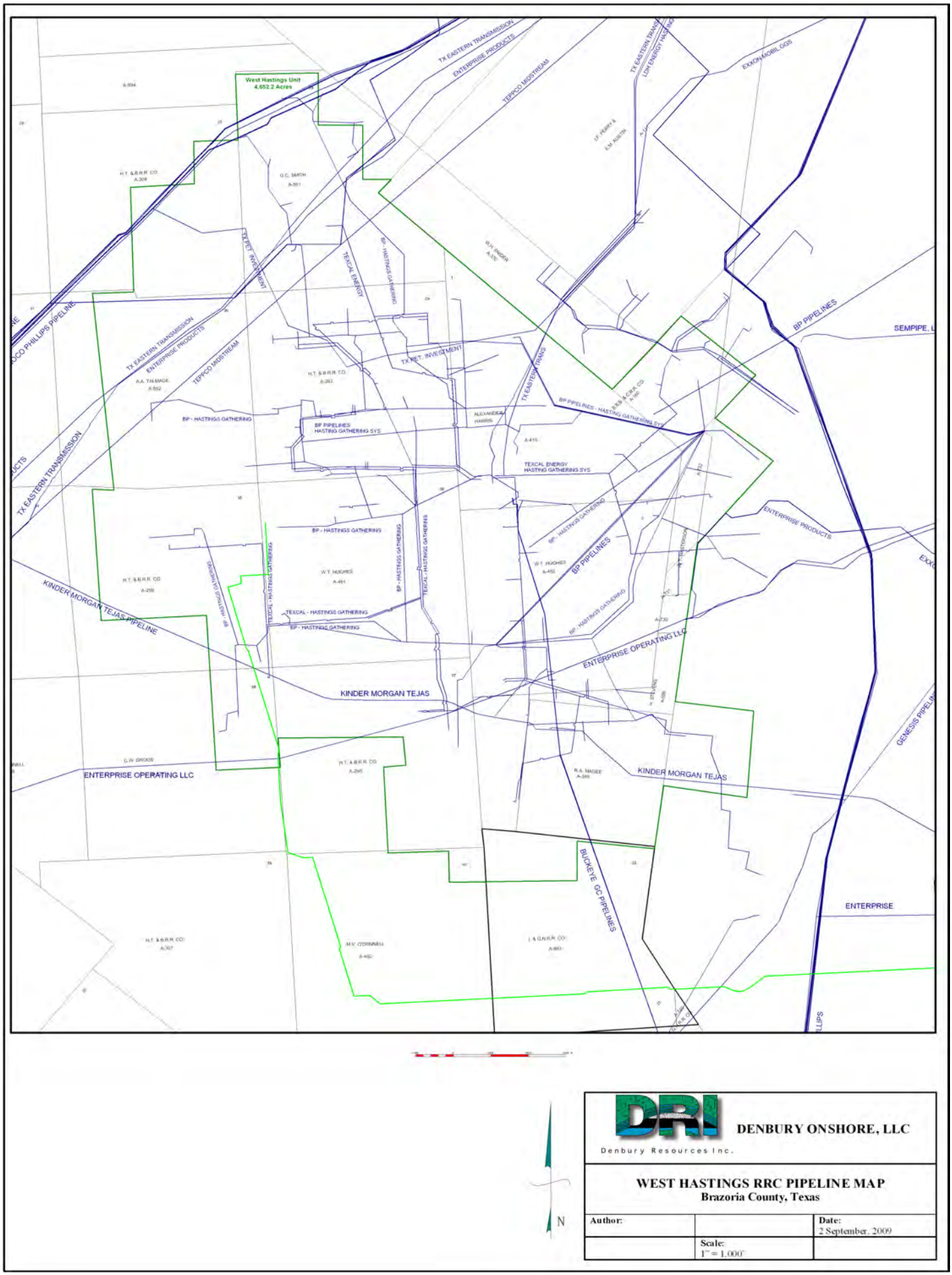
West Hastings RRC Pipeline Map
Brazoria County, Texas

HP Gas Lift Lines

Low Pressure Gas Collection Lines

Production Water Lines & Saltwater Transfer Lines

TexCal Energy Power Distribution Map

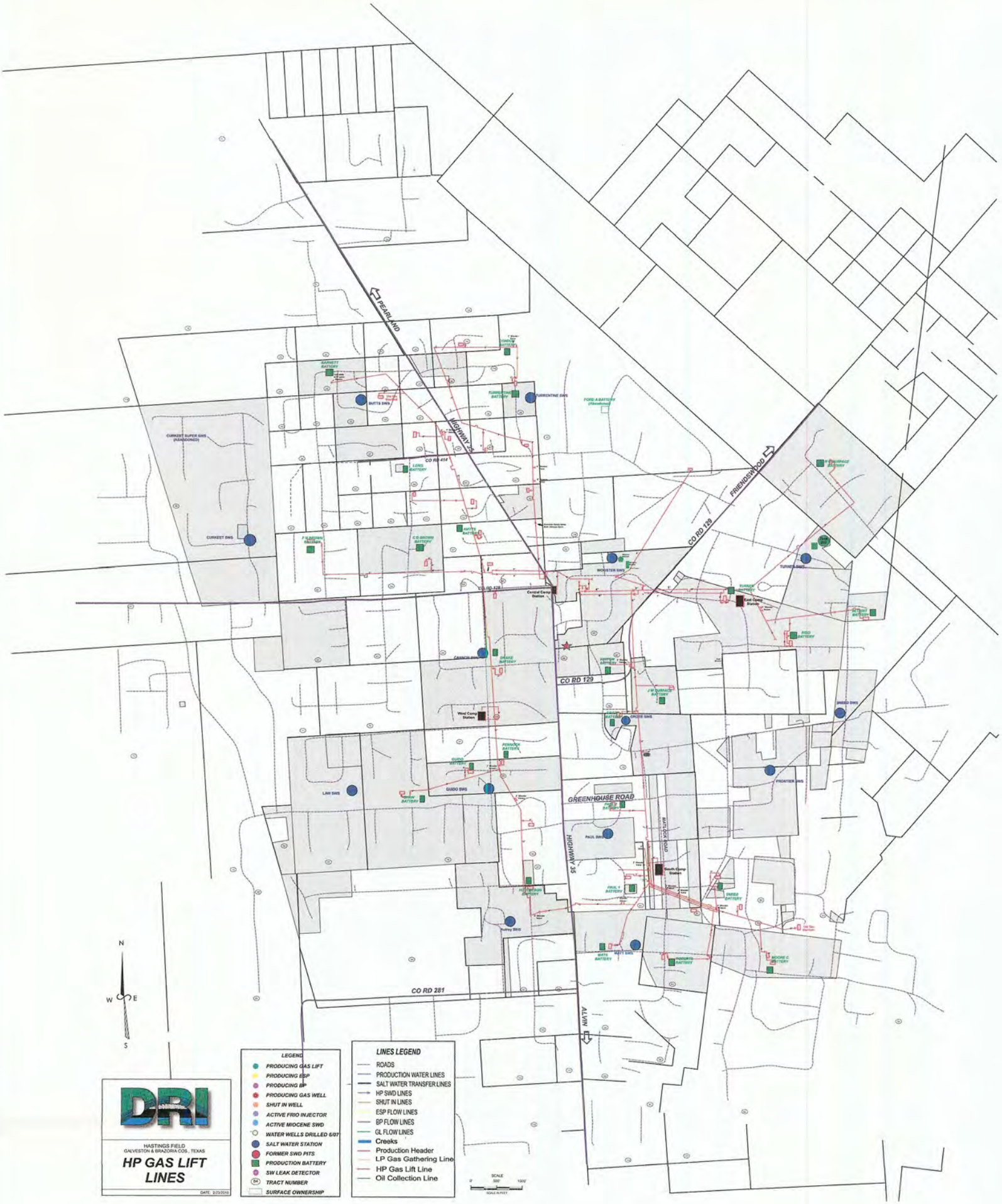


DENBURY ONSHORE, LLC

Denbury Resources Inc.

WEST HASTINGS RRC PIPELINE MAP
Brazoria County, Texas

Author:		Date: 2 September, 2009
	Scale: 1" = 1,000'	


PEARLAND
HIGHWAY 35
FRIENDSWOOD
CO RD 139
CO RD 129
GREENHOUSE ROAD
CO RD 281
ALVIN
HIGHWAY 35
CURKEET SWD (ABANDONED)
CURKEET SWD
BUTTS SWD
BURRITINE SWD
WOOSTER SWD
TURNER SWD
CASSICK SWD
GROSS SWD
GUIDO SWD
LAW SWD
PAUL SWD
FRONTIER SWD
INEED SWD
Central Camp Station
East Camp Station
Wood Camp Station
South Camp Station
Turney SWD
MOTT SWD
MOORE C
N
W
E
S
LEGEND
PRODUCING GAS LIFT
PRODUCING ESP
PRODUCING BP
PRODUCING GAS WELL
SHUT IN WELL
ACTIVE FRIO INJECTOR
ACTIVE MIOCENE SWD
WATER WELLS DRILLED 5/07
SALT WATER STATION
FORMER SWD PITS
PRODUCTION BATTERY
SW LEAK DETECTOR
TRACT NUMBER
SURFACE OWNERSHIP
LINES LEGEND
ROADS
PRODUCTION WATER LINES
SALT WATER TRANSFER LINES
HP SWD LINES
SHUT IN LINES
ESP FLOW LINES
BP FLOW LINES
GL FLOW LINES
Creeks
Production Header
LP Gas Gathering Line
HP Gas Lift Line
Oil Collection Line
SCALE
DRI
HASTINGS FIELD
GALVESTON & BRAZORIA COS., TEXAS
HP GAS LIFT LINES
DATE: 2/23/2010

PEARLAND

CONDON BATTERY

BARNETT BATTERY

BUTTS SWS

TURRENTINE BATTERY

TURRENTINE SWS

FORD A BATTERY (Abandoned)

HIGHWAY 35

CURKEET SUPER SWS (ABANDONED)

CO RD 414

LONG BATTERY

FRIENDSWOOD

CO RD 129

H O SURFACE BATTERY

CURKEET SWS

AWITS BATTERY

F N BROWN BATTERY

C D BROWN BATTERY

WOOSTER SWS

TURNER SWS

TURNER BATTERY

East Comp Station

BLOUNT BATTERY

KIDD BATTERY

CO RD 128

Central Comp Station

CANNON SWS

DRAKE BATTERY

WINTON BATTERY

CO RD 129

J W SURFACE BATTERY

SNEED SWS

GROTE BATTERY

GROTE SWS

West Comp Station

PENNOCK BATTERY

GUIDO BATTERY

FRONTIER SWS

LAW SWS

GUIDO SWS

SHAW BATTERY

GREENHOUSE ROAD

PAUL 2 BATTERY

MATLOCK ROAD

HIGHWAY 35

PAUL SWS

South Comp Station

PAUL 1 BATTERY

HUTCHISON BATTERY

SNEED BATTERY

Autrey SWS

MATS BATTERY

MATT SWS

ROBERTS BATTERY

MOORE C BATTERY

CO RD 281

ALVIN

N

W E

S

DRI

HASTINGS FIELD
GALVESTON & BRAZORIA COS., TEXAS

Low Pressure Gas Collection Lines

DATE: 2/23/2010

LEGEND

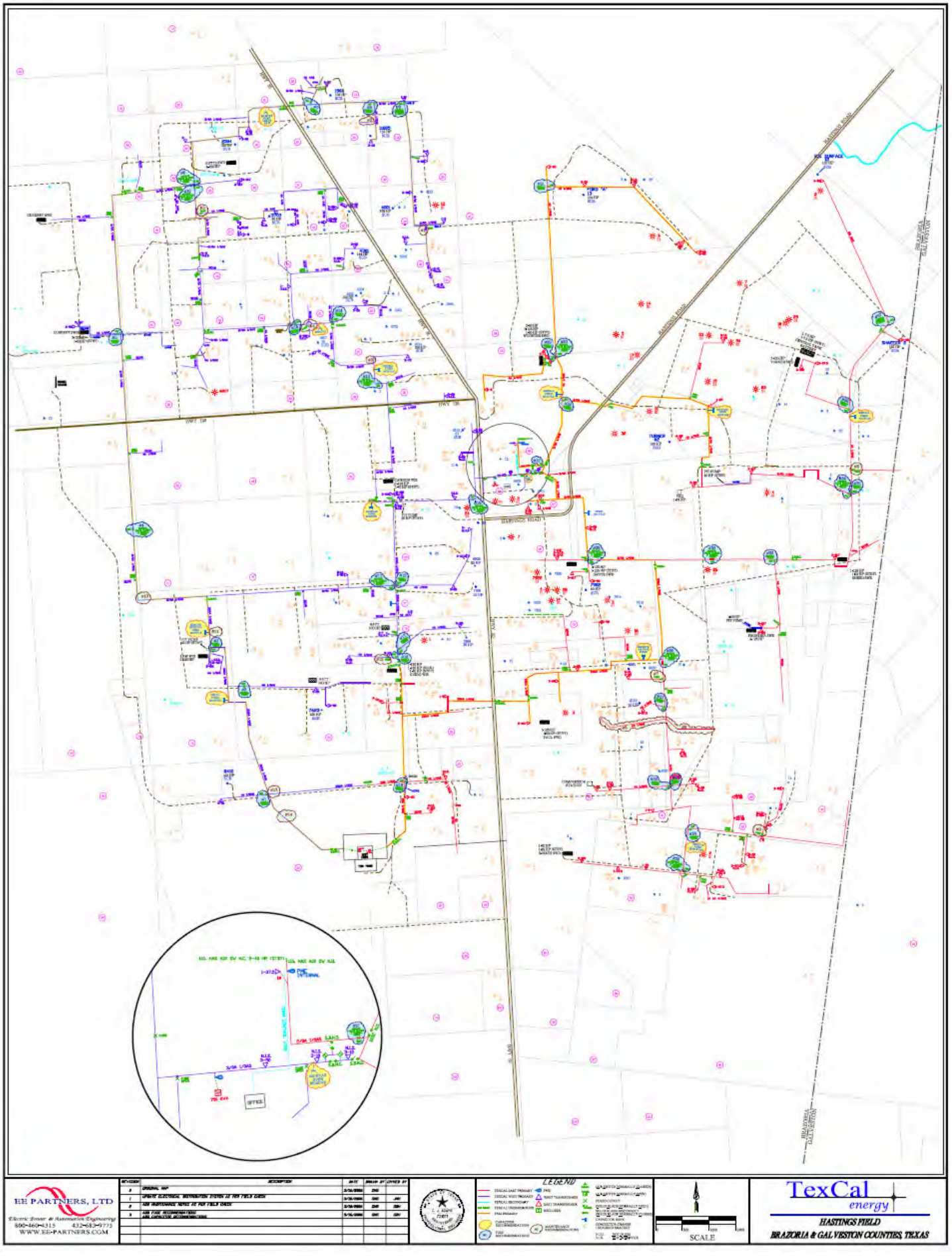
- PRODUCING GAS LIFT
- PRODUCING ESP
- PRODUCING BP
- PRODUCING GAS WELL
- SHUT IN WELL
- ACTIVE FRIO INJECTOR
- ACTIVE MIOCENE SWD
- WATER WELLS DRILLED 6/07
- SALT WATER STATION
- FORMER SWD PITS
- PRODUCTION BATTERY
- SW LEAK DETECTOR
- 84 TRACT NUMBER
- SURFACE OWNERSHIP

LINES LEGEND

- ROADS
- PRODUCTION WATER LINES
- SALT WATER TRANSFER LINES
- HP SWD LINES
- SHUT IN LINES
- ESP FLOW LINES
- BP FLOW LINES
- GL FLOW LINES
- Creeks
- Production Header
- LP Gas Gathering Line
- HP Gas Lift Line
- Oil Collection Line

SCALE
0' 500' 1000'
SCALE IN FEET

PEARLAND
HIGHWAY 35
CO RD 414
CO RD 129
FRIENDSWOOD
CO RD 128
CO RD 129
GREENHOUSE ROAD
HIGHWAY 35
CO RD 281
ALVIN
N
W
E
S
LEGEND
PRODUCING GAS LIFT
PRODUCING ESP
PRODUCING BP
PRODUCING GAS WELL
SHUT IN WELL
ACTIVE FRIO INJECTOR
ACTIVE MIOCENE SWD
WATER WELLS DRILLED 6/07
SALT WATER STATION
FORMER SWD PITS
PRODUCTION BATTERY
SW LEAK DETECTOR
TRACT NUMBER
SURFACE OWNERSHIP
LINES LEGEND
ROADS
PRODUCTION WATER LINES
SALT WATER TRANSFER LINES
HP SWD LINES
SHUT IN LINES
ESP FLOW LINES
BP FLOW LINES
GL FLOW LINES
Creeks
Production Header
LP Gas Gathering Line
HP Gas Lift Line
Oil Collection Line
SCALE
DRI
HASTINGS FIELD
GALVESTON & BRAZORIA COS., TEXAS
Production Water Lines &
Saltwater Transfer Lines
DATE: 2/23/2010


EE PARTNERS, LTD
Electric Power & Automation Engineering
800-460-6315 432-683-9775
WWW.EE-PARTNERS.COM
LEGEND
SCALE
TexCal energy
HASTINGS FIELD
BRAZORIA & GALVESTON COUNTIES, TEXAS

Attachment 3.2.1
Hastings MVA Project Area
Air Quality Monitoring Data

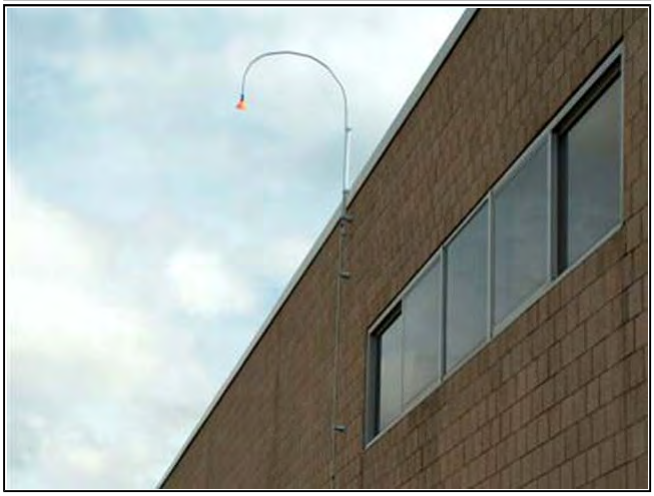
Description of Closest Monitoring Sites and Hourly Ozone Data for 2009
Clear Brook High School (C570)
Manvel Croix Park (C84)
Mustang Bayou (C619)

Fourth Highest Annual Ozone Values for Monitors in
Houston-Galveston-Brazoria Nonattainment Area, 2007-2009

Clear Brook High School C570

CAMS 570 Clear Brook High School C570

- EPA site number: 48-201-0570
- State: Texas
- County: Harris
- City: Friendswood
- Address: 4607 FM 2351
- Site coordinates:
  - Latitude: 29° 32' 56" North (+29.548889°)
  - Longitude: 95° 11' 07" West (-95.185278°)
  - Elevation: 14 m (46 ft)
- Maintained by: University of Clear Lake-Environmental Institute of Houston (Dios Dado-Contractor) Funding provided in part by the Houston Endowment Air Quality Initiative

Area Map	Overall site view	Street level Map
Northwest	North	Northeast
West		East
Southwest	South	Southeast

Current Measurements at Clear Brook High School C570

Monthly Summary Report for Parameters at Clear

Brook High School C570

Yearly Summary Report for Parameters at Clear Brook High School C570

- Real-time monitoring since: Friday, September 12, 2003
- Current status: Active
- Continuous monitors located at this site:
  - Met Data
  - Ozone
- Parameters currently being monitored:
  - Pollution parameters:
    - Ozone
  - Meteorological parameters:
    - Wind Speed
    - Resultant Wind Speed
    - Resultant Wind Direction
    - Maximum Wind Gust
    - Standard Deviation of Horizontal Wind Direction
    - Outdoor Temperature
    - Dew Point Temperature
    - Relative Humidity
    - Solar Radiation
    - Precipitation

PLEASE NOTE: This data has not been verified by the TCEQ and may change. This is the most current data, but it is not official until it has been certified by our technical staff. Data is collected from TCEQ ambient monitoring sites and may include data collected by other outside agencies. This data is updated hourly. All times shown are in Local Standard Time.

©2002-2004 Texas Commission on Environmental Quality.

CAMS 570 Ozone Summary Report for 2009
Clear Brook High School
C570 - EPA Site:

Ozone (POC 1) measured in parts per billion

Data from this instrument does not meet EPA quality assurance criteria and cannot be used for regulatory purposes.

Date	Central Standard Time																									
	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	High	2nd High
1/1/2009	23	23	22	21	17	15	15	11	9	13	14	19	23	28	33	34	34	29	27	19	17	19	21	26	34	
1/2/2009	20	18	16	15	17	14	14	15	14	17	18	20	20	23	23	22	21	17	15	13	14	14	14	14	23	
1/3/2009	14	15	16	15	14	13	16	15	17	23	27	27	27	26	25	25	24	22	20	18	18	17	18	17	27	
1/4/2009	17	16	17	17	17	15	15	15	16	17	18	21	24	24	21	17	10	5	1	6	6	7	9	10	24	
1/5/2009	10	10	11	10	10	7	4	2	2	3	3	2	2	2	2	2	1	0	0	0	0	0	0	0	11	
1/6/2009	0	0	0	0	0	0	0	0	0	0	0	3	5	6	5	10	11	15	9	9	13	11	16	19	19	
1/7/2009	24	26	22	18	15	11	1	1	3	13	25	32	34	38	42	44	43	40	37	37	32	35	35	33	44	
1/8/2009	31	29	22	21	23	22	15	3	5	QAS	QAS	31	36	40	42	45	43	36	30	26	29	26	23	26	45	
1/9/2009	26	27	28	30	30	30	29	26	30	37	43	46	47	46	44	41	37	35	34	31	28	25	23	21	47	
1/10/2009	22	22	22	20	18	16	14	12	13	11	10	11	11	12	14	14	16	16	17	20	19	20	20	21	22	
1/11/2009	21	21	21	20	19	19	19	18	19	21	22	24	27	28	31	33	33	25	9	1	1	1	2	1	33	
1/12/2009	0	0	0	0	0	0	0	0	1	15	30	31	32	38	39	40	39	31	17	5	0	0	3	4	40	
1/13/2009	1	0	4	0	11	12	13	10	18	21	24	26	29	30	31	33	30	27	22	14	5	3	3	5	33	
1/14/2009	3	5	2	1	1	0	0	0	2	12	22	28	32	32	33	40	34	30	16	1	2	2	0	0	40	
1/15/2009	0	0	0	0	0	0	0	0	0	5	24	35	42	48	51	54	54	48	28	18	24	26	22	24	54	
1/16/2009	23	21	17	19	18	12	14	12	20	22	23	23	23	26	29	28	28	24	22	14	6	4	3	1	29	
1/17/2009	2	0	0	0	0	8	9	2	5	23	41	45	46	46	46	45	44	41	37	32	30	28	27	20	46	
1/18/2009	13	22	23	19	18	21	21	22	22	24	29	35	39	41	43	44	43	41	38	24	19	12	9	8	44	
1/19/2009	6	10	18	20	22	24	21	18	20	24	28	32	35	38	38	37	39	36	35	28	26	23	20	17	39	
1/20/2009	19	12	9	11	19	8	2	3	5	20	30	33	35	37	35	36	35	31	20	15	11	19	16	5	37	
1/21/2009	8	6	7	2	1	1	0	0	2	20	33	39	45	46	54	50	48	46	42	37	31	33	31	28	54	
1/22/2009	30	31	30	30	25	15	1	1	11	30	37	44	47	37	38	39	40	38	35	31	26	24	27	31	47	
1/23/2009	32	32	30	26	24	24	21	17	23	30	39	41	42	42	41	41	39	37	35	31	27	25	27	29	42	
1/24/2009	28	27	23	18	14	15	16	11	11	10	11	13	18	22	24	23	20	18	18	17	15	15	14	16	28	
1/25/2009	17	14	12	11	11	9	9	10	10	9	11	12	11	12	14	16	15	14	13	12	12	11	8	10	17	

Date	Central Standard Time																									
	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	High	2nd High
1/26/2009	11	11	13	16	20	17	16	13	13	15	20	25	33	34	34	35	35	34	32	32	32	31	31	33	35	
1/27/2009	30	29	28	27	26	26	24	22	22	29	32	33	35	34	34	32	31	30	26	6	0	0	0	0	35	
1/28/2009	1	2	1	2	3	6	4	4	3	6	7	12	14	17	18	22	19	16	7	2	0	0	0	1	22	
1/29/2009	8	9	6	2	1	0	0	0	3	11	18	23	32	35	35	39	38	22	10	3	2	11	13	16	39	
1/30/2009	17	15	12	13	8	2	0	0	6	32	33	36	46	42	32	36	35	34	11	33	33	34	34	33	46	
1/31/2009	33	33	33	32	27	19	15	13	20	28	38	45	48	51	52	55	53	50	44	40	39	39	34	27	55	
2/1/2009	21	25	30	34	35	40	40	38	36	38	41	41	41	41	40	40	39	36	34	31	27	25	15	12	41	
2/2/2009	19	21	21	20	17	25	27	19	18	28	37	39	40	41	41	41	40	35	28	16	3	4	5	2	41	
2/3/2009	1	2	1	0	0	0	0	0	3	20	33	38	42	42	43	46	46	37	39	34	27	25	29	33	46	
2/4/2009	27	15	8	4	23	25	18	12	23	24	24	29	31	35	40	40	39	35	30	23	13	7	10	5	40	
2/5/2009	7	6	8	10	12	8	1	1	10	30	40	44	45	46	47	45	44	43	41	36	33	33	33	34	47	
2/6/2009	33	32	31	32	30	27	19	18	29	40	43	44	44	44	44	45	45	44	42	41	40	41	41	42	45	
2/7/2009	42	43	43	42	40	40	39	40	40	42	44	44	43	43	42	41	42	41	38	35	33	35	35	35	44	
2/8/2009	33	33	31	29	27	21	16	17	26	32	36	39	41	41	40	41	41	39	38	38	38	37	36	36	41	
2/9/2009	36	36	37	36	36	34	32	30	29	32	32	34	34	33	35	36	36	35	33	31	30	30	30	30	37	
2/10/2009	29	29	28	28	26	25	24	22	29	34	35	35	34	34	32	31	30	29	29	28	28	27	28	29	35	
2/11/2009	27	34	47	42	38	32	24	20	24	QAS	QAS	31	34	37	37	40	39	32	15	0	2	0	3	2	47	
2/12/2009	3	1	0	0	0	0	0	0	5	24	38	46	48	49	49	50	52	53	51	48	47	48	49	46	53	
2/13/2009	43	37	32	38	34	32	25	19	15	12	20	21	21	22	20	20	19	17	13	12	12	13	10	12	43	
2/14/2009	11	11	13	11	8	5	11	17	17	23	27	34	35	29	26	25	21	20	19	14	10	15	16	16	35	
2/15/2009	14	15	9	8	9	10	11	12	13	16	17	21	27	30	37	41	39	35	28	20	27	34	35	35	41	
2/16/2009	33	32	29	27	26	23	17	22	27	33	35	36	41	46	48	44	41	41	39	37	41	40	40	40	48	
2/17/2009	39	37	39	40	36	31	30	26	30	39	43	44	43	42	42	40	38	35	35	33	32	31	31	28	44	
2/18/2009	27	26	22	21	22	20	18	15	15	13	18	19	19	17	14	18	17	14	8	9	10	5	3	2	27	
2/19/2009	4	15	26	21	22	28	19	14	27	36	41	44	44	47	47	47	46	41	37	35	32	24	13	16	47	
2/20/2009	15	21	21	21	11	6	0	2	15	37	40	45	50	54	49	50	50	48	45	36	34	27	23	20	54	
2/21/2009	17	23	30	34	36	35	32	33	35	45	47	48	49	47	33	29	25	29	34	40	38	36	35	36	49	
2/22/2009	37	38	35	35	28	29	15	9	31	36	38	42	42	44	46	49	47	43	32	19	1	1	0	0	49	
2/23/2009	1	0	9	16	7	1	0	2	24	32	35	40	45	50	51	53	53	49	44	38	33	30	30	29	53	
2/24/2009	33	31	30	31	30	25	12	4	24	41	44	45	45	45	44	44	44	45	39	34	32	30	31	32	45	
2/25/2009	32	32	32	32	31	30	29	29	33	38	40	40	40	34	32	33	33	34	31	31	31	31	32	31	40	

Date	Central Standard Time																									
	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	High	2nd High
2/26/2009	32	32	31	31	31	31	29	25	30	34	35	34	33	32	32	31	31	30	29	28	27	27	27	25	35	
2/27/2009	23	22	23	25	25	24	24	23	24	25	27	29	29	29	29	29	31	31	31	32	30	29	27	24	32	
2/28/2009	23	21	18	16	14	12	14	9	12	14	16	21	26	31	38	43	42	41	40	38	36	35	33	33	43	
3/1/2009	32	32	30	30	29	30	29	29	30	32	33	37	41	43	45	44	44	41	39	31	23	16	11	18	45	
3/2/2009	26	28	26	19	13	8	0	2	18	31	43	42	49	42	37	38	39	47	64	57	55	51	43	24	64	
3/3/2009	21	18	6	5	9	12	18	24	31	32	38	47	51	56	57	58	57	57	51	45	40	38	40	38	58	
3/4/2009	36	38	42	43	39	39	26	20	28	42	50	52	53	51	51	50	50	49	46	43	43	43	44	43	53	
3/5/2009	43	43	43	42	40	36	32	31	34	40	42	42	42	40	40	39	40	39	38	35	35	35	33	33	43	
3/6/2009	34	34	33	31	29	27	25	21	32	37	40	41	41	40	39	37	37	36	33	32	32	31	31	31	41	
3/7/2009	30	29	30	29	30	30	29	28	31	36	38	39	38	37	36	35	34	34	33	32	32	31	31	30	39	
3/8/2009	30	30	28	28	27	24	20	10	29	35	38	39	40	40	40	39	39	37	35	35	34	31	33	32	40	
3/9/2009	31	29	28	27	27	26	25	27	29	32	35	36	38	38	39	38	37	38	38	40	37	34	32	31	40	
3/10/2009	30	29	29	29	28	27	27	26	30	34	37	39	39	37	36	37	36	35	32	30	30	29	30	31	39	
3/11/2009	30	30	29	28	28	27	25	25	25	35	39	40	40	40	41	42	42	40	23	9	13	17	17	19	42	
3/12/2009	20	26	27	26	23	19	16	12	12	13	11	10	9	9	6	8	8	10	9	12	14	14	15	14	27	
3/13/2009	13	13	11	11	10	8	6	7	9	12	9	10	7	7	6	7	7	8	8	8	6	5	4	4	13	
3/14/2009	3	5	6	7	8	8	7	5	5	6	6	5	6	8	8	6	7	5	2	1	1	3	7	8	8	
3/15/2009	10	10	9	9	9	8	7	8	12	15	15	17	17	15	20	21	17	13	8	3	4	3	5	4	21	
3/16/2009	4	6	6	4	1	0	0	0	4	13	22	30	31	39	55	66	66	56	40	28	17	27	20	7	66	
3/17/2009	4	2	0	6	20	18	17	16	16	21	23	31	34	38	40	42	42	41	33	22	19	16	13	6	42	
3/18/2009	3	2	5	5	1	1	0	1	7	35	41	47	49	50	50	51	52	53	50	46	38	25	20	15	53	
3/19/2009	10	6	5	5	12	7	0	1	5	26	49	53	58	56	56	58	57	57	54	42	6	1	9	13	58	
3/20/2009	9	8	10	8	1	0	0	5	32	37	43	50	61	66	65	66	60	56	52	46	39	41	33	18	66	
3/21/2009	11	14	15	6	5	1	0	3	31	54	61	62	62	65	65	65	65	60	59	48	42	34	33	32	65	
3/22/2009	32	38	31	32	30	30	30	24	42	55	58	59	58	59	58	55	54	51	49	44	42	49	48	51	59	
3/23/2009	51	50	50	50	49	46	47	48	51	53	52	51	48	45	46	46	43	40	39	37	38	37	37	37	53	
3/24/2009	37	38	37	36	35	35	33	36	39	41	42	41	40	39	39	37	37	36	34	33	32	29	28	28	42	
3/25/2009	27	26	25	26	27	21	12	18	22	29	27	33	37	38	37	36	35	33	29	27	23	29	31	31	38	
3/26/2009	33	33	32	30	30	26	24	25	22	22	21	25	30	28	25	28	26	26	23	26	26	24	22	23	33	
3/27/2009	27	27	22	16	12	10	1	3	18	22	25	27	26	19	20	24	28	30	23	19	32	30	33	32	33	
3/28/2009	32	33	33	33	35	38	40	41	41	41	42	44	46	48	49	50	50	49	48	41	40	38	31	15	50	

Date	Central Standard Time																									
	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	High	2nd High
3/29/2009	11	5	7	11	21	13	7	19	41	43	48	48	57	63	59	55	59	58	52	47	46	42	34	37	63	
3/30/2009	40	36	37	35	33	23	10	35	50	54	55	54	53	52	50	47	48	47	46	44	42	42	40	39	55	
3/31/2009	39	36	35	35	33	27	18	16	14	23	29	36	45	42	37	42	48	47	39	26	18	23	20	24	48	
4/1/2009	30	36	35	38	37	29	27	32	40	40	42	48	48	49	51	48	50	48	43	40	35	31	31	31	51	
4/2/2009	27	29	29	31	27	24	20	33	31	34	52	55	56	53	55	54	54	53	51	48	46	46	48	47	56	
4/3/2009	45	43	41	37	30	27	29	33	44	53	59	56	59	62	65	70	69	66	61	58	50	36	24	22	70	
4/4/2009	30	38	35	33	35	36	30	35	52	56	59	60	57	54	52	52	52	50	48	44	42	43	45	45	60	
4/5/2009	42	42	41	38	34	29	26	24	28	35	39	41	49	57	57	56	53	50	47	45	46	45	44	43	57	
4/6/2009	43	43	43	43	41	37	35	34	35	35	37	40	43	45	47	49	50	49	49	47	45	41	40	31	50	
4/7/2009	27	25	19	14	8	7	4	11	20	36	43	46	49	51	56	58	58	56	51	29	50	47	44	42	58	
4/8/2009	36	32	41	44	41	37	15	33	47	53	56	57	55	54	53	53	52	50	49	46	42	39	42	44	57	
4/9/2009	43	44	43	39	39	38	37	39	QAS	QAS	37	38	38	39	40	40	39	36	35	35	36	35	36	35	44	
4/10/2009	36	35	35	39	41	39	35	35	42	43	46	51	65	80	68	60	62	53	45	43	42	41	41	37	80	
4/11/2009	38	38	41	41	42	41	39	37	38	38	40	45	50	50	52	52	48	44	45	46	49	52	52	53	53	
4/12/2009	49	42	37	33	28	23	20	20	19	21	22	25	34	41	51	56	61	61	57	39	31	23	19	10	61	
4/13/2009	7	2	4	5	12	17	16	22	26	35	41	48	51	53	55	54	53	52	48	44	42	41	40	44	55	
4/14/2009	41	35	32	26	10	4	2	26	41	43	56	55	61	62	63	70	68	66	55	48	31	17	25	27	70	
4/15/2009	25	19	14	12	6	2	0	7	40	53	60	62	61	56	56	57	56	54	52	50	50	49	49	52	62	
4/16/2009	49	46	47	45	42	42	44	47	50	54	56	56	57	60	60	60	56	56	54	53	49	50	51	47	60	
4/17/2009	44	44	43	45	44	43	40	41	41	42	42	42	44	45	46	44	25	25	31	34	37	40	38	38	46	
4/18/2009	38	36	32	35	33	34	34	35	34	33	33	35	35	37	38	35	40	34	37	38	33	27	25	24	40	
4/19/2009	25	25	28	32	35	34	32	30	30	31	36	50	57	60	62	61	59	59	57	52	42	41	32	31	62	
4/20/2009	36	35	36	30	26	21	15	23	32	43	50	53	57	57	62	62	60	56	46	24	14	20	23	23	62	
4/21/2009	31	35	40	39	33	23	21	37	45	50	53	59	63	65	68	69	69	67	60	48	45	43	39	33	69	
4/22/2009	31	30	29	32	26	30	31	39	46	47	51	42	46	48	50	50	51	49	42	36	37	35	34	33	51	
4/23/2009	36	36	34	32	30	31	31	36	42	45	46	46	47	46	45	43	43	42	43	40	39	40	39	39	47	
4/24/2009	40	40	40	37	34	34	37	42	44	45	46	46	44	43	41	41	38	36	31	39	41	40	36	36	46	
4/25/2009	31	31	38	39	40	40	39	39	41	43	43	41	41	41	40	40	38	39	39	40	39	38	37	38	43	
4/26/2009	38	39	39	39	39	40	39	40	42	41	40	39	39	38	37	37	34	33	33	31	29	28	26	25	42	
4/27/2009	25	26	28	28	27	25	22	24	26	27	27	26	24	24	19	21	22	21	38	43	42	40	33	29	43	
4/28/2009	31	33	30	27	27	28	27	24	22	24	25	25	24	23	23	24	24	25	24	23	22	22	24	25	33	

Date	Central Standard Time																									
	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	High	2nd High
4/29/2009	26	25	26	25	24	25	26	25	26	27	27	27	27	26	26	26	26	24	25	24	23	25	25	25	27	
4/30/2009	25	24	23	22	24	23	23	24	24	24	24	23	24	22	23	23	22	22	21	20	20	20	21	21	25	
5/1/2009	20	20	20	20	20	20	20	22	23	23	26	29	27	26	26	26	25	25	26	26	25	24	23	23	29	
5/2/2009	24	25	28	27	25	25	20	18	20	21	23	24	25	26	23	23	24	26	28	26	28	27	27	27	28	
5/3/2009	27	26	26	26	28	26	24	22	24	27	28	29	29	29	28	29	39	37	31	24	19	18	16	23	39	
5/4/2009	23	28	27	28	26	23	18	21	23	30	39	49	65	79	82	81	88	82	53	49	39	39	36	33	88	
5/5/2009	32	31	28	23	16	15	12	19	25	27	30	30	29	30	30	29	28	24	19	17	17	20	22	22	32	
5/6/2009	22	23	22	21	20	25	26	24	25	26	29	30	30	31	23	20	21	20	19	20	22	22	22	21	31	
5/7/2009	21	21	22	23	22	21	19	20	23	27	30	29	27	23	21	22	22	23	26	27	25	27	27	28	30	
5/8/2009	29	27	25	25	25	25	26	28	28	27	26	28	28	28	27	27	27	28	28	28	29	31	31	30	31	
5/9/2009	29	27	26	25	26	25	25	23	26	28	30	30	30	30	32	30	26	30	26	22	17	17	18	19	32	
5/10/2009	17	15	15	16	16	15	15	18	23	22	21	22	23	22	21	23	23	25	24	22	21	19	19	20	25	
5/11/2009	20	21	22	22	21	17	16	21	25	25	25	26	24	25	23	22	24	18	16	15	15	16	15	14	26	
5/12/2009	14	14	15	14	9	5	0	12	24	29	31	32	29	27	26	26	24	23	21	20	19	20	20	21	32	
5/13/2009	23	24	24	24	24	25	27	28	26	27	28	28	27	26	25	25	23	24	22	22	20	18	18	18	28	
5/14/2009	17	18	19	18	13	11	10	20	27	31	28	33	34	34	32	32	29	26	27	23	21	24	24	22	34	
5/15/2009	18	15	16	17	13	11	13	19	22	24	25	25	25	25	25	25	25	24	23	21	19	19	18	16	25	
5/16/2009	14	7	5	3	3	7	8	19	22	24	26	26	28	29	28	25	23	22	28	25	21	19	25	25	29	
5/17/2009	26	24	22	21	20	19	17	24	26	28	30	31	26	22	29	40	38	35	31	30	33	32	28	21	40	
5/18/2009	16	22	25	21	22	5	19	29	37	43	55	54	54	52	54	56	57	53	45	36	27	23	25	26	57	
5/19/2009	30	28	31	25	23	12	12	30	36	44	51	56	58	65	71	71	71	67	65	55	43	14	39	38	71	
5/20/2009	33	37	41	27	17	7	5	27	48	58	65	75	88	88	89	87	86	81	62	39	29	20	13	12	89	
5/21/2009	15	23	28	27	25	9	11	24	38	60	62	67	68	66	66	56	57	57	56	53	33	16	20	20	68	
5/22/2009	20	22	16	8	6	3	6	19	30	37	47	53	35	38	43	38	35	32	25	19	12	23	8	4	53	
5/23/2009	5	6	2	3	5	4	11	27	36	43	41	35	33	43	36	41	43	46	38	29	21	41	26	37	46	
5/24/2009	38	34	31	29	26	20	22	29	35	44	46	41	41	50	53	42	37	37	37	27	24	24	25	21	53	
5/25/2009	24	25	18	23	23	20	20	27	37	43	44	45	47	49	50	52	54	58	48	40	31	25	27	23	58	
5/26/2009	18	15	12	8	6	6	7	12	19	29	44	48	52	57	59	60	58	51	41	32	29	23	18	17	60	
5/27/2009	16	14	13	8	8	5	5	10	22	19	14	13	21	22	31	25	31	38	35	30	27	8	2	2	38	
5/28/2009	0	3	7	11	5	2	13	30	42	51	58	66	68	69	72	74	72	65	50	37	23	44	40	42	74	
5/29/2009	42	37	31	25	10	7	12	28	43	58	71	98	QAS	85	82	77	78	73	73	75	69	56	34	30	98	

Date	Central Standard Time																									
	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	High	2nd High
5/30/2009	30	25	14	7	5	1	5	33	53	61	68	73	78	86	94	82	80	76	67	64	55	48	41	37	94	
5/31/2009	22	14	8	7	7	3	9	47	60	63	65	69	68	65	64	61	57	56	59	60	55	49	42	24	69	
6/1/2009	19	15	9	7	4	2	5	34	48	53	53	54	54	56	53	53	54	50	50	48	46	42	41	37	56	
6/2/2009	35	20	15	11	4	1	3	23	34	35	33	33	30	29	36	31	28	29	27	25	19	21	19	16	36	
6/3/2009	16	13	6	5	3	1	6	23	28	35	35	39	37	36	34	32	31	31	30	25	20	16	12	8	39	
6/4/2009	3	3	3	2	18	22	20	32	38	43	46	56	62	63	65	65	61	57	47	37	33	24	23	23	65	
6/5/2009	19	20	19	19	15	10	15	29	40	48	58	70	74	79	72	74	72	68	62	64	57	51	37	20	79	
6/6/2009	19	9	7	16	5	1	6	28	44	54	59	59	63	69	63	63	63	64	61	58	55	50	43	34	69	
6/7/2009	21	19	13	11	9	7	20	38	44	47	46	45	44	43	42	41	40	39	38	35	31	32	32	32	47	
6/8/2009	28	29	29	29	19	10	20	32	36	39	38	36	34	33	31	31	29	27	25	24	21	16	15	15	39	
6/9/2009	16	15	13	11	7	5	12	16	20	20	21	21	19	20	19	18	19	16	14	13	12	12	12	11	21	
6/10/2009	10	11	11	12	12	12	15	18	24	26	26	24	22	22	23	24	22	21	18	16	14	14	14	14	26	
6/11/2009	14	14	15	16	17	18	18	20	23	25	28	29	29	27	27	27	25	24	18	17	15	15	15	13	29	
6/12/2009	13	14	15	11	13	12	12	18	23	24	25	28	29	28	26	25	24	22	20	19	18	14	13	13	29	
6/13/2009	14	13	10	10	10	10	13	17	19	22	25	26	27	27	28	25	25	22	21	18	17	17	16	17	28	
6/14/2009	15	14	15	13	8	3	5	16	21	25	27	27	27	29	28	27	26	24	22	19	19	19	18	17	29	
6/15/2009	18	17	15	10	5	3	8	18	22	26	28	28	29	28	29	26	25	23	19	17	16	16	17	18	29	
6/16/2009	18	18	17	16	16	12	15	21	25	29	29	25	26	27	28	25	22	20	18	16	15	15	15	15	29	
6/17/2009	14	14	12	11	10	8	11	18	22	24	25	25	23	23	21	21	21	19	19	19	16	15	15	14	25	
6/18/2009	15	15	15	14	12	9	12	15	17	18	18	19	20	20	20	20	18	19	18	17	17	15	15	13	20	
6/19/2009	13	13	13	10	4	1	10	14	17	19	20	20	19	18	18	17	17	18	20	19	14	13	13	13	20	
6/20/2009	14	14	13	12	12	12	12	16	20	24	24	26	26	26	27	27	27	24	22	19	17	17	17	17	27	
6/21/2009	17	19	17	10	5	6	12	20	23	25	27	29	27	28	27	23	21	19	17	16	16	14	12	12	29	
6/22/2009	11	10	7	3	0	0	1	13	17	22	26	30	34	31	28	25	23	19	18	16	12	11	10	8	34	
6/23/2009	8	8	6	5	4	0	4	13	17	21	26	31	37	50	59	59	46	34	22	17	16	14	13	14	59	
6/24/2009	12	9	6	6	7	5	7	10	15	25	39	62	82	83	71	79	76	67	49	39	28	16	12	11	83	
6/25/2009	9	9	9	7	7	3	3	8	11	18	32	53	61	62	73	63	55	47	40	37	32	28	18	15	73	
6/26/2009	10	8	6	4	3	1	2	6	10	18	33	48	54	60	49	52	39	34	24	17	9	8	7	5	60	
6/27/2009	5	4	3	3	2	0	3	13	17	20	22	22	26	32	30	26	24	19	18	14	12	12	10	8	32	
6/28/2009	8	7	6	3	1	2	5	15	20	21	25	32	38	42	46	42	28	24	20	16	13	12	12	11	46	
6/29/2009	11	11	10	10	9	6	6	12	16	22	31	41	48	55	56	56	41	33	28	40	48	31	21	11	56	

Date	Central Standard Time																									
	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	High	2nd High
6/30/2009	12	12	11	7	9	7	5	QAS	PMA	13	19	31	39	40	40	47	53	48	44	42	41	37	29	24	53	
7/1/2009	23	17	13	10	10	8	9	19	39	58	70	76	79	100	120	84	83	81	65	44	28	19	15	12	120	100
7/2/2009	10	9	5	5	4	0	4	10	15	25	38	50	56	58	65	48	37	28	22	20	19	18	17	15	65	
7/3/2009	10	3	3	1	0	0	3	13	18	25	29	22	23	21	23	23	23	22	18	18	17	15	15	15	29	
7/4/2009	13	10	10	11	12	12	14	16	19	26	31	31	31	30	30	30	29	27	24	21	18	15	15	16	31	
7/5/2009	15	15	14	14	15	15	16	19	18	20	23	24	24	25	25	23	21	19	18	14	13	13	12	12	25	
7/6/2009	12	10	6	7	8	4	5	12	16	20	26	29	30	32	31	29	24	20	19	18	16	15	14	13	32	
7/7/2009	12	12	11	9	10	9	7	17	16	17	16	19	29	32	30	27	29	28	25	22	19	17	12	12	32	
7/8/2009	8	6	5	3	2	0	4	12	20	25	28	30	33	31	30	28	26	25	21	16	15	12	12	11	33	
7/9/2009	9	8	7	6	4	2	5	13	19	22	26	29	30	30	27	26	24	21	18	16	14	14	14	13	30	
7/10/2009	10	8	6	1	1	2	1	14	18	22	27	29	31	26	20	20	19	19	20	21	19	16	13	12	31	
7/11/2009	10	8	3	1	0	1	3	13	21	24	25	26	26	28	26	25	22	21	21	21	19	18	15	11	28	
7/12/2009	8	3	4	4	3	2	4	13	16	19	23	27	31	37	38	30	28	27	21	15	14	12	10	8	38	
7/13/2009	8	10	10	8	8	6	7	10	14	17	20	24	28	32	37	27	22	19	18	13	12	9	9	8	37	
7/14/2009	7	7	6	6	5	4	5	11	15	18	20	22	20	17	20	19	17	15	14	13	13	11	9	11	22	
7/15/2009	11	9	9	8	6	3	0	9	15	19	22	23	25	26	24	22	19	17	15	14	13	11	11	10	26	
7/16/2009	8	9	9	2	0	0	2	12	18	20	23	25	25	28	29	26	23	22	18	15	11	11	10	10	29	
7/17/2009	9	6	4	0	1	0	1	12	15	17	19	35	60	61	65	64	55	50	36	24	14	15	16	17	65	
7/18/2009	19	11	5	6	5	1	3	15	29	29	35	50	60	67	60	46	44	33	31	42	40	37	30	25	67	
7/19/2009	20	15	12	8	4	1	9	23	35	37	37	49	50	42	48	46	53	48	42	43	40	36	34	32	53	
7/20/2009	27	23	20	18	12	11	9	15	23	24	26	27	29	29	31	25	21	18	17	18	18	16	15	16	31	
7/21/2009	16	15	15	13	12	11	12	13	17	20	19	22	18	18	18	18	15	14	13	12	10	11	10	8	22	
7/22/2009	9	9	8	6	3	2	3	4	QAS	QAS	QAS	22	25	28	29	31	31	24	21	15	13	12	10	9	31	
7/23/2009	8	6	6	5	3	2	2	8	12	16	22	29	37	41	44	40	32	40	35	20	16	12	8	6	44	
7/24/2009	8	10	5	4	2	1	0	1	7	14	20	24	31	35	42	42	45	40	35	30	26	20	7	3	45	
7/25/2009	10	7	3	1	0	0	3	16	23	27	31	36	39	43	39	31	29	24	20	18	16	13	12	9	43	
7/26/2009	8	9	7	6	6	6	7	10	15	19	22	25	27	29	29	25	21	21	18	17	15	14	13	12	29	
7/27/2009	15	14	12	10	8	4	2	12	17	22	25	27	26	24	23	23	28	27	23	19	20	21	26	25	28	
7/28/2009	23	17	16	16	15	14	15	21	24	25	26	17	20	19	19	18	17	16	15	15	13	12	11	9	26	
7/29/2009	8	8	7	9	10	9	10	14	18	19	22	24	24	23	22	20	18	16	14	13	12	11	12	14	24	
7/30/2009	16	14	13	12	11	10	10	14	17	20	21	22	22	21	21	20	20	19	16	14	15	13	14	14	22	

Date	Central Standard Time																									
	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	High	2nd High
7/31/2009	13	12	11	10	8	6	6	8	13	16	19	18	20	19	14	20	31	21	13	11	10	10	10	13	31	
8/1/2009	16	16	14	16	16	14	13	16	19	21	22	23	23	24	24	25	25	23	19	15	15	13	11	11	25	
8/2/2009	12	9	11	12	12	13	11	14	18	20	23	27	29	30	30	30	25	23	21	19	17	16	14	12	30	
8/3/2009	14	13	13	12	11	10	7	12	15	18	22	28	32	27	23	21	19	18	17	17	15	15	14	13	32	
8/4/2009	11	9	6	1	1	0	0	11	17	22	23	23	24	21	22	22	21	18	18	17	15	13	13	11	24	
8/5/2009	8	5	4	6	4	0	0	9	14	18	21	25	27	31	27	25	23	21	18	14	13	11	11	9	31	
8/6/2009	10	9	8	7	5	0	2	9	17	21	24	28	32	35	41	47	30	22	18	16	15	13	12	11	47	
8/7/2009	9	7	6	6	6	0	0	8	15	19	24	28	27	33	26	19	21	24	22	18	14	13	13	13	33	
8/8/2009	12	15	19	18	14	5	5	26	39	40	37	33	32	30	27	25	24	22	21	18	17	14	12	11	40	
8/9/2009	9	10	7	9	3	5	7	14	21	23	24	24	24	22	23	25	24	24	24	21	19	17	13	10	25	
8/10/2009	10	5	3	2	2	0	1	9	13	20	23	25	28	19	17	17	16	15	14	12	11	6	3	3	28	
8/11/2009	4	4	3	3	1	0	0	3	7	11	15	16	18	23	25	21	17	16	16	12	10	8	7	6	25	
8/12/2009	6	4	3	2	1	0	0	3	8	12	21	35	49	65	80	88	90	48	48	42	32	36	33	28	90	
8/13/2009	24	20	14	8	4	0	1	8	26	44	55	61	64	68	48	42	47	43	30	22	18	11	12	9	68	
8/14/2009	3	3	1	0	0	0	0	6	27	43	50	55	54	52	54	57	53	48	46	42	39	39	35	25	57	
8/15/2009	20	13	11	8	7	2	1	15	30	37	39	46	47	44	43	39	36	33	34	27	24	19	16	6	47	
8/16/2009	3	4	7	3	2	2	2	10	23	24	26	28	30	29	29	28	27	22	19	19	16	13	11	10	30	
8/17/2009	10	9	3	0	0	0	0	6	15	21	24	25	26	24	23	26	24	17	12	11	10	9	8	7	26	
8/18/2009	6	4	3	0	0	0	0	4	16	20	23	23	24	26	18	19	23	24	18	12	6	3	4	10	26	
8/19/2009	10	8	6	3	0	0	0	3	14	19	20	21	22	23	22	20	21	20	19	16	14	13	12	11	23	
8/20/2009	10	10	9	3	0	1	3	9	15	19	21	20	21	21	21	22	16	15	14	13	13	13	13	12	22	
8/21/2009	12	10	8	4	0	0	0	6	15	17	20	24	27	28	28	30	27	25	16	17	17	11	7	3	30	
8/22/2009	1	0	0	0	0	2	2	9	15	21	24	33	45	55	69	76	66	58	43	30	24	20	16	13	76	
8/23/2009	11	9	7	5	3	1	1	5	11	15	24	32	44	43	41	42	50	47	46	43	34	29	25	23	50	
8/24/2009	26	29	23	12	9	2	3	1	13	21	27	29	36	38	39	43	43	43	42	38	34	29	22	12	43	
8/25/2009	11	7	7	8	4	2	2	8	17	29	35	41	66	62	57	49	47	47	48	43	42	40	39	32	66	
8/26/2009	29	27	35	29	19	10	12	30	44	51	52	54	55	55	QAS	QAS	43	43	41	38	38	39	33	26	55	
8/27/2009	21	16	12	10	9	1	0	12	40	47	50	55	57	62	72	61	57	56	48	40	40	40	37	36	72	
8/28/2009	33	25	26	26	38	35	25	22	25	30	34	40	51	53	67	64	55	49	44	47	47	31	19	16	67	
8/29/2009	13	9	8	4	2	0	2	10	39	58	71	78	85	91	84	96	98	82	68	49	42	35	36	33	98	
8/30/2009	32	32	36	34	25	28	30	26	42	56	66	64	65	64	64	69	66	57	57	100	91	66	46	41	100	91

Date	Central Standard Time																									
	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	High	2nd High
8/31/2009	31	30	25	20	19	6	4	13	25	31	39	45	54	64	69	71	66	53	40	32	21	41	21	21	71	
9/1/2009	15	10	15	12	14	22	24	27	31	36	41	47	52	64	74	78	55	43	32	5	0	0	0	0	78	
9/2/2009	2	2	8	8	8	1	1	7	25	41	50	60	81	113	91	81	82	75	62	52	56	49	31	21	113	91
9/3/2009	17	17	13	9	11	5	0	9	31	55	65	85	102	128	108	90	80	72	76	76	76	69	59	46	128	108
9/4/2009	33	27	25	13	32	30	27	28	34	38	53	68	90	81	73	70	70	63	55	45	28	25	17	13	90	
9/5/2009	8	7	10	13	16	13	11	16	37	63	67	69	66	60	62	64	61	50	44	38	35	26	12	10	69	
9/6/2009	6	8	4	2	0	0	3	14	40	44	43	42	49	48	45	41	46	42	37	31	28	25	12	3	49	
9/7/2009	1	2	1	1	4	1	1	7	24	50	63	68	54	48	49	53	53	49	45	42	39	29	20	17	68	
9/8/2009	13	8	5	2	1	0	LST	3	21	42	43	40	43	24	28	29	32	30	25	21	18	11	6	2	43	
9/9/2009	0	0	0	0	0	0	7	8	10	12	15	22	24	17	19	21	19	17	11	5	4	3	2	0	24	
9/10/2009	0	0	0	0	0	0	0	3	10	19	23	22	25	26	30	29	27	26	24	18	16	6	0	5	30	
9/11/2009	3	9	13	13	13	1	2	8	13	20	23	23	25	29	31	31	30	29	28	26	25	23	19	17	31	
9/12/2009	16	14	15	12	10	11	13	13	14	18	19	17	15	19	22	24	25	24	21	21	17	15	11	9	25	
9/13/2009	8	11	13	11	11	8	4	14	25	37	41	43	43	39	38	37	37	36	33	29	24	21	24	22	43	
9/14/2009	22	22	20	16	14	11	7	8	15	23	34	39	40	43	42	39	35	36	32	25	28	30	28	27	43	
9/15/2009	27	26	23	20	20	19	20	20	21	22	25	27	32	30	34	33	31	31	28	23	23	21	14	12	34	
9/16/2009	10	10	12	14	14	6	3	9	17	30	46	53	52	51	52	49	46	43	38	33	31	30	28	22	53	
9/17/2009	21	18	22	22	20	14	14	19	27	40	47	49	48	43	46	45	43	41	40	35	31	27	22	20	49	
9/18/2009	20	17	20	20	16	14	8	10	13	23	24	28	33	35	36	39	41	39	31	18	15	24	25	19	41	
9/19/2009	15	10	9	12	12	8	5	9	19	31	33	37	44	50	52	51	48	41	28	18	7	4	5	2	52	
9/20/2009	7	6	7	2	3	4	4	19	40	47	51	53	57	61	56	54	53	52	48	47	45	41	40	37	61	
9/21/2009	35	32	28	27	21	16	5	11	32	41	48	48	45	40	38	37	35	33	31	30	29	29	30	29	48	
9/22/2009	22	20	16	10	2	0	3	13	28	33	40	41	36	36	37	32	25	22	21	20	18	14	13	11	41	
9/23/2009	9	12	13	13	13	10	8	8	13	24	36	46	QAS	QAS	26	24	24	24	21	20	19	17	15	16	46	
9/24/2009	18	20	18	18	15	11	9	9	14	14	17	20	30	32	33	32	33	26	24	20	18	17	17	18	33	
9/25/2009	16	15	15	14	12	11	6	7	9	12	16	27	30	44	49	54	42	29	23	18	19	20	17	13	54	
9/26/2009	14	11	9	6	4	4	1	5	15	22	37	54	62	74	76	67	67	77	83	54	37	35	33	28	83	
9/27/2009	23	23	25	27	30	29	25	26	29	32	37	36	35	34	35	35	33	24	20	16	15	13	12	13	37	
9/28/2009	11	10	9	7	4	1	1	6	12	17	19	22	28	28	26	25	19	16	13	10	8	3	1	2	28	
9/29/2009	6	8	6	8	11	14	19	23	25	29	32	38	44	54	60	64	58	49	40	36	34	27	11	14	64	
9/30/2009	14	12	5	2	0	0	0	10	28	40	48	54	58	62	61	61	60	61	61	51	42	41	36	33	62	

Date	Central Standard Time																									
	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	High	2nd High
10/1/2009	30	29	28	23	14	19	20	22	26	28	30	26	26	25	23	24	23	16	10	8	7	7	5	5	30	
10/2/2009	2	1	1	21	25	26	13	22	27	31	34	39	47	52	57	60	57	55	50	38	12	12	8	25	60	
10/3/2009	28	23	18	16	17	15	14	16	20	23	25	28	33	29	27	23	24	25	20	19	18	20	20	19	33	
10/4/2009	20	16	18	20	14	13	13	13	13	14	16	17	20	17	18	20	16	14	9	7	4	1	3	0	20	
10/5/2009	1	3	5	5	2	0	0	0	2	4	7	13	21	23	25	18	15	14	13	11	10	10	12	10	25	
10/6/2009	9	8	8	8	8	3	2	9	15	16	18	19	14	12	14	15	14	12	12	12	11	10	8	6	19	
10/7/2009	7	10	10	7	4	2	4	14	20	21	23	22	22	24	25	23	22	20	19	18	15	14	16	16	25	
10/8/2009	14	13	12	12	12	13	13	14	16	19	19	20	20	19	19	17	17	16	16	14	14	13	13	14	20	
10/9/2009	14	14	13	15	17	16	16	16	17	18	26	28	26	24	22	25	21	20	7	0	1	2	3	4	28	
10/10/2009	6	6	5	5	4	4	4	4	5	8	12	17	18	23	27	23	19	16	14	14	13	6	7	11	27	
10/11/2009	8	13	13	15	13	9	5	5	4	7	8	8	10	12	13	13	11	9	5	5	4	4	3	1	15	
10/12/2009	2	1	3	2	0	0	0	0	0	1	11	23	22	20	13	15	17	17	11	3	6	2	0	0	23	
10/13/2009	0	5	7	8	8	3	7	18	17	18	18	15	13	16	21	19	18	14	12	12	11	9	6	6	21	
10/14/2009	9	6	3	3	4	2	1	3	8	12	16	16	17	17	17	18	19	18	12	9	7	6	5	6	19	
10/15/2009	7	8	10	10	10	10	9	9	12	14	17	19	21	21	22	20	19	18	13	10	9	8	9	17	22	
10/16/2009	13	9	7	8	7	6	9	15	17	20	24	29	34	37	36	35	27	23	22	25	27	25	26	19	37	
10/17/2009	17	17	14	13	18	18	12	14	20	24	31	36	39	40	41	39	39	33	17	8	1	0	5	25	41	
10/18/2009	25	23	21	21	21	20	21	23	26	29	31	33	36	39	43	46	42	37	31	26	21	20	10	11	46	
10/19/2009	24	26	24	12	3	0	0	4	21	25	41	43	43	43	44	44	42	39	29	20	19	17	22	31	44	
10/20/2009	29	26	25	28	26	15	8	16	31	36	40	40	39	37	38	39	38	34	29	33	35	36	40	37	40	
10/21/2009	39	38	33	35	35	31	27	19	17	22	40	39	34	QAS	QAS	QAS	22	21	24	20	20	21	23	23	40	
10/22/2009	21	22	21	22	21	22	21	24	23	19	19	24	30	33	36	33	28	23	17	18	17	16	13	14	36	
10/23/2009	14	14	14	14	12	8	4	6	9	17	22	24	29	33	38	38	35	31	25	12	4	2	0	1	38	
10/24/2009	3	0	0	0	0	0	2	5	16	27	36	40	44	50	49	46	47	43	39	33	19	24	17	15	50	
10/25/2009	10	14	18	27	30	30	20	28	37	43	45	46	47	47	47	47	46	45	41	38	37	37	38	42	47	
10/26/2009	46	46	45	42	39	35	36	32	26	35	28	27	32	32	30	27	26	21	18	18	18	21	19	19	46	
10/27/2009	8	7	7	7	5	4	5	5	8	10	10	15	21	27	34	39	38	27	11	2	1	0	0	0	39	
10/28/2009	1	1	2	5	1	1	0	3	18	29	34	33	27	26	25	23	24	19	23	22	22	20	18	16	34	
10/29/2009	15	14	14	12	11	10	9	9	9	12	14	14	14	15	13	12	11	11	10	10	24	26	29	32	32	
10/30/2009	34	31	29	27	30	34	33	29	28	25	25	20	19	20	18	18	14	7	0	0	0	0	0	2	34	
10/31/2009	1	0	4	4	2	1	1	6	13	24	32	35	39	43	45	46	43	31	7	0	0	0	0	0	46	

Date	Central Standard Time																									
	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	High	2nd High
11/1/2009	0	0	0	0	0	0	0	0	10	32	37	38	40	42	43	44	41	28	10	7	2	0	1	3	44	
11/2/2009	4	5	4	2	0	0	0	2	11	20	34	38	56	76	63	56	44	19	3	0	0	0	0	0	76	
11/3/2009	0	1	3	2	1	0	0	1	10	26	32	37	41	44	49	49	47	26	1	0	0	0	0	0	49	
11/4/2009	0	0	0	0	0	0	0	0	7	28	38	47	49	44	42	46	48	36	13	1	0	0	1	0	49	
11/5/2009	2	1	2	2	0	0	0	1	6	24	39	43	50	57	60	64	61	44	32	21	3	0	0	0	64	
11/6/2009	2	1	1	0	0	0	0	0	8	34	56	62	68	69	68	68	65	54	43	32	16	4	1	0	69	
11/7/2009	4	3	2	2	4	3	2	2	14	31	42	50	52	55	52	48	45	42	35	34	36	33	27	24	55	
11/8/2009	25	30	31	30	28	27	27	28	30	31	33	36	39	42	42	40	38	36	36	36	32	28	27	26	42	
11/9/2009	PMA	22	23	21	21	16	7	9	12	9	19	22	27	31	33	29	21	20	16	10	18	15	13	13	33	
11/10/2009	13	13	12	10	9	5	1	2	9	15	25	33	38	41	39	39	37	32	22	15	5	0	1	0	41	
11/11/2009	0	0	0	0	1	7	3	2	10	21	39	47	52	54	51	47	44	30	26	12	8	1	0	0	54	
11/12/2009	3	13	20	24	15	10	2	3	13	31	44	52	59	60	63	63	60	42	27	33	31	22	14	7	63	
11/13/2009	4	0	1	6	1	1	1	0	7	42	53	53	53	53	54	53	50	44	39	36	34	33	31	23	54	
11/14/2009	30	32	30	28	26	25	13	7	14	35	44	47	48	47	46	46	46	44	41	38	35	31	31	31	48	
11/15/2009	26	30	33	31	28	24	22	24	32	40	41	40	40	41	40	40	39	37	35	33	33	32	34	29	41	
11/16/2009	27	25	21	22	18	16	21	16	9	11	18	18	18	27	28	30	30	29	32	31	27	22	21	22	32	
11/17/2009	19	15	17	19	22	22	19	12	18	28	29	35	37	40	40	41	39	32	24	6	3	5	7	13	41	
11/18/2009	13	7	2	0	1	0	0	2	8	26	37	44	48	50	QAS	QAS	38	41	31	29	23	13	3	1	50	
11/19/2009	1	6	5	6	11	5	10	14	24	32	42	47	47	49	49	47	46	45	42	43	44	45	46	48	49	
11/20/2009	44	43	46	40	40	42	38	24	33	36	33	35	30	31	32	32	21	20	22	23	25	25	24	19	46	
11/21/2009	18	20	21	17	23	19	26	24	21	21	24	25	25	28	28	25	23	25	23	25	30	26	21	16	30	
11/22/2009	7	7	7	9	7	3	0	3	11	21	32	35	39	42	45	47	48	30	7	1	4	15	22	23	48	
11/23/2009	19	10	6	7	2	1	0	0	7	19	24	34	46	46	47	49	46	37	27	24	23	22	21	22	49	
11/24/2009	25	28	30	31	27	21	19	16	14	19	13	14	17	9	14	17	14	17	17	17	24	31	32	29	32	
11/25/2009	29	29	27	23	15	5	0	2	7	20	31	31	34	37	39	38	33	12	0	0	0	0	0	0	39	
11/26/2009	0	0	0	0	0	0	2	9	18	23	26	32	38	40	40	40	36	29	15	10	2	1	2	1	40	
11/27/2009	0	0	0	0	0	0	0	0	1	10	28	36	34	38	42	43	42	41	38	34	30	27	28	32	43	
11/28/2009	31	25	18	13	8	17	22	21	25	36	42	42	42	39	38	37	39	37	33	33	36	37	36	36	42	
11/29/2009	34	34	32	28	22	19	17	19	24	28	35	38	37	37	37	36	34	30	31	31	30	28	26	26	38	
11/30/2009	22	16	7	6	9	9	6	6	5	7	7	7	7	7	6	7	4	1	2	5	16	19	20	17	22	
12/1/2009	13	18	17	16	14	15	12	10	10	11	12	11	11	8	4	3	2	2	3	2	8	6	7	8	18	

Date	Central Standard Time																									
	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	High	2nd High
12/2/2009	11	10	11	12	13	17	17	16	17	20	23	26	27	28	29	33	32	28	25	24	22	22	20	20	33	
12/3/2009	21	21	22	21	17	9	2	1	3	11	16	18	22	20	21	21	15	12	12	16	20	20	20	20	22	
12/4/2009	19	18	17	14	15	8	9	11	6	9	9	10	12	9	13	14	10	10	13	8	1	0	0	4	19	
12/5/2009	4	3	0	0	0	0	0	1	3	14	21	26	28	31	31	25	24	24	15	6	0	0	0	3	31	
12/6/2009	12	4	11	18	22	22	23	20	20	23	25	30	31	27	21	23	24	25	26	27	28	27	26	23	31	
12/7/2009	20	18	17	15	8	5	4	3	9	11	12	14	15	16	15	7	7	8	7	7	7	10	12	11	20	
12/8/2009	11	9	6	6	3	1	1	0	5	12	13	15	16	18	19	19	20	20	21	21	21	20	12	10	21	
12/9/2009	10	11	13	10	6	3	2	6	12	15	19	19	19	20	17	17	12	5	8	14	19	21	21	21	21	
12/10/2009	22	21	20	11	8	10	6	12	17	16	17	17	20	20	22	22	15	12	14	21	21	19	23	22	23	
12/11/2009	20	19	18	17	11	14	12	11	11	17	18	18	20	21	22	21	21	19	21	22	22	23	22	21	23	
12/12/2009	19	17	19	20	20	19	18	16	15	14	15	16	17	17	14	11	8	1	0	0	0	0	0	0	20	
12/13/2009	0	0	0	0	3	9	11	9	8	7	8	10	12	13	16	18	17	11	11	10	11	24	24	19	24	
12/14/2009	18	13	11	13	16	11	3	3	8	3	3	3	4	5	2	3	1	0	0	0	0	0	0	0	18	
12/15/2009	0	0	0	0	0	3	5	4	6	9	10	10	6	5	5	5	5	6	5	7	8	10	7	11	11	
12/16/2009	10	12	11	16	15	12	9	9	11	12	13	13	14	QAS	QAS	QAS	12	6	3	6	11	17	19	14	19	
12/17/2009	16	16	17	17	16	12	9	7	6	8	15	19	17	16	18	15	15	13	12	13	10	10	10	6	19	
12/18/2009	5	1	2	3	0	0	0	0	1	4	7	12	18	25	28	27	30	27	18	11	5	2	11	18	30	
12/19/2009	20	19	13	6	4	5	3	5	8	11	18	23	27	31	32	32	33	31	21	14	10	5	7	4	33	
12/20/2009	0	4	11	10	10	9	7	8	14	19	20	27	37	39	45	49	46	27	19	12	8	3	5	3	49	
12/21/2009	1	0	0	0	0	0	0	0	2	21	34	40	43	44	46	46	44	43	29	17	12	13	19	34	46	
12/22/2009	32	31	31	31	33	32	31	31	33	36	39	37	37	39	39	39	37	35	36	36	35	33	32	34	39	
12/23/2009	35	35	34	35	36	36	36	32	33	35	37	39	38	38	38	37	36	34	31	31	29	29	28	28	39	
12/24/2009	27	25	28	29	29	24	28	26	34	39	40	35	30	23	19	17	17	19	22	23	24	26	26	27	40	
12/25/2009	30	33	34	34	34	34	34	34	35	35	36	37	38	39	40	40	38	27	26	19	17	7	4	7	40	
12/26/2009	5	1	1	0	0	0	2	8	12	26	25	29	28	29	30	24	23	20	19	20	21	15	20	22	30	
12/27/2009	17	12	9	18	20	17	19	19	21	27	35	39	41	41	43	43	42	39	32	24	17	21	26	27	43	
12/28/2009	26	23	19	17	18	21	11	5	14	21	24	26	29	30	30	31	30	20	6	2	2	2	4	2	31	
12/29/2009	2	2	0	1	0	0	1	4	9	11	15	20	23	22	17	8	11	10	16	18	17	18	21	23	23	
12/30/2009	23	23	21	16	15	15	14	3	6	3	3	2	4	5	6	8	14	15	15	15	20	20	19	19	23	
12/31/2009	17	16	15	14	14	12	11	10	8	8	11	13	13	21	72	50	19	12	10	10	3	9	7	6	72	

Date	Central Standard Time																									
	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	High	2nd High
																						Annual High/2nd Hig			128	108

PLEASE NOTE: This data has not been verified by the TCEQ and may change. This is the most current databut it is not official until it has been certified by our technical staff. Data is collected from TCEQ ambient monitoring sites and may include data collected by other outside agencies. This data is updated hourly. All times shown are in Local Standard Time.

Site Navigation

- Rules, Policy & Legislation
- Permits, Licenses & Registrations
- Compliance, Enforcement & Cleanups
- Drinking Water & Water Availability
- Reporting
- Environmental Quality
- Assistance, Education & Participation
- Pollution Prevention & Recycling
- Contracts, Funding & Fees
- TCEQ Home

- About TCEQ
- Contact Us

Have you had contact with the TCEQ lately? Complete our Customer Satisfaction Survey.

Additional Information

Air Monitoring Site Information

Monitoring Sites in this Region

BACK TO: Air Quality

Questions or Comments:
monops@tceq.state.tx.us

Manvel Croix Park C84

CAMS 84 Manvel Croix Park C84

- EPA site number: 48-039-1004
- State: Texas
- County: Brazoria
- City: Manvel
- Address: 4503 Croix Parkway
- Site coordinates:
  - Latitude: 29° 31' 13" North (+29.520278°)
  - Longitude: 95° 23' 33" West (-95.392500°)
  - Elevation: 18 m (59 ft)
- Maintained by: Enviroplan Consulting for the TCEQ

Area Map	Overall site view	Street level Map
Northwest	North	Northeast
West		East
Southwest	South	Southeast

Current Measurements at Manvel Croix Park C84

Monthly Summary Report for Parameters at Manvel Croix Park C84

Yearly Summary Report for Parameters at Manvel Croix

Park C84

- Real-time monitoring since: Thursday, August 23, 2001
- Current status: Active
- Continuous monitors located at this site:
  - Met Data
  - Ozone
  - Nitrous Oxides
- Parameters currently being monitored:
  - Pollution parameters:
    - Nitric Oxide
    - Nitrogen Dioxide
    - Oxides of Nitrogen
    - Ozone
  - Meteorological parameters:
    - Wind Speed
    - Resultant Wind Speed
    - Resultant Wind Direction
    - Maximum Wind Gust
    - Standard Deviation of Horizontal Wind Direction
    - Outdoor Temperature

PLEASE NOTE: This data has not been verified by the TCEQ and may change. This is the most current data, but it is not official until it has been certified by our technical staff. Data is collected from TCEQ ambient monitoring sites and may include data collected by other outside agencies. This data is updated hourly. All times shown are in Local Standard Time.

Web Policies | Disclaimer | Site Help

Rules, Policy & Legislation | Permits, Licenses & Registrations | Compliance, Enforcement & Cleanups
Drinking Water & Water Availability | Reporting | Environmental Quality | Assistance, Education & Participation | Pollution Prevention & Recycling | Contracts, Funding & Fees | TCEQ Home

About TCEQ | Contact Us

Last Modified February 27, 2010
©2002-2004 Texas Commission on Environmental Quality.

CAMS 84 Ozone Summary Report for 2009

Manvel Croix Park C84 - EPA Site: 48_039_1004

Ozone (POC 1) measured in parts per billion

Data from this instrument meets EPA quality assurance criteria for regulatory purposes.

Date	Central Standard Time																									
	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	High	2nd High
1/1/2009	21	21	20	19	17	13	10	11	12	14	18	25	32	37	42	45	43	39	34	28	28	29	27	26	45	
1/2/2009	22	18	16	16	14	13	16	16	16	16	16	21	23	24	23	22	22	18	16	13	12	13	12	12	24	
1/3/2009	14	13	15	16	16	15	10	13	12	22	26	26	26	26	26	25	24	23	20	17	15	13	SPN	9	26	
1/4/2009	10	12	14	15	17	16	15	12	13	15	19	21	24	17	12	11	10	5	5	8	7	8	10	11	24	
1/5/2009	11	12	12	11	11	8	7	5	4	3	4	4	4	6	6	4	2	0	0	0	0	0	0	0	12	
1/6/2009	0	0	0	0	0	0	0	0	0	0	2	5	6	8	9	12	17	16	14	13	13	14	18	20	20	
1/7/2009	22	21	20	19	15	8	0	0	2	15	27	32	36	40	42	43	43	41	31	25	30	31	32	32	43	
1/8/2009	32	29	23	21	13	10	10	16	13	22	34	40	43	45	47	49	46	36	26	24	17	20	23	22	49	
1/9/2009	24	25	28	21	16	12	1	18	27	33	40	45	46	44	41	38	34	30	29	28	25	23	21	20	46	
1/10/2009	21	21	20	20	20	17	15	13	10	10	12	13	13	15	17	19	20	21	19	20	18	18	SPN	20	21	
1/11/2009	21	21	22	22	21	21	19	19	20	22	23	23	24	26	28	31	30	27	22	19	14	2	1	1	31	
1/12/2009	0	0	0	0	0	0	0	0	2	12	24	33	35	37	42	43	42	30	22	19	12	9	6	3	43	
1/13/2009	2	0	0	8	20	19	18	16	21	24	26	30	32	34	36	37	37	31	25	17	7	2	1	0	37	
1/14/2009	1	0	0	0	0	0	0	0	3	12	23	33	35	37	42	41	37	34	22	20	18	22	17	8	42	
1/15/2009	5	1	0	0	0	0	0	0	3	8	18	35	44	57	62	64	55	47	39	30	22	20	20	19	64	
1/16/2009	18	22	18	15	16	14	8	8	16	21	23	26	27	27	30	34	31	20	12	18	15	12	9	6	34	
1/17/2009	5	5	9	9	12	13	9	3	17	33	42	47	47	46	46	45	45	42	32	21	31	29	SPN	23	47	
1/18/2009	16	14	15	24	22	23	23	23	22	27	33	37	39	PMA	44	44	43	41	36	32	25	23	20	13	44	
1/19/2009	19	18	19	18	20	23	23	25	26	25	30	34	36	39	42	41	42	40	37	33	30	32	30	24	42	
1/20/2009	21	18	16	11	12	13	9	11	9	21	29	PMA	PMA	PMA	PMA	PMA	PMA	LST	LST	LST	LST	LST	LST	LST	29	
1/21/2009	LST	LST	LST	LST	LST	LST	LST	LST	LST	LST	LST	LST	LST	LST	PMA	47	48	CAL	CAL	32	29	28	28	29	48	
1/22/2009	27	28	28	20	16	19	11	0	8	29	38	43	48	47	45	44	44	QAS	28	26	29	22	21	25	48	
1/23/2009	26	27	26	16	19	21	18	14	12	28	40	41	42	41	41	41	39	38	33	23	23	20	26	26	42	
1/24/2009	29	29	26	22	19	16	15	14	13	13	14	17	20	24	25	24	21	20	16	14	15	16	CAL	CAL	29	
1/25/2009	17	15	15	13	11	10	8	8	10	12	13	14	15	15	16	16	15	13	11	13	12	13	12	11	17	
1/26/2009	12	13	13	15	19	18	16	15	13	12	22	31	33	33	32	33	33	31	27	24	25	26	27	30	33	
1/27/2009	30	28	26	26	19	14	11	6	12	26	32	34	35	35	33	32	31	30	14	0	0	0	0	1	35	

Date	Central Standard Time																									
	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	High	2nd High
1/28/2009	2	3	4	4	6	8	7	6	4	7	11	15	18	21	23	25	24	21	7	1	2	4	1	4	25	
1/29/2009	12	10	8	6	4	0	0	1	5	8	14	19	24	27	29	32	34	28	23	13	2	3	12	19	34	
1/30/2009	18	16	16	18	18	12	5	4	9	14	23	33	36	33	36	39	40	39	30	27	6	23	33	35	40	
1/31/2009	38	35	31	24	23	20	20	16	18	34	41	45	49	51	51	53	51	47	42	38	33	30	SPN	25	53	
2/1/2009	28	30	33	27	30	26	27	29	30	36	40	41	41	40	40	40	40	38	34	27	18	15	14	13	41	
2/2/2009	13	14	21	21	20	30	25	21	20	27	37	38	38	40	41	40	38	35	22	16	7	2	1	0	41	
2/3/2009	0	0	0	0	0	0	0	0	3	19	36	40	42	44	46	46	46	44	41	26	26	29	28	29	46	
2/4/2009	27	16	13	4	11	15	10	7	18	24	26	29	31	33	39	42	42	37	29	24	17	17	14	13	42	
2/5/2009	8	11	20	20	17	10	3	2	18	32	40	42	43	45	45	45	42	40	33	28	28	29	28	26	45	
2/6/2009	26	26	25	27	21	11	10	3	18	35	41	42	43	42	42	42	41	41	39	37	38	37	37	37	43	
2/7/2009	38	37	36	36	32	30	27	28	35	39	42	42	42	41	41	40	39	38	30	27	27	28	SPN	25	42	
2/8/2009	21	22	25	24	24	25	23	25	26	30	37	38	38	40	38	39	39	38	37	38	37	37	36	34	40	
2/9/2009	33	32	33	33	31	27	24	21	25	26	29	30	32	33	35	35	35	33	31	28	25	25	25	27	35	
2/10/2009	25	23	25	23	20	18	13	14	22	29	29	31	32	31	30	27	26	26	25	25	24	25	24	25	32	
2/11/2009	25	37	42	34	31	26	22	22	25	34	37	39	41	44	46	47	47	45	34	29	21	8	0	0	47	
2/12/2009	0	0	0	0	0	0	0	0	4	22	39	46	51	51	51	51	50	48	44	44	41	38	34	35	51	
2/13/2009	32	32	21	27	28	21	14	14	15	13	16	20	20	19	18	19	18	16	11	10	9	7	7	8	32	
2/14/2009	7	11	10	10	9	9	18	21	21	23	27	32	30	29	31	24	24	22	15	11	13	20	SPN	15	32	
2/15/2009	12	8	13	14	14	14	11	12	14	15	17	17	23	28	36	39	39	36	30	25	21	28	29	28	39	
2/16/2009	30	28	26	25	25	21	20	19	25	29	32	36	39	42	47	46	43	39	40	37	35	33	34	30	47	
2/17/2009	31	29	34	31	30	31	31	30	31	34	36	40	38	38	35	32	31	28	26	25	24	24	23	23	40	
2/18/2009	22	23	21	20	20	19	19	18	16	18	18	19	18	15	16	17	18	16	11	10	9	7	5	1	23	
2/19/2009	11	29	32	34	34	29	14	15	30	36	39	40	41	42	43	45	43	40	33	29	24	22	24	21	45	
2/20/2009	25	23	22	20	12	7	0	3	16	30	38	41	46	49	49	48	47	44	38	22	23	20	22	27	49	
2/21/2009	28	28	25	26	22	19	21	19	32	41	45	46	48	41	31	27	26	31	37	37	36	35	CAL	CAL	48	
2/22/2009	35	34	35	38	36	33	27	24	33	35	37	40	40	42	44	47	48	47	33	22	15	14	5	4	48	
2/23/2009	10	9	16	14	10	4	1	4	16	29	37	41	46	50	52	52	53	52	48	43	38	29	25	29	53	
2/24/2009	31	31	30	26	27	13	7	12	27	41	45	46	45	45	45	44	44	44	40	34	25	21	22	29	46	
2/25/2009	29	27	24	24	23	20	18	14	29	36	39	41	41	40	38	38	36	34	32	31	30	30	29	27	41	
2/26/2009	32	32	32	32	31	26	19	20	30	33	36	35	34	34	33	32	32	31	28	27	26	25	24	21	36	
2/27/2009	22	24	25	26	27	27	25	25	26	27	28	30	30	30	30	29	29	29	28	26	24	24	24	20	30	

Date	Central Standard Time																									
	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	High	2nd High
2/28/2009	18	17	17	12	12	14	13	12	14	17	19	23	30	34	39	44	45	41	43	41	38	36	SPN	34	45	
3/1/2009	33	31	31	30	29	28	28	29	30	31	34	37	41	44	45	46	45	44	41	35	27	23	20	18	46	
3/2/2009	14	17	23	22	15	7	2	5	18	26	37	38	37	39	42	44	45	46	54	51	51	43	43	25	54	
3/3/2009	22	33	25	28	21	12	11	19	30	36	42	49	53	55	56	57	56	55	51	46	43	43	42	39	57	
3/4/2009	39	38	37	37	36	31	29	27	35	44	49	50	50	50	49	48	48	46	41	40	38	36	36	36	50	
3/5/2009	38	38	35	33	33	17	10	18	33	40	41	41	40	39	39	39	38	38	34	31	28	28	30	28	41	
3/6/2009	27	26	26	25	21	13	9	8	24	34	40	42	42	42	41	40	38	35	29	30	30	29	28	28	42	
3/7/2009	29	27	26	29	28	24	19	18	27	35	38	39	39	38	36	35	34	33	32	31	30	29	SPN	28	39	
3/8/2009	28	25	22	21	21	19	12	10	23	33	39	38	39	39	38	38	38	37	33	31	28	29	30	26	39	
3/9/2009	29	27	25	25	21	19	21	23	27	31	37	36	37	37	37	38	36	35	35	36	36	33	32	30	38	
3/10/2009	30	28	27	29	27	24	23	25	30	33	37	39	39	38	36	35	35	34	31	33	31	31	30	28	39	
3/11/2009	27	24	26	26	22	16	13	21	27	35	39	39	39	41	41	41	39	36	15	9	12	13	16	20	41	
3/12/2009	23	27	26	26	23	20	16	10	10	9	10	10	11	6	7	9	8	9	12	12	13	15	12	14	27	
3/13/2009	14	12	11	10	9	8	6	7	7	9	7	8	9	11	QAS	6	6	9	10	6	8	7	7	8	14	
3/14/2009	9	9	9	11	13	13	11	9	9	11	10	11	10	11	11	11	12	12	9	7	6	7	SPN	8	13	
3/15/2009	6	8	8	12	10	11	10	11	13	14	13	13	14	13	21	24	28	26	12	5	0	0	1	4	28	
3/16/2009	3	3	2	2	1	0	0	1	5	14	21	28	35	38	45	51	53	55	63	41	38	32	28	21	63	
3/17/2009	18	17	20	15	9	16	19	17	19	21	27	31	36	42	45	PMA	CAL	CAL	36	30	28	16	16	13	45	
3/18/2009	11	5	9	7	8	0	1	6	6	25	44	49	56	59	58	55	55	52	43	37	36	29	23	27	59	
3/19/2009	25	19	11	10	8	1	2	4	7	16	39	54	62	64	65	62	62	57	50	40	32	27	24	17	65	
3/20/2009	14	19	10	7	4	2	1	4	21	41	53	58	61	65	66	65	63	62	52	41	44	35	31	21	66	
3/21/2009	16	11	7	13	13	15	15	17	33	49	58	60	62	61	61	63	62	60	61	55	51	44	CAL	CAL	63	
3/22/2009	39	41	39	26	27	34	38	41	47	55	60	61	60	59	58	57	56	54	52	50	49	48	50	51	61	
3/23/2009	51	47	46	44	40	40	43	43	48	51	50	49	47	46	45	45	43	41	39	37	37	37	37	37	51	
3/24/2009	36	36	37	36	33	33	30	35	39	40	41	40	38	38	39	39	38	35	34	33	33	30	29	25	41	
3/25/2009	23	23	24	23	21	17	16	13	22	28	31	35	37	38	37	37	35	33	29	28	27	31	29	28	38	
3/26/2009	30	31	30	29	27	26	25	23	24	24	25	27	28	24	32	31	27	22	24	20	12	12	18	23	32	
3/27/2009	25	27	24	20	16	7	2	6	17	32	34	36	35	35	40	46	44	40	40	38	34	34	36	34	46	
3/28/2009	34	34	33	33	36	39	41	42	42	43	44	45	48	50	51	51	51	52	50	43	37	33	SPN	16	52	
3/29/2009	13	14	9	7	8	8	12	21	34	41	44	48	53	62	65	63	65	58	53	45	41	40	36	35	65	
3/30/2009	33	30	37	30	24	12	17	29	48	52	53	51	51	49	45	44	44	44	43	40	38	36	36	33	53	

Date	Central Standard Time																									
	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	High	2nd High
3/31/2009	33	35	35	34	30	25	22	18	22	31	30	36	41	42	46	49	51	50	46	37	26	22	11	24	51	
4/1/2009	32	35	37	33	28	22	16	21	35	40	42	49	50	50	49	48	48	47	45	41	39	35	32	34	50	
4/2/2009	34	32	33	28	22	21	26	37	34	39	52	55	56	54	54	55	55	54	51	47	46	45	40	35	56	
4/3/2009	33	34	38	38	36	33	23	32	40	41	52	69	72	65	63	68	64	64	59	58	54	46	38	37	72	
4/4/2009	36	35	28	24	28	26	29	34	43	56	58	59	58	54	52	50	50	50	50	48	45	42	SPN	41	59	
4/5/2009	41	42	39	35	31	28	26	25	31	37	37	42	51	55	55	55	53	51	49	47	47	46	44	43	55	
4/6/2009	43	44	44	43	41	39	35	37	37	39	41	42	QAS	49	51	52	52	52	51	47	46	43	39	34	52	
4/7/2009	32	24	21	19	15	11	11	13	33	41	45	49	53	57	59	61	62	61	48	32	41	45	45	37	62	
4/8/2009	37	29	29	28	28	28	15	26	48	55	57	57	56	54	53	52	52	50	47	45	40	36	32	36	57	
4/9/2009	36	38	39	37	37	38	38	41	44	46	45	45	44	44	44	44	42	40	39	37	37	38	40	39	46	
4/10/2009	38	38	38	38	41	42	43	40	44	47	50	55	65	75	77	60	59	56	50	47	43	42	44	44	77	
4/11/2009	42	41	42	43	41	41	39	38	39	39	40	43	47	50	52	55	49	44	46	47	50	52	SPN	53	55	
4/12/2009	48	42	40	35	29	22	19	19	19	22	24	34	35	42	53	59	60	58	47	29	32	32	27	19	60	
4/13/2009	16	12	4	5	5	11	20	20	29	38	45	49	51	53	53	52	52	52	51	46	43	40	39	42	53	
4/14/2009	43	43	33	22	10	5	5	25	38	45	57	58	54	61	67	75	77	74	62	54	52	45	39	33	77	
4/15/2009	19	18	12	5	4	6	16	20	42	54	61	62	62	64	62	60	59	58	53	48	44	43	41	45	64	
4/16/2009	39	39	43	36	30	32	37	41	47	52	55	54	57	59	59	58	57	57	56	53	51	48	49	48	59	
4/17/2009	44	41	41	40	41	40	40	38	39	41	41	42	42	45	43	35	22	27	30	32	32	34	35	37	45	
4/18/2009	36	34	30	34	34	33	36	36	35	34	34	35	37	39	39	39	44	40	37	35	33	27	CAL	CAL	44	
4/19/2009	25	29	29	36	35	32	31	32	30	31	38	47	54	57	58	58	59	59	57	55	47	28	25	17	59	
4/20/2009	38	39	37	30	29	25	19	23	33	39	47	53	60	61	62	62	60	60	55	40	32	8	10	13	62	
4/21/2009	21	26	30	32	32	29	25	33	43	PMA	54	58	63	65	66	68	67	67	56	45	40	37	35	33	68	
4/22/2009	32	33	33	31	28	22	21	35	44	47	51	56	57	57	56	54	53	50	43	36	34	34	34	32	57	
4/23/2009	30	30	30	24	27	28	27	33	40	47	49	49	48	47	47	45	42	40	40	40	38	38	38	40	49	
4/24/2009	40	39	36	36	33	27	31	38	41	43	44	46	44	42	41	39	37	36	41	44	43	40	41	36	46	
4/25/2009	34	32	37	42	41	40	38	38	40	43	44	41	40	38	38	37	39	38	39	39	38	37	SPN	38	44	
4/26/2009	40	41	40	39	40	39	38	39	41	41	40	39	40	38	36	35	34	35	34	32	30	27	27	26	41	
4/27/2009	24	25	25	26	24	21	20	24	26	26	27	24	25	24	23	20	19	34	46	45	43	41	32	27	46	
4/28/2009	27	31	27	27	25	23	22	22	21	23	24	25	25	25	25	24	24	23	24	24	23	24	25	26	31	
4/29/2009	25	25	25	25	23	23	24	25	25	26	26	27	26	25	26	25	24	24	23	23	25	25	24	24	27	
4/30/2009	23	22	20	21	22	23	21	23	24	23	23	23	25	26	25	25	22	21	20	20	20	20	20	21	26	

Date	Central Standard Time																									
	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	High	2nd High
5/1/2009	20	20	20	19	17	15	16	19	21	24	27	29	29	28	28	25	24	24	24	24	25	25	24	22	29	
5/2/2009	22	24	25	26	24	21	19	18	20	21	24	26	26	27	25	25	25	26	26	25	25	26	SPN	27	27	
5/3/2009	24	25	26	26	26	27	27	27	29	31	32	34	34	30	29	29	42	42	35	29	29	24	23	24	42	
5/4/2009	30	30	29	29	26	26	20	19	18	21	31	41	51	65	73	76	78	74	48	50	40	31	31	28	78	
5/5/2009	27	25	27	22	11	6	9	17	24	27	30	32	33	34	34	32	29	25	21	17	15	16	19	21	34	
5/6/2009	22	21	17	16	13	19	21	22	24	29	31	30	31	30	28	23	22	22	17	17	18	17	16	17	31	
5/7/2009	18	19	18	17	15	14	15	16	22	28	32	32	30	27	26	27	28	23	24	22	21	23	25	29	32	
5/8/2009	28	26	24	25	24	23	23	28	30	30	28	29	29	29	28	28	28	28	27	26	27	29	31	28	31	
5/9/2009	25	23	20	19	20	25	19	23	26	28	30	32	31	32	32	30	30	26	25	21	19	17	SPN	17	32	
5/10/2009	15	16	14	13	11	9	11	17	22	26	28	26	25	24	24	21	21	22	22	19	20	16	15	16	28	
5/11/2009	14	14	14	16	13	7	13	21	26	28	30	29	28	27	24	20	21	20	16	15	15	14	13	11	30	
5/12/2009	12	10	9	6	5	0	4	13	23	30	32	33	30	28	26	27	25	23	20	20	19	18	19	20	33	
5/13/2009	20	21	21	19	16	12	17	24	26	29	29	29	31	29	29	27	27	24	23	20	20	18	18	17	31	
5/14/2009	17	16	17	14	13	8	13	19	28	30	31	32	33	33	33	33	30	27	23	25	20	19	19	12	33	
5/15/2009	8	7	11	12	5	5	8	17	22	25	27	27	26	26	25	25	25	24	22	17	14	13	11	8	27	
5/16/2009	7	7	6	8	5	2	8	15	23	25	28	29	33	33	31	27	26	28	33	31	28	25	CAL	CAL	33	
5/17/2009	26	25	23	24	24	22	21	23	24	28	33	36	31	25	34	40	39	38	36	33	30	29	30	27	40	
5/18/2009	21	17	20	25	22	23	22	36	41	46	52	53	54	55	58	59	59	55	52	46	34	26	25	35	59	
5/19/2009	33	31	34	34	25	4	15	29	38	46	53	59	66	70	78	80	78	71	65	57	46	32	26	19	80	
5/20/2009	17	19	36	37	24	13	13	27	43	60	69	77	98	107	100	98	94	87	77	56	38	29	25	19	107	100
5/21/2009	13	13	13	16	16	16	15	20	36	63	77	86	83	72	62	59	57	56	55	52	43	37	28	27	86	
5/22/2009	30	27	26	14	10	6	10	22	34	40	58	49	46	43	41	42	39	29	21	21	15	13	8	5	58	
5/23/2009	6	2	2	5	4	5	8	18	31	38	41	49	48	44	42	44	44	45	41	30	21	34	SPN	35	49	
5/24/2009	38	34	27	23	17	13	18	28	35	44	PMA	PMA	48	47	48	43	41	42	39	29	28	29	28	21	48	
5/25/2009	20	22	17	16	15	16	19	29	39	43	44	44	46	49	50	51	53	54	44	40	31	21	20	14	54	
5/26/2009	14	14	11	6	3	3	1	7	17	31	45	49	51	58	59	62	59	50	45	38	32	26	21	18	62	
5/27/2009	17	15	11	4	3	10	11	14	16	5	10	13	20	23	30	35	42	40	35	24	13	21	11	7	42	
5/28/2009	6	6	9	12	5	3	14	24	38	49	55	64	73	79	81	85	88	75	61	42	46	38	32	25	88	
5/29/2009	34	30	32	24	18	15	16	30	49	59	67	78	121	124	97	92	91	89	81	76	64	52	39	30	124	121
5/30/2009	32	25	18	13	14	8	7	40	57	67	71	74	78	85	85	79	75	73	67	59	49	44	SPN	32	85	
5/31/2009	23	15	16	9	8	9	11	43	63	64	64	66	71	73	68	61	57	55	55	52	43	33	21	24	73	

Date	Central Standard Time																									
	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	High	2nd High
6/1/2009	18	16	11	11	8	8	16	36	51	55	55	55	55	53	QAS	50	50	48	48	44	41	37	37	32	55	
6/2/2009	22	18	10	10	7	5	12	27	38	39	36	36	34	35	37	29	24	29	28	26	22	14	10	8	39	
6/3/2009	15	17	11	7	3	2	5	20	26	30	33	35	42	40	38	36	34	35	32	22	24	17	12	5	42	
6/4/2009	9	14	11	7	14	26	29	32	39	47	52	56	59	61	62	63	62	62	59	44	37	30	24	22	63	
6/5/2009	20	18	8	6	6	4	12	26	37	61	76	73	78	78	87	87	87	83	74	54	49	42	44	28	87	
6/6/2009	25	16	10	8	7	8	13	30	48	60	66	67	69	69	65	65	66	63	62	59	52	43	SPN	34	69	
6/7/2009	32	30	20	19	15	12	23	36	43	45	47	46	46	45	43	42	40	39	37	32	25	24	21	13	47	
6/8/2009	12	15	14	8	4	2	11	27	35	38	40	40	38	39	38	36	31	28	25	20	16	15	11	10	40	
6/9/2009	9	9	9	6	2	1	5	13	20	23	25	25	26	25	26	25	24	23	18	14	11	10	8	6	26	
6/10/2009	8	8	9	8	6	4	9	18	25	28	28	27	25	23	23	23	23	22	19	16	13	14	13	12	28	
6/11/2009	12	14	14	14	11	12	15	21	25	27	27	28	29	29	28	27	26	25	22	18	14	14	12	9	29	
6/12/2009	11	16	15	9	3	1	7	17	23	28	30	29	29	29	29	31	31	29	26	20	16	15	12	12	31	
6/13/2009	10	9	9	8	7	6	10	16	20	23	24	25	27	28	29	29	30	28	23	20	17	12	CAL	CAL	30	
6/14/2009	11	12	13	12	9	6	6	16	21	23	25	25	28	30	30	29	28	28	23	19	18	17	14	13	30	
6/15/2009	14	13	13	7	2	1	4	16	21	24	26	26	26	26	27	28	28	26	22	17	15	15	15	16	28	
6/16/2009	15	14	11	9	3	1	5	18	25	28	29	30	30	30	30	28	26	25	22	17	16	15	15	14	30	
6/17/2009	14	13	10	7	2	1	5	17	22	27	29	32	31	32	28	24	22	21	18	19	14	10	9	9	32	
6/18/2009	7	10	11	9	3	1	7	15	18	19	22	24	24	26	25	23	20	19	18	16	12	11	10	8	26	
6/19/2009	10	10	9	3	1	1	5	13	18	19	20	24	25	25	23	23	20	18	19	16	14	7	6	2	25	
6/20/2009	4	3	4	3	6	5	6	15	20	23	26	30	29	29	28	27	27	27	24	17	15	12	SPN	7	30	
6/21/2009	10	16	15	10	6	5	11	19	21	23	23	25	25	26	27	27	27	25	22	18	14	12	11	10	27	
6/22/2009	9	5	3	1	1	1	4	12	18	22	23	24	27	28	27	25	25	27	23	17	11	9	8	7	28	
6/23/2009	3	4	4	2	1	1	6	13	19	22	26	34	37	36	39	35	30	30	26	19	15	15	13	11	39	
6/24/2009	7	4	4	3	2	2	6	12	21	28	38	55	63	77	83	83	64	55	50	35	21	15	13	10	83	
6/25/2009	9	8	7	5	7	7	8	12	15	21	36	49	52	53	59	57	52	44	37	42	34	18	11	4	59	
6/26/2009	6	4	2	2	1	1	2	7	13	19	33	48	59	60	65	50	41	40	36	25	12	10	8	5	65	
6/27/2009	5	2	1	1	1	1	1	10	17	23	27	30	33	34	34	33	32	28	21	16	12	12	SPN	5	34	
6/28/2009	2	2	2	1	1	1	2	12	19	24	31	39	42	43	45	49	40	31	23	19	15	14	12	11	49	
6/29/2009	11	9	11	10	7	3	7	13	17	23	31	41	49	56	59	53	44	32	27	37	53	40	31	27	59	
6/30/2009	18	12	8	1	0	0	1	9	16	22	26	35	43	39	51	64	62	PMA	PMA	PMA	PMA	PMA	PMA	LST	64	
7/1/2009	PMA	12	8	7	8	9	12	22	40	60	75	87	87	96	114	119	72	81	71	45	27	19	17	11	119	114

Date	Central Standard Time																									
	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	High	2nd High
7/2/2009	4	3	2	1	1	0	3	11	16	27	39	50	52	52	53	46	35	32	25	17	9	10	11	8	53	
7/3/2009	5	1	1	1	0	1	1	10	18	24	28	28	26	24	25	26	27	26	20	17	14	9	8	11	28	
7/4/2009	10	10	4	3	4	6	8	14	19	29	33	34	34	32	32	31	29	27	24	22	17	16	SPN	11	34	
7/5/2009	11	9	5	8	11	9	6	15	18	19	20	21	21	22	23	22	20	18	17	14	13	11	11	10	23	
7/6/2009	8	5	7	6	1	0	0	11	16	21	25	28	32	33	32	30	24	20	18	18	16	14	13	12	33	
7/7/2009	11	6	3	4	6	6	6	8	18	16	20	23	29	31	29	30	31	28	26	20	15	10	7	6	31	
7/8/2009	4	3	4	0	0	0	2	10	19	24	27	35	36	33	30	29	25	22	19	16	16	14	12	11	36	
7/9/2009	7	7	6	3	0	0	1	10	18	22	26	27	29	30	30	28	26	23	22	18	15	11	7	4	30	
7/10/2009	3	2	5	3	0	0	0	10	17	20	23	28	34	32	26	24	20	19	19	18	15	11	9	10	34	
7/11/2009	9	5	1	0	0	0	2	11	17	21	24	26	28	28	24	25	27	22	18	21	17	15	CAL	CAL	28	
7/12/2009	4	2	2	1	0	1	4	12	17	19	20	24	30	34	36	34	31	26	21	16	13	13	10	8	36	
7/13/2009	5	4	5	4	4	5	5	9	14	18	22	27	31	34	37	37	27	22	19	15	10	7	3	5	37	
7/14/2009	4	4	2	4	2	2	1	7	15	19	23	24	22	23	24	25	26	23	19	16	13	10	8	9	26	
7/15/2009	6	3	2	0	0	0	1	8	16	19	22	24	25	26	26	27	27	20	17	14	12	11	8	5	27	
7/16/2009	5	3	1	0	1	1	3	13	18	21	24	26	26	29	31	30	27	26	19	16	11	9	7	5	31	
7/17/2009	2	0	0	0	0	0	1	9	16	19	21	41	56	60	59	64	66	57	52	40	39	30	24	23	66	
7/18/2009	20	16	8	7	4	1	5	18	26	28	34	37	49	53	44	47	53	47	41	PMA	PMA	PMA	PMA	AQI	53	
7/19/2009	AQI	PMA	12	15	9	8	8	25	42	45	42	42	41	42	44	44	44	44	41	39	35	33	29	23	45	
7/20/2009	19	16	15	17	15	2	3	10	21	23	23	25	24	25	22	17	20	19	17	15	13	11	14	15	25	
7/21/2009	14	13	13	11	7	3	5	13	20	19	19	18	19	20	21	20	16	16	14	11	9	5	4	9	21	
7/22/2009	7	6	7	2	0	1	3	6	10	15	20	24	26	31	33	33	33	24	18	15	14	11	11	6	33	
7/23/2009	5	3	4	2	0	0	0	6	13	18	22	30	35	38	QAS	41	34	33	34	26	17	12	7	1	41	
7/24/2009	0	1	3	3	4	2	1	4	10	16	19	26	28	33	39	39	40	33	30	26	18	14	13	12	40	
7/25/2009	8	8	5	3	0	0	2	8	20	26	31	37	39	38	38	33	31	25	19	16	12	11	SPN	7	39	
7/26/2009	6	4	3	1	0	0	4	7	14	20	25	28	29	28	25	23	22	20	17	15	15	13	11	9	29	
7/27/2009	8	9	9	1	0	0	1	7	15	21	23	24	23	26	18	21	24	25	22	18	15	19	21	20	26	
7/28/2009	19	15	13	9	3	3	9	18	23	23	22	23	22	21	20	19	17	16	15	15	13	10	6	9	23	
7/29/2009	8	8	5	6	4	1	2	12	18	21	22	23	23	23	22	20	18	17	15	13	10	9	10	12	23	
7/30/2009	13	13	10	9	6	2	3	12	16	18	20	20	20	19	20	19	18	18	17	16	15	12	10	9	20	
7/31/2009	10	9	2	0	0	3	1	6	12	15	22	23	22	19	17	22	30	28	16	12	10	9	8	10	30	
8/1/2009	14	13	12	11	11	10	13	16	18	20	22	24	25	25	24	25	24	23	21	16	12	5	SPN	7	25	

Date	Central Standard Time																									
	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	High	2nd High
8/2/2009	8	6	10	10	12	11	7	12	18	20	23	26	29	32	30	30	26	24	22	20	16	13	13	12	32	
8/3/2009	11	12	12	11	9	5	1	5	13	19	23	24	26	25	27	26	24	19	17	16	13	10	6	10	27	
8/4/2009	10	9	4	1	0	0	1	7	16	22	25	26	26	25	25	22	20	17	16	15	12	11	10	8	26	
8/5/2009	7	4	3	2	3	1	3	9	14	18	20	24	27	29	27	25	24	23	20	14	12	11	11	8	29	
8/6/2009	7	8	5	5	3	0	0	9	17	22	27	33	39	43	37	36	32	25	19	15	13	11	11	4	43	
8/7/2009	3	1	1	0	0	0	0	6	14	19	23	27	31	32	27	22	22	23	22	19	13	9	9	7	32	
8/8/2009	7	10	7	6	2	2	3	24	38	38	34	33	30	30	28	27	26	23	20	16	13	9	CAL	CAL	38	
8/9/2009	5	3	3	4	3	1	5	15	22	25	19	21	25	28	27	29	25	26	22	18	15	13	9	6	29	
8/10/2009	3	1	1	0	0	0	0	4	14	18	21	22	21	22	21	12	19	15	14	11	9	6	3	4	22	
8/11/2009	4	4	5	5	3	1	2	7	12	17	21	25	27	31	30	26	24	19	16	12	10	8	6	3	31	
8/12/2009	3	2	1	0	0	0	1	4	10	18	26	34	42	57	61	66	55	PMA	PMA	PMA	34	33	29	26	66	
8/13/2009	26	17	14	5	5	1	2	11	24	45	61	68	65	61	54	51	51	42	36	29	15	19	14	5	68	
8/14/2009	5	2	1	0	1	0	1	10	28	40	46	51	57	AQI	50	53	48	45	40	30	26	27	21	10	57	
8/15/2009	9	11	6	3	1	3	4	18	33	37	43	48	48	41	38	37	33	35	32	25	20	14	SPN	SPN	48	
8/16/2009	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	SPZ	SPZ	0	
8/17/2009	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	PMA	LIM	LIM	PMA	CAL	CAL	CAL	LIM	LIM	LIM	LIM	LIM	LIM	LIM	SPZ	SPZ	0	
8/18/2009	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	PMA	LIM	LIM	LIM	LIM	PMA	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	SPZ	SPZ	0	
8/19/2009	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	PMA	LIM	LIM	LIM	LIM	SPZ	SPZ	0	
8/20/2009	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	PMA	PMA	PMA	LIM	LIM	PMA	LIM	LIM	LIM	LIM	LIM	LIM	SPZ	SPZ	0	
8/21/2009	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	PMA	LIM	LIM	LIM	LIM	SPZ	SPZ	0	
8/22/2009	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	SPN	SPN	SPN	0	
8/23/2009	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	SPZ	SPZ	0	
8/24/2009	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	SPZ	SPZ	0	
8/25/2009	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	PMA	58	52	43	44	32	26	30	33	26	58	
8/26/2009	23	21	20	21	6	5	10	27	45	CAL	CAL	53	53	54	52	57	54	52	48	42	37	37	31	15	57	
8/27/2009	16	12	7	6	6	5	2	17	41	51	54	57	59	60	70	65	56	55	46	35	29	29	24	22	70	
8/28/2009	20	20	21	41	37	24	19	17	27	31	CAL	CAL	CAL	52	60	61	55	56	46	40	46	41	34	20	61	
8/29/2009	10	4	6	3	5	5	6	19	34	47	62	74	85	86	80	77	68	60	49	39	39	43	SPN	28	86	
8/30/2009	22	22	20	15	11	27	30	34	44	57	61	62	61	60	63	63	64	67	71	81	61	61	56	42	81	
8/31/2009	40	32	28	24	17	6	6	12	24	32	40	49	59	75	72	67	68	68	50	35	36	33	28	21	75	
9/1/2009	11	11	8	5	3	8	18	23	28	35	40	48	56	64	72	88	81	66	38	16	18	7	7	4	88	

Date	Central Standard Time																									
	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	High	2nd High
9/2/2009	5	4	2	10	8	5	3	9	26	40	54	72	88	106	113	112	96	86	74	74	62	56	46	28	113	112
9/3/2009	23	18	21	20	10	2	3	16	51	62	67	79	88	95	101	127	103	75	65	61	60	57	50	33	127	103
9/4/2009	24	22	20	18	32	42	35	25	32	26	40	57	68	83	101	93	82	72	58	45	41	38	27	19	101	93
9/5/2009	14	11	7	13	15	8	5	16	40	67	73	74	77	76	69	64	65	59	48	40	29	22	CAL	CAL	77	
9/6/2009	17	12	9	4	4	7	8	17	38	52	58	49	44	49	46	41	45	43	35	26	20	15	12	7	58	
9/7/2009	7	2	3	4	5	3	3	9	29	39	55	73	76	62	51	50	53	46	42	31	27	19	15	6	76	
9/8/2009	5	2	3	1	2	1	2	9	28	44	50	52	45	31	31	QAS	37	29	22	14	7	3	3	4	52	
9/9/2009	1	1	1	1	1	1	2	10	15	13	18	23	23	18	20	17	20	15	7	7	3	4	5	5	23	
9/10/2009	3	4	2	1	1	1	1	6	13	21	26	28	28	35	35	35	35	32	25	16	7	5	3	5	35	
9/11/2009	4	2	3	6	6	4	2	4	11	14	21	26	30	34	34	32	32	30	28	27	28	25	25	18	34	
9/12/2009	17	14	13	13	12	11	12	13	15	17	20	18	16	20	21	27	30	27	23	19	17	12	SPN	9	30	
9/13/2009	8	12	14	12	11	8	7	10	19	31	36	39	37	39	37	37	36	36	31	22	20	17	21	16	39	
9/14/2009	17	15	12	9	10	7	4	7	14	23	35	36	39	40	38	35	34	34	31	28	28	27	28	26	40	
9/15/2009	25	24	18	16	19	21	20	21	23	25	25	28	32	31	33	33	32	33	25	22	19	14	11	7	33	
9/16/2009	9	6	8	12	11	8	5	10	21	34	45	48	48	47	46	45	45	42	39	36	31	25	19	20	48	
9/17/2009	18	16	20	17	16	15	16	22	34	41	45	46	45	44	45	43	43	41	37	34	29	28	24	22	46	
9/18/2009	19	16	18	17	11	8	7	12	16	21	29	34	40	37	40	41	44	40	36	30	26	25	24	18	44	
9/19/2009	16	16	16	13	12	9	7	10	19	27	34	41	45	49	50	51	49	47	39	25	15	18	SPN	23	51	
9/20/2009	20	20	15	8	8	5	6	24	39	48	52	52	54	53	53	55	56	52	48	42	37	32	33	30	56	
9/21/2009	27	32	29	25	16	11	7	16	30	49	52	51	49	44	39	38	39	34	32	29	29	28	29	26	52	
9/22/2009	23	20	16	11	7	10	15	31	38	40	39	39	37	36	37	34	25	28	23	20	21	19	16	16	40	
9/23/2009	16	16	16	17	18	15	13	13	16	20	28	33	39	44	42	39	35	32	28	23	23	24	24	24	44	
9/24/2009	25	25	23	22	19	15	9	11	10	PMA	CAL	CAL	CAL	26	29	33	30	27	24	20	19	18	18	18	33	
9/25/2009	16	17	16	14	13	10	7	6	10	11	14	19	37	40	45	49	50	49	32	16	16	17	16	10	50	
9/26/2009	8	6	4	3	2	3	3	6	10	21	38	56	64	61	58	60	63	62	46	38	37	30	SPN	20	64	
9/27/2009	12	14	19	24	25	24	19	20	31	33	37	38	36	35	36	35	34	35	27	19	16	15	13	13	38	
9/28/2009	12	10	7	4	0	0	1	5	12	17	21	25	30	26	20	23	20	22	19	13	12	9	7	5	30	
9/29/2009	3	9	14	15	12	9	14	19	24	29	37	45	49	54	64	74	78	69	45	38	33	27	26	22	78	
9/30/2009	17	11	13	8	5	4	5	15	29	PMA	53	59	63	68	65	62	59	56	52	50	44	39	37	27	68	
10/1/2009	26	22	18	14	5	3	4	16	26	29	29	23	26	24	21	20	18	16	12	8	6	6	5	6	29	
10/2/2009	3	3	2	21	33	30	17	20	28	32	43	42	51	58	65	70	79	53	28	31	25	20	18	25	79	

Date	Central Standard Time																									
	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	High	2nd High
10/3/2009	19	13	15	14	13	12	13	17	21	24	27	28	33	33	31	28	26	22	23	21	19	20	CAL	CAL	33	
10/4/2009	17	17	14	12	10	13	12	14	16	16	17	16	17	18	21	19	18	16	15	13	11	5	1	4	21	
10/5/2009	5	3	4	4	2	1	1	3	7	10	17	19	25	29	26	23	20	16	13	10	9	8	9	8	29	
10/6/2009	9	8	8	5	3	1	3	9	16	19	19	20	20	20	19	19	18	17	13	12	13	11	10	6	20	
10/7/2009	6	9	5	2	1	2	2	12	21	25	25	26	29	31	30	28	25	21	19	16	15	14	14	14	31	
10/8/2009	14	13	12	11	12	10	11	14	17	20	21	22	23	22	22	21	19	17	17	16	16	15	15	15	23	
10/9/2009	15	15	15	16	18	17	16	18	19	19	35	31	29	29	26	28	25	15	1	1	4	4	5	6	35	
10/10/2009	8	9	9	8	9	7	6	7	8	9	10	16	19	21	23	25	24	23	19	16	15	13	SPN	11	25	
10/11/2009	10	14	14	14	14	13	7	5	7	8	8	10	11	11	12	12	9	7	5	3	4	4	4	3	14	
10/12/2009	3	3	2	1	1	0	0	1	1	3	15	24	25	21	19	19	17	20	12	10	9	5	6	5	25	
10/13/2009	3	2	5	7	8	5	2	11	16	19	18	14	14	20	21	23	17	14	7	8	6	7	7	8	23	
10/14/2009	12	11	8	5	3	2	1	5	9	14	16	17	16	18	19	19	19	18	14	10	9	5	4	9	19	
10/15/2009	10	12	12	12	12	10	9	10	14	16	18	19	19	20	20	20	20	17	14	11	8	9	14	20	20	
10/16/2009	18	13	10	9	9	11	15	16	18	22	26	31	36	39	41	42	40	35	35	30	26	28	25	25	42	
10/17/2009	23	24	22	21	21	20	16	18	24	30	36	36	40	44	46	46	41	35	26	16	6	5	SPN	16	46	
10/18/2009	22	21	20	16	14	14	13	17	23	27	31	34	37	42	44	47	45	38	31	24	21	22	23	16	47	
10/19/2009	15	13	17	17	10	4	6	8	21	32	41	42	43	49	46	42	41	35	25	20	22	20	21	22	49	
10/20/2009	25	27	26	18	18	12	6	19	29	36	38	40	38	38	38	38	QAS	34	28	27	30	34	35	36	40	
10/21/2009	37	36	34	31	29	26	26	19	20	24	37	38	37	36	36	32	31	27	25	23	22	18	25	20	38	
10/22/2009	22	22	22	24	24	24	25	27	27	QAS	QAS	34	35	37	37	32	29	25	22	20	19	18	15	14	37	
10/23/2009	14	14	12	11	8	3	2	7	14	20	24	30	34	37	38	38	38	33	29	20	14	9	3	7	38	
10/24/2009	9	5	2	3	1	0	2	5	17	25	39	44	49	51	53	55	50	36	34	34	30	31	SPN	20	55	
10/25/2009	21	22	25	27	28	26	21	29	37	43	45	46	47	45	46	45	45	45	41	39	38	39	38	42	47	
10/26/2009	42	43	41	40	37	33	31	27	25	40	36	33	33	34	32	27	26	22	22	20	24	30	20	10	43	
10/27/2009	8	8	9	8	8	10	11	12	14	15	19	23	28	36	40	41	40	33	25	5	2	3	7	5	41	
10/28/2009	4	9	11	10	3	1	3	8	19	34	38	37	36	34	33	31	30	29	30	28	24	22	21	17	38	
10/29/2009	16	16	17	14	12	11	11	11	13	14	15	16	16	16	15	15	13	12	11	20	32	32	38	38	38	
10/30/2009	38	36	35	33	36	30	30	29	22	25	24	20	21	24	24	26	32	28	16	3	1	1	1	1	38	
10/31/2009	1	6	8	8	5	4	5	8	17	29	35	40	43	46	48	49	47	35	16	9	11	1	CAL	CAL	49	
11/1/2009	4	2	0	0	0	0	1	2	8	28	44	40	39	42	44	44	42	29	15	13	6	4	6	4	44	
11/2/2009	5	2	2	1	0	0	0	LST	LST	LST	LST	LST	LST	LST	LST	LST	LST	LST	LST	LST	LST	LST	LST	LST	5	

Date	Central Standard Time																									
	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	High	2nd High
11/3/2009	LST	LST	LST	LST	LST	LST	LST	LST	LST	LST	LST	LST	38	41	54	60	46	29	12	3	CAL	CAL	CAL	2	60	
11/4/2009	2	1	1	1	1	1	1	2	4	19	45	52	58	65	62	60	55	35	23	15	9	7	5	7	65	
11/5/2009	3	3	3	1	1	1	1	2	6	18	38	46	51	58	65	67	64	56	36	24	14	13	9	5	67	
11/6/2009	4	3	1	1	1	1	1	2	11	33	57	64	68	67	63	62	59	47	36	33	19	16	17	17	68	
11/7/2009	19	16	16	14	9	7	11	9	22	35	45	48	49	51	51	51	47	40	33	29	31	25	SPN	20	51	
11/8/2009	24	27	24	28	30	29	25	28	31	33	34	37	38	39	42	41	39	38	36	37	35	31	29	27	42	
11/9/2009	26	25	26	24	21	20	11	9	12	13	17	21	29	32	33	30	24	16	14	16	14	14	13	14	33	
11/10/2009	12	12	14	12	11	9	7	5	10	14	25	31	37	40	39	42	42	37	24	15	9	6	2	1	42	
11/11/2009	1	1	3	4	7	9	9	6	9	19	29	39	47	53	55	54	49	41	21	14	8	6	2	1	55	
11/12/2009	1	1	1	1	2	2	1	4	17	32	44	50	69	85	89	89	79	47	32	34	30	24	22	11	89	
11/13/2009	12	5	6	5	0	1	1	2	18	43	53	54	58	56	51	50	45	40	35	28	26	26	27	28	58	
11/14/2009	27	26	28	17	14	6	3	9	22	32	41	49	48	46	45	46	43	38	31	32	31	29	SPN	26	49	
11/15/2009	23	23	25	22	18	18	16	22	31	38	39	39	39	39	39	36	35	31	30	28	24	23	18	23	39	
11/16/2009	21	19	15	21	21	15	15	16	11	13	15	18	23	27	30	31	33	33	32	30	25	21	20	22	33	
11/17/2009	19	20	20	21	20	18	18	13	21	30	33	36	39	41	42	42	41	37	30	26	16	10	11	13	42	
11/18/2009	10	8	6	7	2	1	1	4	10	31	41	45	47	48	49	49	47	30	25	30	26	20	21	19	49	
11/19/2009	17	12	20	26	22	15	20	25	25	31	44	49	49	48	47	47	46	44	41	43	45	46	46	46	49	
11/20/2009	46	47	47	46	42	44	40	32	39	38	35	36	36	35	31	32	27	21	21	26	25	27	28	23	47	
11/21/2009	21	21	21	22	28	31	30	28	27	25	25	28	28	29	31	29	29	27	26	26	27	29	SPN	12	31	
11/22/2009	10	11	9	11	8	6	5	8	14	24	31	38	42	47	48	49	45	34	23	18	4	7	17	22	49	
11/23/2009	19	13	3	8	1	2	1	4	16	28	36	43	49	46	47	49	46	37	29	28	22	18	16	18	49	
11/24/2009	20	24	22	20	21	21	20	15	6	13	16	16	12	14	18	21	24	14	10	24	27	24	31	33	33	
11/25/2009	32	28	24	27	20	13	4	6	11	18	29	32	34	35	37	38	37	29	17	8	4	4	2	2	38	
11/26/2009	2	2	1	1	4	6	8	15	20	25	28	33	37	39	39	40	37	34	27	20	15	11	10	6	40	
11/27/2009	3	3	2	2	2	1	2	4	4	11	26	33	34	39	42	42	41	36	30	28	25	24	24	19	42	
11/28/2009	23	26	21	16	19	25	22	22	29	38	41	41	41	41	41	40	37	35	35	36	35	33	CAL	CAL	41	
11/29/2009	33	32	28	26	27	26	26	21	24	29	38	38	38	36	36	35	33	31	31	28	28	26	26	26	38	
11/30/2009	23	8	8	10	12	13	12	9	8	8	7	8	9	9	8	6	6	5	1	1	3	16	17	18	23	
12/1/2009	17	17	17	15	16	14	12	12	11	11	11	12	10	9	7	5	3	2	5	8	14	11	9	14	17	
12/2/2009	14	14	15	15	19	19	19	18	19	22	27	31	31	31	34	36	35	33	30	26	25	24	22	23	36	
12/3/2009	23	22	23	20	14	9	6	4	5	10	15	17	20	22	25	26	25	23	15	18	20	19	21	22	26	

Date	Central Standard Time																									
	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	High	2nd High
12/4/2009	22	21	20	20	19	17	15	14	11	9	8	12	12	12	15	15	8	15	12	6	2	1	2	5	22	
12/5/2009	2	1	1	1	1	1	1	2	6	15	23	27	30	34	36	35	31	26	21	14	11	9	SPN	8	36	
12/6/2009	13	10	11	17	17	20	22	22	20	21	29	31	34	34	34	32	23	25	26	28	29	27	27	23	34	
12/7/2009	20	18	15	12	4	4	13	13	11	12	14	15	14	13	10	9	6	2	2	5	5	6	7	12	20	
12/8/2009	8	2	11	9	5	3	2	2	4	11	16	18	19	22	24	24	25	26	29	28	18	10	9	12	29	
12/9/2009	12	14	19	16	14	16	8	9	12	13	19	17	QAS	QAS	17	CAL	CAL	18	20	23	20	18	22	22	23	
12/10/2009	22	22	20	20	19	17	12	11	14	15	15	18	20	21	23	20	16	13	10	17	17	17	22	22	23	
12/11/2009	22	20	18	18	14	10	9	7	9	14	15	19	22	22	21	22	22	22	20	22	24	24	24	23	24	
12/12/2009	22	21	20	23	22	21	21	21	19	19	19	19	20	19	18	15	11	2	1	1	1	1	SPN	2	23	
12/13/2009	3	4	4	7	12	13	10	11	11	11	12	13	15	16	17	19	18	16	15	18	19	22	25	27	27	
12/14/2009	24	20	16	11	13	8	7	6	4	3	4	7	6	5	5	5	3	2	2	1	1	1	1	1	24	
12/15/2009	1	1	1	1	2	5	7	8	11	14	14	8	6	7	7	7	6	7	11	13	15	16	16	15	16	
12/16/2009	16	17	18	19	20	18	15	11	11	12	13	14	15	14	14	13	10	5	1	1	1	4	15	9	20	
12/17/2009	14	15	16	16	15	20	15	6	6	7	11	12	15	17	16	15	14	14	15	16	12	9	10	9	20	
12/18/2009	7	5	4	4	4	3	1	1	4	8	14	20	26	30	35	39	40	37	31	22	16	14	11	19	40	
12/19/2009	16	12	12	14	14	11	8	5	10	16	22	28	33	36	36	37	35	32	26	18	20	19	SPN	11	37	
12/20/2009	1	2	5	6	5	5	3	3	10	19	24	29	36	40	41	42	40	24	19	18	12	10	7	4	42	
12/21/2009	1	2	2	0	1	1	1	1	7	24	35	42	43	46	47	47	42	32	28	31	27	26	25	35	47	
12/22/2009	34	34	29	27	26	21	17	16	28	35	41	38	39	41	40	39	37	35	35	34	33	32	31	36	41	
12/23/2009	38	37	35	37	37	35	34	35	34	36	37	40	41	41	40	39	38	36	33	30	30	32	31	30	41	
12/24/2009	30	29	31	35	27	31	33	29	40	42	40	34	28	22	19	LST	19	22	24	25	27	27	27	30	42	
12/25/2009	32	35	35	36	37	37	36	35	36	37	38	39	41	42	43	43	43	39	26	14	23	26	11	12	43	
12/26/2009	12	7	1	3	13	6	1	6	16	26	27	29	31	32	30	26	24	25	24	19	16	9	CAL	CAL	32	
12/27/2009	10	5	7	19	20	14	15	15	19	27	34	38	42	45	46	46	45	41	34	26	21	25	28	23	46	
12/28/2009	23	23	23	27	22	17	12	15	19	24	24	26	28	30	31	31	30	23	13	8	4	3	5	3	31	
12/29/2009	4	1	1	2	6	6	2	3	7	11	15	19	20	18	11	10	10	8	10	18	19	19	20	23	23	
12/30/2009	24	25	23	18	17	16	3	9	3	3	5	6	10	11	15	22	26	24	23	24	24	22	20	26	26	
12/31/2009	24	23	18	19	19	16	12	10	13	12	13	14	18	21	21	23	21	16	11	8	6	11	10	12	24	
																					Annual High/Second High				127	121

Mustang Bayou C619

CAMS 619 Mustang Bayou C619

- EPA site number: 48-039-0619
- State: Texas
- County: Brazoria
- City: Liverpool
- Address: FM 2917 at County Road 169
- Site coordinates:
  - Latitude: 29° 18' 49" North (+29.313611°)
  - Longitude: 95° 12' 05" West (-95.201389°)
  - Elevation: 6 m (20 ft)
- Maintained by: URS Corp. for Brazoria County - Chocolate Bayou Industry Group

Area Map	Overall site view not available	Street level Map
View to the Northwest not available	North	View to the Northeast not available
West		East

View to the Southwest not available	South	View to the Southeast not available

Current Measurements at Mustang Bayou C619

Monthly Summary Report for Parameters at Mustang Bayou C619

Yearly Summary Report for Parameters at Mustang Bayou C619

- Real-time monitoring since: Tuesday, June 10, 2003
- Current status: Active
- Continuous monitors located at this site:
  - Met Data
  - Ozone
  - Nitrous Oxides
- Parameters currently being monitored:
  - Pollution parameters:
    - Nitric Oxide
    - Nitrogen Dioxide
    - Oxides of Nitrogen
    - Ozone
  - Meteorological parameters:
    - Wind Speed
    - Resultant Wind Speed
    - Resultant Wind Direction
    - Maximum Wind Gust
    - Standard Deviation of Horizontal Wind Direction
    - Outdoor Temperature
    - Net Radiation

PLEASE NOTE: This data has not been verified by the TCEQ and may change. This is the most current data, but it is not official until it has been certified by our technical staff. Data is collected from TCEQ ambient monitoring sites and may include data collected by other outside agencies. This data is updated hourly. All times shown are in Local Standard Time.

Last Modified February 27, 2010

©2002-2004 Texas Commission on Environmental Quality.

CAMS 619 Ozone Summary Report for 2009
Mustang Bayou C619 - EPA Site: 48_039_0619
Ozone (POC 1) measured in parts per billion
Data from this instrument meets EPA quality assurance criteria for regulatory purposes

Date	Central Standard Time																									
	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	Max	2nd Max
1/1/2009	23	19	16	16	18	17	15	15	15	15	18	29	35	41	43	44	43	40	36	31	29	29	26	23	44	43
1/2/2009	17	14	14	17	18	16	16	17	17	17	18	19	22	21	21	21	19	17	13	14	15	15	15	17	22	21
1/3/2009	16	16	13	9	14	14	17	19	22	23	23	24	26	26	25	24	23	21	20	18	15	17	SPN	17	26	26
1/4/2009	17	18	17	16	16	16	17	16	16	12	15	18	19	24	25	19	12	9	6	5	4	6	8	10	25	24
1/5/2009	10	10	10	10	9	9	8	6	4	5	5	6	5	6	6	6	5	2	1	1	2	2	1	1	10	10
1/6/2009	1	1	1	1	1	1	1	1	2	2	2	5	7	8	8	12	16	14	14	12	12	14	13	19	19	16
1/7/2009	18	12	18	17	15	15	11	9	13	23	30	33	38	37	41	45	41	40	38	33	30	28	28	28	45	41
1/8/2009	27	26	26	26	21	21	21	19	19	29	33	38	43	44	43	44	43	35	30	28	25	23	21	27	44	44
1/9/2009	27	28	29	31	29	28	28	28	27	36	42	45	46	45	43	38	36	37	32	30	27	25	24	23	46	45
1/10/2009	23	21	22	20	17	18	17	14	14	13	11	13	14	15	14	17	18	18	18	18	18	18	SPN	19	23	22
1/11/2009	20	20	20	20	20	20	20	19	21	22	23	25	27	29	29	32	32	31	27	17	13	8	7	4	32	32
1/12/2009	4	5	4	4	4	3	3	4	11	20	29	35	38	41	42	43	43	41	37	24	24	20	16	10	43	43
1/13/2009	7	3	10	11	16	18	16	16	20	23	24	28	31	32	33	36	38	38	32	24	18	15	13	8	38	38
1/14/2009	4	2	3	3	4	5	9	9	13	23	30	34	36	37	38	42	45	43	39	32	33	28	31	25	45	43
1/15/2009	18	20	15	15	13	15	17	20	23	29	QAS	37	42	45	48	51	52	49	39	26	24	23	21	26	52	51
1/16/2009	26	23	21	20	20	21	21	21	22	23	24	26	28	29	30	31	31	27	21	20	17	17	17	19	31	31
1/17/2009	18	16	16	16	17	20	31	35	36	37	43	45	46	46	45	46	44	39	36	35	33	30	SPN	28	46	46
1/18/2009	20	16	15	19	22	18	20	19	21	26	31	36	39	41	42	43	41	36	28	31	26	19	20	21	43	42
1/19/2009	22	21	21	24	24	23	23	23	24	27	29	31	34	37	40	40	39	38	35	33	26	23	23	22	40	40
1/20/2009	17	18	18	15	8	12	11	12	16	19	28	33	35	36	39	39	38	35	30	24	15	14	11	12	39	39
1/21/2009	11	6	6	12	14	6	3	2	7	22	35	39	41	44	45	46	46	44	42	40	37	33	37	30	46	46
1/22/2009	30	30	28	30	29	27	22	22	27	32	37	46	45	45	45	44	42	39	32	31	31	30	28	26	46	45
1/23/2009	25	27	27	26	27	23	22	27	29	33	41	41	41	41	41	40	38	36	31	23	25	25	23	26	41	41
1/24/2009	28	29	28	25	16	11	10	14	15	14	15	16	19	23	26	26	26	21	20	19	18	15	CAL	CAL	29	28
1/25/2009	16	16	14	14	13	12	11	10	12	13	14	14	15	16	18	20	16	13	12	12	15	15	15	16	20	18
1/26/2009	18	19	20	22	25	25	22	21	21	24	29	30	32	33	33	31	33	33	29	29	28	29	29	29	33	33
1/27/2009	27	26	24	23	23	22	22	21	24	28	31	31	32	32	31	31	30	29	27	20	0	1	1	1	32	32

Date	Central Standard Time																									
	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	Max	2nd Max
1/28/2009	1	3	3	3	4	6	6	5	7	7	8	13	16	19	21	22	22	16	11	7	9	12	11	9	22	22
1/29/2009	10	11	10	9	9	7	7	7	10	16	21	35	36	48	47	42	42	39	32	26	19	10	9	15	48	47
1/30/2009	15	12	12	14	12	15	17	15	20	26	32	37	38	42	50	42	38	43	41	39	36	34	36	37	50	43
1/31/2009	36	30	28	29	28	29	25	23	26	31	37	42	45	49	49	48	48	45	40	39	36	34	SPN	40	49	49
2/1/2009	39	39	37	36	35	37	37	32	35	38	39	39	39	38	38	37	35	34	30	29	26	22	23	16	39	39
2/2/2009	18	23	14	18	15	18	28	25	21	23	34	41	41	42	43	42	40	38	32	26	19	12	14	6	43	42
2/3/2009	3	1	1	1	1	1	1	3	9	25	35	38	41	43	45	47	45	44	40	37	38	32	29	25	47	45
2/4/2009	19	28	18	14	17	27	26	23	22	24	28	32	35	37	39	41	41	38	38	34	31	31	33	29	41	41
2/5/2009	22	24	29	27	25	26	25	23	27	38	40	42	42	42	42	41	40	41	35	31	31	30	28	30	42	42
2/6/2009	29	30	30	31	29	28	27	27	35	39	41	41	41	41	42	41	42	39	38	37	38	37	39	38	42	42
2/7/2009	39	40	38	36	34	35	36	37	39	39	40	40	41	40	39	39	39	37	34	30	28	31	SPN	30	41	40
2/8/2009	29	27	27	26	24	24	24	27	30	35	37	37	39	38	39	39	38	36	36	35	36	35	34	32	39	39
2/9/2009	33	32	32	32	32	31	30	28	29	32	32	32	30	31	32	32	33	32	31	28	28	27	28	28	33	33
2/10/2009	26	25	24	23	23	23	24	23	28	32	33	32	31	31	30	30	28	27	27	26	26	26	26	23	33	32
2/11/2009	26	25	41	36	30	31	26	23	23	31	35	37	38	42	44	45	45	44	34	28	27	23	21	23	45	45
2/12/2009	14	13	12	13	11	15	7	10	18	30	40	45	47	48	50	51	53	53	49	44	41	46	45	44	53	53
2/13/2009	41	41	40	42	42	41	38	34	29	26	22	20	21	21	21	20	18	15	15	14	14	11	12	14	42	42
2/14/2009	14	13	11	11	10	9	9	10	17	21	24	25	26	23	26	25	25	24	23	24	24	15	SPN	17	26	26
2/15/2009	18	19	14	12	8	8	8	11	14	16	18	22	27	29	33	41	41	36	30	28	24	27	32	34	41	41
2/16/2009	32	31	29	27	25	23	22	22	28	32	31	33	38	42	42	43	43	41	40	37	36	37	41	43	43	43
2/17/2009	42	39	39	36	38	37	38	39	38	41	43	43	43	43	42	40	39	38	36	34	33	31	30	28	43	43
2/18/2009	26	23	21	20	20	20	20	19	19	19	17	19	21	22	20	21	21	17	14	13	11	10	6	5	26	23
2/19/2009	5	16	28	29	29	30	31	30	32	36	39	40	47	48	47	48	46	43	38	34	29	28	28	25	48	48
2/20/2009	24	23	23	20	13	17	21	23	25	36	42	45	46	47	48	47	47	45	42	40	39	41	40	40	48	47
2/21/2009	38	38	36	36	39	39	39	39	41	42	45	46	45	44	39	27	28	25	27	35	37	34	CAL	CAL	46	45
2/22/2009	34	35	34	32	35	33	31	29	33	34	36	38	41	47	50	49	49	46	43	31	32	32	31	26	50	49
2/23/2009	24	18	9	14	20	15	11	16	25	30	35	41	46	48	49	51	51	50	47	44	44	44	41	31	51	51
2/24/2009	34	32	30	34	37	33	29	31	35	40	41	41	41	40	41	41	41	39	35	29	29	28	29	31	41	41
2/25/2009	30	31	31	29	30	29	30	31	34	37	39	38	37	37	37	36	35	35	33	32	32	31	31	29	39	38
2/26/2009	30	29	29	29	29	29	28	27	31	33	33	32	30	30	30	30	29	27	27	26	27	26	26	22	33	33
2/27/2009	24	24	24	24	22	22	22	22	22	24	26	27	28	29	29	30	31	32	33	31	28	27	25	23	33	32
2/28/2009	24	23	19	15	13	11	14	12	13	14	18	20	26	33	35	40	42	40	37	39	38	35	SPN	30	42	40

Date	Central Standard Time																									
	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	Max	2nd Max
3/1/2009	31	30	30	27	24	25	28	28	30	30	32	35	38	40	42	42	42	41	37	29	23	22	21	18	42	42
3/2/2009	14	11	11	17	17	17	16	17	28	35	39	43	50	50	46	47	54	58	56	53	51	49	44	39	58	56
3/3/2009	30	28	34	28	33	32	25	21	28	40	43	47	50	52	53	53	55	56	54	50	47	42	42	41	56	55
3/4/2009	41	40	41	40	38	36	33	36	41	46	47	48	48	48	48	47	47	46	43	38	38	39	38	38	48	48
3/5/2009	38	38	35	37	36	35	35	34	34	37	39	38	37	36	36	37	36	35	35	33	31	31	31	32	39	38
3/6/2009	31	29	31	29	27	26	26	27	33	36	37	37	37	36	35	34	35	33	34	31	30	28	27	26	37	37
3/7/2009	25	26	27	26	27	26	26	25	30	35	37	37	36	35	35	34	33	33	32	30	29	29	SPN	28	37	37
3/8/2009	29	27	23	22	28	26	24	21	31	34	36	37	37	36	36	35	36	37	35	36	34	32	31	30	37	37
3/9/2009	29	28	27	26	26	26	26	27	28	31	31	34	36	36	36	36	37	38	38	39	36	31	30	30	39	38
3/10/2009	28	28	27	26	26	27	26	28	31	33	34	35	36	36	35	35	36	35	35	30	31	31	30	28	36	36
3/11/2009	27	26	24	25	27	27	24	23	30	34	36	37	38	38	40	40	39	39	37	32	29	20	21	23	40	40
3/12/2009	24	22	24	25	26	24	19	18	18	18	16	14	14	12	12	6	11	11	11	11	13	14	16	16	26	25
3/13/2009	15	13	12	11	13	12	11	9	9	10	13	15	FEW	LST	LST	LST	LST	LST	PMA	8	9	7	6	6	15	15
3/14/2009	6	5	6	7	8	9	9	9	8	8	9	10	10	8	7	8	8	8	7	7	5	5	SPN	5	10	10
3/15/2009	8	7	8	8	7	8	8	10	13	16	18	25	28	27	21	17	16	15	14	12	9	7	5	5	28	27
3/16/2009	6	7	8	6	5	3	1	4	9	17	25	29	34	42	45	55	62	62	41	31	28	27	22	14	62	62
3/17/2009	14	14	18	15	16	19	19	21	23	24	28	30	33	36	38	39	38	37	33	30	30	23	21	21	39	38
3/18/2009	20	14	6	9	15	9	12	13	17	31	38	41	42	42	42	43	42	44	42	38	35	29	26	23	44	43
3/19/2009	23	20	14	16	18	15	13	17	26	37	44	49	49	50	49	49	52	52	50	40	37	30	19	12	52	52
3/20/2009	13	13	12	14	17	18	14	14	29	33	38	43	54	53	52	53	52	52	50	45	42	44	35	33	54	53
3/21/2009	27	29	32	24	23	25	17	21	28	47	53	52	52	55	56	55	55	56	55	52	48	41	CAL	CAL	56	56
3/22/2009	47	45	48	40	39	30	35	38	55	55	56	55	55	55	55	54	54	53	52	51	48	48	49	50	56	55
3/23/2009	48	47	46	47	47	46	46	47	49	51	51	48	46	45	45	44	41	39	36	35	35	35	34	33	51	51
3/24/2009	34	35	34	33	33	33	35	37	38	38	40	40	39	39	37	35	35	35	34	32	29	28	28	28	40	40
3/25/2009	27	24	27	26	25	24	23	26	30	32	34	35	37	37	37	37	36	32	26	24	24	23	26	30	37	37
3/26/2009	31	28	25	27	25	25	24	22	22	25	28	30	31	31	29	32	27	25	25	25	22	29	28	25	32	31
3/27/2009	23	20	18	22	22	24	24	25	26	30	30	30	30	31	33	34	33	37	32	27	33	34	31	31	37	34
3/28/2009	31	31	30	29	30	28	34	38	39	40	40	42	44	46	48	49	48	47	42	31	24	20	SPN	22	49	48
3/29/2009	21	16	5	3	8	13	14	21	35	40	45	51	55	54	58	59	56	56	58	53	49	49	44	46	59	58
3/30/2009	45	40	43	42	43	41	42	45	50	52	51	50	50	49	50	48	46	46	44	41	39	37	36	36	52	51
3/31/2009	35	33	31	32	29	33	28	22	23	27	31	35	43	44	42	41	43	45	41	36	32	27	17	24	45	44
4/1/2009	24	26	31	36	35	32	32	28	33	43	47	48	49	49	48	49	49	47	44	41	40	43	42	42	49	49

Date	Central Standard Time																									
	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	Max	2nd Max
4/2/2009	38	34	31	29	25	24	21	31	34	34	47	53	52	53	51	51	51	51	48	44	39	41	39	29	53	53
4/3/2009	21	30	34	35	35	33	30	35	41	44	50	54	59	59	59	63	62	63	65	60	51	47	47	46	65	63
4/4/2009	48	48	47	49	46	44	43	47	53	55	56	54	52	50	50	51	52	51	51	46	44	42	SPN	37	56	55
4/5/2009	35	33	31	34	32	30	27	25	28	32	37	40	45	52	54	54	52	49	46	44	43	43	42	40	54	54
4/6/2009	40	40	40	40	40	37	36	34	34	36	37	41	42	45	47	48	48	48	46	39	32	29	21	33	48	48
4/7/2009	30	23	25	24	20	16	14	22	37	42	44	46	49	53	56	57	58	57	53	51	46	43	40	41	58	57
4/8/2009	40	42	43	43	42	42	43	43	47	51	53	54	53	51	50	49	47	46	45	43	41	40	39	43	54	53
4/9/2009	43	40	40	39	37	41	40	41	43	45	43	42	42	43	42	41	39	38	35	38	38	36	37	37	45	43
4/10/2009	36	37	38	38	39	37	32	32	43	48	48	49	55	62	66	58	51	51	52	45	44	46	44	44	66	62
4/11/2009	44	44	42	42	42	40	38	37	35	33	36	38	41	44	44	46	48	49	49	49	49	49	SPN	49	49	49
4/12/2009	46	44	42	37	27	22	20	19	20	22	24	27	32	38	45	52	56	58	54	39	34	30	29	22	58	56
4/13/2009	17	24	13	12	9	10	22	25	30	33	42	47	49	51	51	52	51	50	48	44	40	35	37	38	52	51
4/14/2009	36	35	31	22	24	29	23	34	42	47	50	54	62	76	74	71	73	71	68	64	50	41	51	40	**76**	74
4/15/2009	32	32	24	23	21	20	24	28	53	56	56	54	56	56	57	56	58	56	52	52	50	49	49	50	58	57
4/16/2009	49	44	45	44	42	42	42	45	48	52	53	55	57	59	58	56	54	53	50	49	45	46	47	43	59	58
4/17/2009	41	41	42	41	40	40	41	40	42	44	45	45	46	45	46	46	37	27	35	36	37	35	34	38	46	46
4/18/2009	37	35	37	38	36	38	39	38	37	37	37	39	39	37	35	37	38	37	38	35	31	27	CAL	CAL	39	39
4/19/2009	29	31	31	31	31	30	28	30	29	29	34	41	49	54	56	56	56	54	53	50	46	41	32	30	56	56
4/20/2009	25	26	29	24	18	17	18	23	27	38	48	53	57	59	62	61	59	55	51	39	38	35	32	32	62	61
4/21/2009	36	34	36	38	35	34	35	39	44	49	51	53	57	59	62	64	62	55	50	44	40	39	31	33	64	62
4/22/2009	37	37	40	40	38	40	40	42	46	45	45	47	48	49	50	48	47	44	40	38	38	38	36	35	50	49
4/23/2009	33	36	35	36	36	36	37	38	39	41	43	43	43	43	41	40	41	41	42	39	38	38	38	38	43	43
4/24/2009	37	36	36	34	33	35	38	40	42	42	43	42	42	41	39	39	38	36	36	33	32	35	34	35	43	42
4/25/2009	35	35	37	37	38	39	38	38	40	41	40	40	38	40	39	41	40	40	39	39	37	36	SPN	37	41	41
4/26/2009	38	38	38	37	37	37	37	39	39	39	38	37	36	35	35	34	35	35	33	31	29	26	25	24	39	39
4/27/2009	24	25	26	26	25	23	24	25	26	26	26	26	25	25	24	23	23	21	28	40	40	37	35	31	40	40
4/28/2009	33	28	27	27	27	26	25	24	24	25	24	23	23	23	22	24	25	26	26	27	25	26	26	27	33	28
4/29/2009	26	26	25	24	24	26	27	26	26	26	26	25	24	24	24	25	26	25	25	26	27	26	26	25	27	27
4/30/2009	24	23	23	24	25	25	26	25	24	25	25	21	19	19	QAS	22	21	21	22	20	21	21	21	21	26	25
5/1/2009	20	20	20	21	20	21	21	23	23	24	26	24	24	23	24	25	25	25	27	26	25	24	24	23	27	26
5/2/2009	23	26	24	22	24	21	19	19	20	21	22	23	24	22	21	21	25	27	29	29	27	27	SPN	27	29	29
5/3/2009	27	26	27	27	27	23	22	21	23	25	26	26	26	25	25	24	22	20	19	18	16	11	11	12	27	27

Date	Central Standard Time																									
	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	Max	2nd Max
5/4/2009	16	16	22	24	24	24	21	20	22	26	33	50	69	74	66	64	52	51	53	40	39	39	39	31	74	69
5/5/2009	29	29	23	19	19	21	21	23	25	26	26	26	27	26	26	26	24	20	18	17	20	23	24	26	29	29
5/6/2009	24	24	24	24	26	27	25	25	24	25	26	26	28	23	19	19	18	20	22	25	26	25	24	25	28	27
5/7/2009	23	24	23	24	25	24	24	24	26	27	27	26	25	20	20	21	21	25	27	28	29	30	32	30	32	30
5/8/2009	27	26	25	26	28	30	31	30	28	25	26	26	26	24	24	25	28	28	27	30	32	33	32	31	33	32
5/9/2009	28	27	24	23	26	24	24	24	26	27	26	26	26	26	26	26	25	28	26	25	23	19	SPN	23	28	28
5/10/2009	21	18	18	16	17	20	19	21	20	20	18	19	20	19	20	22	25	24	23	23	24	24	23	23	25	24
5/11/2009	23	24	26	24	22	22	22	23	25	25	24	22	20	19	19	19	19	17	17	18	20	20	18	17	26	25
5/12/2009	17	18	20	21	20	18	20	26	28	29	31	29	28	26	26	24	24	23	22	21	22	21	23	26	31	29
5/13/2009	26	25	27	31	28	31	30	26	26	26	25	24	23	23	24	23	23	23	22	22	20	19	19	18	31	31
5/14/2009	17	18	19	20	19	20	23	26	26	27	28	28	28	27	30	28	26	25	27	24	27	26	26	23	30	28
5/15/2009	24	23	21	20	20	20	21	23	24	23	23	22	21	21	23	23	23	22	22	21	21	21	20	20	24	24
5/16/2009	20	20	19	19	18	18	17	20	21	21	22	24	26	24	21	22	21	22	22	29	25	21	CAL	CAL	29	26
5/17/2009	20	21	19	18	18	17	17	20	23	26	27	29	33	29	24	34	40	36	33	30	32	31	27	23	40	36
5/18/2009	22	21	21	26	34	28	29	33	38	40	43	52	64	61	57	54	56	52	47	40	33	34	34	32	64	61
5/19/2009	25	30	25	22	22	20	22	28	36	42	47	50	51	52	56	60	60	62	59	51	30	35	28	27	62	60
5/20/2009	32	31	35	35	34	30	28	31	45	56	60	61	65	74	79	79	75	71	66	54	35	20	12	26	**79**	**79**
5/21/2009	26	26	16	12	14	14	13	28	36	47	54	54	53	55	60	63	59	61	58	51	37	31	18	18	63	61
5/22/2009	27	25	23	19	13	12	14	21	29	37	41	40	39	38	40	35	32	38	34	37	33	28	30	16	41	40
5/23/2009	12	5	12	11	5	4	10	25	38	48	44	46	37	40	47	52	47	44	46	48	50	50	SPN	45	52	50
5/24/2009	44	32	30	28	29	27	26	34	34	37	41	43	46	45	43	41	38	35	34	30	28	29	32	31	46	45
5/25/2009	29	27	28	23	23	18	20	26	33	41	44	46	44	45	55	59	53	46	41	31	27	27	23	18	59	55
5/26/2009	14	14	12	13	13	14	13	17	24	39	43	46	46	50	50	46	45	39	31	32	23	20	21	19	50	50
5/27/2009	19	15	17	16	15	6	10	15	26	19	21	22	22	24	39	37	34	39	34	28	23	25	20	13	39	39
5/28/2009	17	18	10	5	10	13	21	33	45	53	65	77	71	75	81	81	76	71	65	63	55	54	43	35	**81**	**81**
5/29/2009	38	40	29	23	20	25	24	42	52	58	62	65	83	89	90	83	81	80	77	68	58	47	36	24	**90**	**89**
5/30/2009	32	36	35	29	12	16	29	40	50	61	69	71	69	71	70	71	68	63	63	55	52	52	SPN	41	71	71
5/31/2009	29	24	25	18	13	22	20	43	53	54	56	57	58	55	54	54	54	53	59	58	51	47	44	39	59	58
6/1/2009	30	24	26	22	26	35	39	48	50	48	CAL	42	43	42	41	42	CAL	CAL	44	42	41	40	39	36	50	48
6/2/2009	36	32	30	24	17	18	17	27	29	31	30	28	29	27	29	24	27	25	26	24	22	21	24	26	36	32
6/3/2009	23	26	24	15	10	10	11	24	28	30	29	29	33	38	28	31	29	29	27	24	20	18	15	6	38	33
6/4/2009	9	16	12	10	6	14	22	26	32	38	48	53	56	58	59	59	59	57	51	39	30	25	23	21	59	59

Date	Central Standard Time																									
	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	Max	2nd Max
6/5/2009	20	21	20	18	16	14	18	25	35	41	44	47	54	63	78	75	76	63	60	54	51	51	48	32	**78**	**76**
6/6/2009	20	27	26	17	20	18	25	34	44	53	57	56	56	58	56	58	60	60	57	55	52	45	SPN	30	60	60
6/7/2009	28	37	31	21	20	25	34	40	41	41	40	39	38	37	36	36	35	33	31	29	28	29	31	30	41	41
6/8/2009	29	26	22	28	29	27	31	33	33	33	31	28	26	25	24	23	24	23	23	20	16	16	15	14	33	33
6/9/2009	13	13	14	13	14	15	15	18	18	18	17	16	16	17	15	15	14	14	14	11	10	12	12	11	18	18
6/10/2009	11	9	13	17	17	16	17	21	23	23	22	20	18	18	20	20	19	17	16	14	13	14	15	15	23	23
6/11/2009	12	13	15	15	14	14	17	20	22	22	23	22	22	21	20	20	20	18	16	15	14	12	15	15	23	22
6/12/2009	15	13	14	15	13	13	14	19	20	21	23	24	24	22	22	21	20	19	20	18	16	15	17	16	24	24
6/13/2009	15	13	13	13	14	15	15	18	19	21	21	21	22	22	20	21	20	20	19	18	19	16	CAL	CAL	22	22
6/14/2009	13	17	17	13	16	15	14	17	21	22	24	24	26	24	22	21	21	20	19	20	20	20	19	21	26	24
6/15/2009	20	18	19	18	19	17	15	19	21	23	25	26	27	25	23	21	20	19	16	17	17	18	19	19	27	26
6/16/2009	21	21	19	19	20	19	19	21	24	26	27	27	28	27	25	21	20	18	16	14	14	19	15	19	28	27
6/17/2009	16	15	15	15	14	15	16	19	20	20	20	19	18	18	19	18	18	18	21	16	16	17	13	16	21	20
6/18/2009	15	14	15	14	14	14	14	15	15	15	16	17	16	17	19	17	17	18	16	17	15	16	16	15	19	18
6/19/2009	16	14	12	13	13	10	13	14	15	16	16	15	14	15	14	16	17	18	18	13	14	14	13	13	18	18
6/20/2009	15	15	13	15	14	14	14	17	18	20	20	21	22	22	22	21	21	19	17	17	16	17	SPN	21	22	22
6/21/2009	21	21	22	21	19	15	17	20	21	22	21	22	21	19	19	17	17	17	17	16	15	14	13	12	22	22
6/22/2009	13	12	11	11	7	4	6	12	17	18	20	19	17	18	18	18	15	16	15	13	12	10	6	10	20	19
6/23/2009	7	8	7	5	2	1	3	11	17	22	29	30	24	21	20	22	18	18	16	17	16	14	14	16	30	29
6/24/2009	13	8	6	3	1	3	7	13	17	20	28	35	42	44	43	56	57	41	35	20	13	12	10	10	57	56
6/25/2009	7	4	4	3	3	3	5	8	11	15	23	32	36	39	39	34	42	43	29	26	22	15	8	SPZ	43	42
6/26/2009	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	SPZ	SPZ		
6/27/2009	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	SPN	SPN	SPN		
6/28/2009	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	SPZ	SPZ		
6/29/2009	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	CAL	CAL	CAL	CAL	CAL	33	26	28	28	24	18	14	13	13	10	11	33	28
6/30/2009	10	10	9	6	5	2	4	13	17	18	23	28	30	31	45	37	32	19	30	24	35	36	35	20	45	37
7/1/2009	14	11	16	9	7	10	14	25	36	46	50	56	60	61	60	49	62	59	34	25	21	18	13	12	62	61
7/2/2009	9	5	3	1	1	1	3	8	15	21	29	32	35	31	26	22	20	19	19	17	16	15	17	17	35	32
7/3/2009	11	7	5	2	0	1	5	12	17	19	20	19	20	19	19	19	18	18	19	17	17	15	13	18	20	20
7/4/2009	16	14	14	13	14	16	12	15	23	29	27	26	27	27	27	25	23	21	20	18	18	17	SPN	14	29	27
7/5/2009	13	14	20	21	20	19	16	16	17	18	18	17	18	19	20	19	18	17	15	13	13	12	11	13	21	20
7/6/2009	13	13	10	12	10	6	6	11	16	18	22	24	26	26	24	22	20	19	17	16	16	16	12	11	26	26

Date	Central Standard Time																									
	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	Max	2nd Max
7/7/2009	11	10	10	10	8	8	7	15	15	16	17	20	22	24	24	24	26	26	23	18	19	12	11	9	26	26
7/8/2009	9	9	6	5	5	6	8	13	19	23	24	25	24	25	25	22	21	20	18	18	15	15	14	14	25	25
7/9/2009	11	9	9	8	4	3	7	17	20	23	23	24	22	22	21	20	19	18	18	17	17	16	14	13	24	23
7/10/2009	12	12	13	12	11	10	12	15	17	18	19	19	17	16	16	16	17	18	18	17	14	13	14	9	19	19
7/11/2009	11	10	9	5	3	1	3	12	18	20	25	26	21	21	20	16	17	21	20	21	18	14	CAL	CAL	26	25
7/12/2009	13	10	4	1	1	0	2	11	14	16	18	21	26	22	20	20	18	16	15	13	14	11	12	10	26	22
7/13/2009	12	12	10	7	5	5	8	11	15	16	20	24	27	22	18	16	15	15	13	11	9	9	5	8	27	24
7/14/2009	9	8	5	6	7	4	6	11	14	17	18	19	18	18	18	18	16	16	15	14	13	11	14	14	19	18
7/15/2009	13	12	9	9	9	6	7	13	17	20	22	23	19	18	17	17	15	14	13	13	12	10	13	15	23	22
7/16/2009	11	12	11	9	4	2	12	18	17	18	21	21	22	21	20	17	17	16	15	12	10	11	10	10	22	21
7/17/2009	9	8	3	1	2	0	3	10	16	17	20	25	33	43	45	44	36	31	23	16	12	11	3	13	45	44
7/18/2009	12	12	9	9	5	1	6	17	21	26	30	37	41	45	42	46	37	28	19	33	38	35	SPN	28	46	45
7/19/2009	31	19	8	12	7	9	12	19	27	26	25	30	37	37	40	39	41	40	39	36	36	33	29	28	41	40
7/20/2009	26	22	24	21	18	16	15	20	22	22	22	21	19	27	20	17	16	15	14	14	11	14	12	14	27	26
7/21/2009	14	13	13	13	13	11	12	14	13	15	15	14	14	14	14	13	12	12	12	10	10	8	8	9	15	15
7/22/2009	9	9	8	6	4	6	6	7	10	13	15	18	21	21	22	20	20	19	15	14	14	11	10	7	22	21
7/23/2009	6	4	2	2	5	6	6	9	15	15	16	18	22	25	20	22	37	24	23	22	17	13	7	4	37	25
7/24/2009	3	3	1	2	2	2	4	8	15	17	16	20	21	24	28	36	31	31	26	24	16	12	8	13	36	31
7/25/2009	9	8	7	1	1	5	5	17	23	26	33	34	32	24	23	22	21	18	19	18	14	12	SPN	15	34	33
7/26/2009	11	11	9	9	6	6	6	12	17	21	21	22	22	22	20	18	17	17	18	18	17	16	16	21	22	22
7/27/2009	15	14	AQI	AQI	AQI	AQI	AQI	AQI	AQI	AQI	AQI	AQI	AQI	AQI	AQI	AQI	AQI	AQI	AQI	AQI	AQI	AQI	AQI	AQI	15	14
7/28/2009	AQI	AQI	AQI	AQI	AQI	AQI	AQI	AQI	AQI	AQI	AQI	AQI	AQI	AQI	AQI	AQI	AQI	AQI	AQI	AQI	AQI	AQI	AQI	AQI		
7/29/2009	AQI	AQI	AQI	AQI	AQI	AQI	AQI	AQI	AQI	AQI	AQI	AQI	AQI	AQI	AQI	AQI	AQI	AQI	AQI	AQI	AQI	AQI	AQI	AQI		
7/30/2009	AQI	AQI	AQI	AQI	AQI	AQI	AQI	AQI	PMA	PMA	PMA	AQI	AQI	AQI	AQI	AQI	CAL	CAL	16	17	19	16	20	24	24	20
7/31/2009	15	14	12	13	12	9	11	13	15	13	13	17	16	17	16	18	15	15	15	13	15	17	20	27	27	20
8/1/2009	16	18	18	18	18	16	16	17	18	20	22	22	23	23	23	23	21	20	18	17	15	16	SPN	22	23	23
8/2/2009	19	18	17	14	16	15	14	15	18	21	22	25	26	27	26	23	23	21	19	18	16	13	15	14	27	26
8/3/2009	11	13	13	13	11	6	5	10	15	21	24	22	19	17	17	18	17	17	17	12	13	16	18	16	24	22
8/4/2009	16	10	10	9	8	6	6	11	16	17	19	19	18	18	18	18	16	17	17	15	9	13	14	12	19	19
8/5/2009	12	8	10	10	9	7	5	12	15	18	21	26	24	21	20	20	18	17	15	15	12	10	10	12	26	24
8/6/2009	10	9	7	5	2	2	4	11	16	21	22	24	25	28	27	23	18	16	16	15	16	16	16	12	28	27
8/7/2009	8	9	10	5	3	3	4	13	20	22	23	21	22	17	17	18	21	20	17	14	16	18	14	20	23	22

Date	Central Standard Time																									
	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	Max	2nd Max
8/8/2009	25	22	31	27	30	29	23	33	35	33	31	29	27	23	23	21	21	20	19	18	16	11	CAL	CAL	35	33
8/9/2009	14	14	15	15	14	12	16	18	19	21	20	21	21	21	21	21	22	22	20	19	15	15	10	11	22	22
8/10/2009	10	10	6	9	8	11	10	13	16	15	18	17	16	16	15	16	15	14	13	14	16	15	12	12	18	17
8/11/2009	10	8	9	9	6	3	4	11	12	16	21	22	23	18	19	17	16	14	13	13	11	10	8	9	23	22
8/12/2009	7	6	3	1	0	0	2	6	10	13	17	29	36	40	41	59	62	55	51	26	18	24	24	21	62	59
8/13/2009	17	10	6	10	4	5	7	18	28	44	51	52	48	40	37	38	32	31	43	41	35	31	28	25	52	51
8/14/2009	17	5	3	3	2	2	6	14	26	35	40	50	50	47	47	43	43	41	39	42	42	35	32	16	50	50
8/15/2009	12	5	5	6	9	6	7	21	32	33	34	35	33	32	33	34	32	31	28	24	20	17	SPN	17	35	34
8/16/2009	15	7	6	8	7	8	9	17	22	24	26	25	25	21	19	18	17	17	16	13	10	10	8	12	26	25
8/17/2009	13	13	11	4	4	3	2	10	16	19	19	18	17	18	21	17	15	15	13	15	13	12	9	13	21	19
8/18/2009	7	10	7	7	14	12	9	10	16	20	21	22	23	22	22	24	23	22	21	20	14	8	15	13	24	23
8/19/2009	14	18	12	10	9	7	5	11	19	20	20	21	22	20	19	18	20	18	15	12	12	10	8	11	22	21
8/20/2009	13	16	14	14	12	12	12	13	15	17	17	19	19	18	18	15	14	14	15	11	14	17	17	16	19	19
8/21/2009	13	14	13	11	11	6	5	8	15	18	22	23	25	25	27	25	19	16	14	17	20	14	9	6	27	25
8/22/2009	6	2	4	2	1	6	9	15	22	26	25	30	36	40	42	41	42	35	28	24	20	17	SPN	11	42	42
8/23/2009	9	6	3	3	1	2	3	10	12	18	27	34	33	38	39	41	42	41	34	25	23	19	15	32	42	41
8/24/2009	28	26	15	13	5	2	2	3	8	16	20	28	32	36	40	41	40	39	34	27	23	26	28	30	41	40
8/25/2009	29	11	9	6	6	3	8	10	24	29	34	39	42	37	39	42	42	41	40	37	32	28	31	38	42	42
8/26/2009	28	31	33	35	29	32	32	31	45	48	51	49	49	49	49	50	49	45	40	41	38	34	35	31	51	50
8/27/2009	30	33	30	27	17	8	13	27	41	45	46	46	46	45	47	44	46	41	38	36	34	32	30	28	47	46
8/28/2009	29	16	16	20	20	14	19	28	32	31	33	35	36	41	49	43	43	41	39	36	36	39	33	21	49	43
8/29/2009	14	15	14	6	7	5	5	14	30	46	67	68	75	86	71	59	51	46	44	37	34	21	SPN	15	**86**	**75**
8/30/2009	7	6	12	17	14	20	17	29	42	51	58	64	62	59	56	56	74	86	99	70	53	44	45	35	**99**	**86**
8/31/2009	22	27	22	17	14	15	14	12	20	26	35	44	45	48	49	50	51	52	48	38	26	20	20	22	52	51
9/1/2009	17	21	19	18	15	19	18	15	24	30	36	45	50	50	54	60	67	65	52	37	25	21	18	22	67	65
9/2/2009	12	17	13	14	17	18	20	23	32	41	48	49	56	61	67	69	84	76	63	58	49	31	25	28	**84**	**76**
9/3/2009	26	15	14	12	11	13	15	26	45	56	62	64	69	80	90	76	73	69	71	69	63	55	49	27	**90**	**80**
9/4/2009	22	24	23	21	23	32	28	34	40	49	59	77	72	69	70	66	67	66	58	49	39	31	20	19	**77**	72
9/5/2009	15	5	15	15	16	13	14	24	39	53	58	55	53	53	64	60	45	41	40	34	28	26	CAL	CAL	64	60
9/6/2009	13	13	11	9	10	10	12	20	30	38	43	45	41	38	38	37	35	35	34	31	19	11	13	11	45	43
9/7/2009	7	4	5	7	9	8	11	15	31	41	50	48	43	46	44	41	40	39	35	35	32	24	18	12	50	48
9/8/2009	17	11	6	6	8	12	13	21	32	36	40	35	32	25	31	27	28	28	24	12	9	15	15	1	40	36

Date	Central Standard Time																									
	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	Max	2nd Max
9/9/2009	4	5	4	4	4	6	10	16	20	18	20	23	25	24	21	22	19	13	11	6	3	1	0	0	25	24
9/10/2009	0	1	2	2	1	1	3	7	15	21	23	25	28	30	29	28	28	27	25	22	19	10	7	4	30	29
9/11/2009	6	7	5	5	6	7	9	11	16	18	20	21	24	27	26	26	26	26	25	21	24	23	21	18	27	26
9/12/2009	18	18	16	14	12	11	13	13	15	17	15	15	14	15	19	26	26	26	21	18	14	11	SPN	11	26	26
9/13/2009	7	7	7	11	6	6	3	9	20	26	30	31	32	27	33	34	32	31	28	24	22	21	19	20	34	33
9/14/2009	21	20	20	17	15	13	9	11	17	21	29	32	33	33	33	31	30	28	25	22	19	17	19	18	33	33
9/15/2009	15	14	14	13	11	9	10	13	17	22	25	28	29	30	30	30	29	29	21	10	13	12	10	9	30	30
9/16/2009	9	11	10	11	7	7	6	12	20	30	39	46	45	43	43	40	39	39	36	26	19	14	19	14	46	45
9/17/2009	14	13	11	15	12	17	17	18	30	35	40	41	40	39	39	41	41	39	30	25	22	23	23	20	41	41
9/18/2009	16	15	14	12	10	8	7	9	15	21	25	32	36	39	40	41	41	38	31	14	14	19	7	6	41	41
9/19/2009	8	9	9	9	8	6	6	10	18	27	32	40	45	48	50	48	48	47	43	62	48	41	SPN	SPN	62	50
9/20/2009	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	SPZ	SPZ		
9/21/2009	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	SPZ	SPZ		
9/22/2009	LIM	LIM	LIM	LIM	LIM	LIM	LIM	LIM	CAL	CAL	LIM	LIM	CAL	CAL	CAL	CAL	33	26	21	21	20	16	15	11	33	26
9/23/2009	9	8	10	11	12	11	10	11	14	24	36	45	47	44	40	39	30	29	25	23	21	19	17	17	47	45
9/24/2009	14	17	17	19	16	14	12	12	14	18	20	25	34	40	42	38	32	29	24	22	20	18	18	19	42	40
9/25/2009	16	13	13	15	16	15	12	11	13	16	17	19	22	30	34	42	36	36	30	22	18	17	15	14	42	36
9/26/2009	12	12	9	8	7	5	7	6	13	17	27	39	42	42	49	52	50	50	41	36	34	31	SPN	28	52	50
9/27/2009	24	28	26	24	22	18	14	19	26	30	35	36	32	28	27	27	23	22	18	16	14	13	12	12	36	35
9/28/2009	10	11	11	9	8	5	3	11	13	16	19	19	21	20	23	22	21	15	13	12	8	6	2	6	23	22
9/29/2009	3	1	2	3	4	8	15	18	21	26	27	33	40	46	48	53	56	56	49	39	32	16	16	12	56	56
9/30/2009	15	9	10	6	12	15	15	17	26	40	48	51	52	51	56	55	55	57	48	42	36	31	30	28	57	56
10/1/2009	28	30	28	22	25	22	22	21	27	29	27	26	24	23	22	21	18	14	11	11	8	7	7	9	30	29
10/2/2009	6	3	2	2	PMA	PMA	PMA	21	24	28	31	36	43	44	45	46	46	44	41	28	20	19	15	16	46	46
10/3/2009	17	19	20	15	12	14	15	15	15	20	24	29	28	28	27	24	21	18	17	12	12	16	CAL	CAL	29	28
10/4/2009	17	16	13	12	15	17	17	17	17	16	15	21	20	17	17	16	15	13	12	11	8	8	6	7	21	20
10/5/2009	7	5	6	9	10	6	8	9	16	18	18	19	18	16	17	15	16	16	15	12	8	13	11	15	19	18
10/6/2009	11	13	13	12	12	13	15	15	16	16	16	17	16	17	17	16	17	16	13	13	13	13	11	17	17	17
10/7/2009	15	14	14	12	15	14	14	18	20	21	22	22	22	22	22	21	21	21	19	17	16	16	16	19	22	22
10/8/2009	15	13	13	14	15	15	15	16	17	18	19	19	20	18	18	18	18	17	16	15	14	14	14	14	20	19
10/9/2009	11	11	15	17	17	17	14	16	17	16	19	29	28	27	25	26	28	23	10	0	0	1	2	4	29	28
10/10/2009	5	6	5	5	5	4	4	6	6	8	14	18	26	28	32	33	26	19	17	18	14	12	SPN	11	33	32

Date	Central Standard Time																									
	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	Max	2nd Max
10/11/2009	12	13	12	13	12	10	8	6	8	9	9	10	10	10	10	11	10	8	9	8	7	6	4	5	13	13
10/12/2009	4	5	5	5	3	2	2	3	5	12	20	23	19	19	18	17	18	16	12	11	11	9	7	3	23	20
10/13/2009	5	10	12	10	11	9	18	19	18	19	18	15	16	18	19	18	17	15	13	12	10	11	10	12	19	19
10/14/2009	10	9	7	6	8	8	6	8	11	14	15	15	15	16	16	15	14	14	12	11	10	9	6	12	16	16
10/15/2009	12	11	8	10	10	8	7	10	13	14	15	15	16	16	15	15	15	12	11	10	8	6	6	10	16	16
10/16/2009	11	12	9	7	8	9	10	15	19	22	27	32	37	39	39	38	35	30	27	27	27	28	27	20	39	39
10/17/2009	19	20	16	17	19	18	14	17	21	24	30	35	45	44	41	38	36	33	23	20	19	16	SPN	18	45	44
10/18/2009	19	19	10	11	15	13	13	20	24	28	31	34	35	37	38	39	39	33	25	23	25	25	20	22	39	39
10/19/2009	23	24	18	12	7	5	6	10	20	35	39	40	34	35	34	QAS	39	36	33	33	31	32	32	34	40	39
10/20/2009	35	33	34	34	29	25	30	29	34	36	37	36	35	36	36	36	35	33	32	33	35	35	36	36	37	36
10/21/2009	36	34	34	35	33	31	27	30	32	34	37	35	36	36	34	34	30	28	26	23	22	25	27	25	37	36
10/22/2009	24	24	22	23	20	24	22	26	25	24	26	30	33	34	36	32	28	25	17	15	18	13	10	10	36	34
10/23/2009	12	11	8	8	9	8	7	9	14	18	22	26	31	34	36	35	34	27	23	21	14	11	17	9	36	35
10/24/2009	6	3	5	10	14	10	6	10	14	27	34	39	42	45	44	44	45	44	37	35	24	28	SPN	26	45	45
10/25/2009	21	22	25	30	30	30	29	31	36	39	40	41	40	41	41	42	43	40	40	38	40	39	39	41	43	42
10/26/2009	39	38	37	36	36	35	32	33	35	35	35	35	33	32	30	28	27	24	22	22	16	16	21	11	39	38
10/27/2009	7	7	7	8	6	7	8	10	10	14	16	19	25	29	33	36	36	32	27	23	17	10	15	10	36	36
10/28/2009	11	6	10	17	26	19	22	28	31	34	35	34	32	31	31	30	30	30	29	26	21	20	18	15	35	34
10/29/2009	13	13	14	11	10	10	10	11	12	14	17	17	16	16	16	14	13	12	11	8	16	26	28	29	29	28
10/30/2009	32	31	28	26	26	34	35	30	24	23	25	25	24	24	23	18	16	14	11	8	6	11	13	8	35	34
10/31/2009	5	3	2	4	4	10	8	14	21	26	33	36	39	41	43	44	42	34	23	15	15	13	CAL	CAL	44	43
11/1/2009	4	3	6	13	9	5	2	5	17	29	34	35	37	39	36	36	35	34	31	25	14	14	14	4	39	37
11/2/2009	5	6	7	8	5	7	4	5	18	29	34	37	37	36	39	43	51	42	21	14	13	10	5	3	51	43
11/3/2009	2	2	4	4	4	5	5	9	17	25	33	36	38	41	46	49	48	40	26	24	18	17	11	8	49	48
11/4/2009	8	5	6	4	6	9	7	8	17	29	39	47	50	52	53	50	48	44	26	20	23	21	19	9	53	52
11/5/2009	8	7	6	8	11	11	3	7	15	26	38	44	47	51	58	59	52	45	31	26	20	19	11	15	59	58
11/6/2009	13	11	8	9	14	10	8	12	27	42	55	60	60	60	60	58	58	55	39	33	33	35	30	28	60	60
11/7/2009	29	25	19	21	18	25	23	21	29	39	43	44	44	44	45	44	42	39	34	30	27	25	SPN	25	45	44
11/8/2009	24	20	21	30	31	31	31	29	30	30	32	35	37	38	37	38	36	34	34	33	30	28	26	25	38	38
11/9/2009	24	25	25	22	20	18	16	16	14	17	20	24	29	31	32	31	30	23	17	17	19	20	18	13	32	31
11/10/2009	11	10	9	8	9	8	8	8	12	18	25	32	38	41	41	41	37	32	26	24	11	6	3	3	41	41
11/11/2009	2	1	2	3	3	2	7	8	14	24	45	50	51	52	51	49	46	39	35	24	11	11	9	11	52	51

Date	Central Standard Time																									
	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	Max	2nd Max
11/12/2009	9	5	10	7	4	10	11	17	25	34	43	50	54	55	56	57	57	47	44	40	37	31	17	23	57	57
11/13/2009	17	16	15	7	8	11	14	15	23	42	48	47	47	47	46	46	45	41	37	33	35	36	36	33	48	47
11/14/2009	33	37	37	37	36	29	24	23	32	41	44	44	43	43	43	42	42	39	35	33	31	29	SPN	32	44	44
11/15/2009	32	31	32	29	29	26	26	28	31	36	38	37	37	38	36	36	36	33	30	27	27	27	25	26	38	38
11/16/2009	27	24	23	25	22	21	19	20	11	12	16	17	18	24	27	28	27	25	21	30	22	14	16	14	30	28
11/17/2009	11	15	14	12	11	9	11	14	23	30	32	34	36	38	39	39	36	30	25	22	24	23	23	20	39	39
11/18/2009	19	16	14	12	14	11	11	15	23	33	38	41	45	48	48	48	47	40	38	33	21	22	21	18	48	48
11/19/2009	27	21	17	27	29	29	30	32	34	41	47	47	46	46	45	45	44	43	44	43	43	43	43	45	47	47
11/20/2009	43	44	43	43	43	43	41	40	40	37	36	36	36	35	34	32	29	35	26	25	25	26	24	19	44	43
11/21/2009	18	20	25	24	25	24	24	23	24	23	25	25	27	26	26	27	26	25	22	20	23	29	SPN	15	29	27
11/22/2009	15	6	9	10	9	6	7	10	16	23	31	36	38	41	42	42	40	28	35	30	31	31	30	27	42	42
11/23/2009	21	15	14	8	9	12	10	15	21	29	38	40	42	44	46	44	42	37	29	24	22	29	27	22	46	44
11/24/2009	23	27	25	24	19	23	20	24	22	24	25	24	18	19	10	15	16	15	18	18	14	21	24	22	27	25
11/25/2009	20	22	23	19	12	12	8	10	16	22	29	31	38	36	36	37	34	28	15	11	4	2	2	6	38	37
11/26/2009	2	2	4	5	5	7	5	10	17	24	29	32	36	38	38	37	35	29	19	13	10	9	7	9	38	38
11/27/2009	9	13	10	12	6	6	7	6	7	15	19	23	30	38	39	39	37	35	34	32	31	26	28	21	39	39
11/28/2009	14	16	17	18	16	16	24	25	28	36	39	39	39	37	35	36	35	34	35	35	35	34	CAL	CAL	39	39
11/29/2009	28	27	27	27	27	22	23	24	25	27	32	31	34	33	32	31	30	29	27	26	27	25	21	27	34	33
11/30/2009	27	22	5	3	7	9	10	7	7	7	8	9	9	9	11	9	7	8	7	10	16	19	18	17	27	22
12/1/2009	17	16	15	15	15	14	14	13	13	13	12	12	12	11	10	9	6	5	6	6	12	11	11	11	17	16
12/2/2009	13	12	12	13	15	16	18	16	17	21	24	26	29	29	30	32	31	29	28	24	22	20	19	16	32	31
12/3/2009	13	15	18	19	17	13	7	5	9	12	16	20	23	25	22	21	19	16	15	12	17	19	16	18	25	23
12/4/2009	17	15	16	15	15	17	16	13	15	12	12	14	13	13	13	14	13	11	13	8	7	5	2	3	17	17
12/5/2009	3	4	6	5	2	1	2	4	9	16	22	26	27	28	30	32	32	27	19	17	15	14	SPN	14	32	32
12/6/2009	22	26	26	29	30	33	33	33	33	34	33	AQI	PMA	PMA	PMA	PMA	PMA	PMA	PMA	PMA	PMA	PMA	PMA	PMA	34	33
12/7/2009	PMA	PMA	PMA	PMA	PMA	PMA	PMA	PMA	PMA	PMA	LST	LST	LST	LST	LST	LST	PMA	PMA	PMA	PMA	PMA	PMA	PMA	PMA		
12/8/2009	PMA	PMA	PMA	PMA	PMA	PMA	PMA	PMA	PMA	PMA	CAL	CAL	CAL	17	18	18	19	19	21	23	23	22	21	17	23	23
12/9/2009	11	12	15	15	12	7	8	7	10	16	20	23	18	18	18	17	14	10	11	12	14	18	18	20	23	20
12/10/2009	19	17	17	17	17	17	16	16	19	20	20	21	23	24	25	24	23	22	22	22	22	21	20	18	25	24
12/11/2009	17	17	17	18	17	16	16	16	16	17	19	20	22	23	23	23	22	21	22	22	22	21	19	19	23	23
12/12/2009	18	18	17	17	15	16	17	17	20	21	20	20	19	21	21	24	20	12	6	5	2	1	SPN	1	24	21
12/13/2009	2	3	4	4	5	10	11	11	11	11	11	13	14	14	16	17	17	19	18	24	29	26	23	18	29	26

Date	Central Standard Time																									
	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	Max	2nd Max
12/14/2009	15	11	8	9	11	11	13	13	12	13	14	14	17	22	19	16	13	10	11	11	7	1	2	3	22	19
12/15/2009	2	1	1	1	2	0	3	7	8	14	15	14	12	7	8	8	7	8	8	9	9	11	11	13	15	14
12/16/2009	13	15	15	16	17	17	16	15	14	15	16	17	18	19	19	19	18	18	16	14	13	8	16	20	20	19
12/17/2009	18	17	16	18	18	19	18	17	16	15	17	22	23	27	28	27	21	20	15	15	15	13	12	10	28	27
12/18/2009	5	5	6	5	2	2	2	2	6	9	13	16	20	24	27	31	32	27	23	21	16	12	12	8	32	31
12/19/2009	9	12	4	7	8	4	8	7	9	18	23	24	29	31	32	33	29	22	19	16	18	21	SPN	10	33	32
12/20/2009	10	6	3	2	2	6	8	8	15	20	22	25	28	30	33	33	28	25	23	22	13	10	11	8	33	33
12/21/2009	5	4	1	1	2	4	6	11	15	24	33	37	40	40	41	41	39	37	33	29	29	30	31	30	41	41
12/22/2009	29	30	31	32	30	29	27	30	34	35	36	38	37	37	36	35	33	33	33	33	32	31	32	33	38	37
12/23/2009	32	33	31	32	32	32	32	32	33	34	35	36	35	36	37	36	34	32	30	29	28	28	28	25	37	36
12/24/2009	23	24	28	27	25	23	28	27	34	37	37	33	28	21	16	16	17	17	19	21	22	23	23	25	37	37
12/25/2009	26	28	29	30	30	31	30	30	30	32	33	34	35	36	36	37	36	37	32	27	16	17	22	12	37	37
12/26/2009	10	13	17	14	15	10	15	22	23	24	22	25	26	25	25	25	25	24	24	24	23	24	CAL	CAL	26	25
12/27/2009	20	17	14	12	15	17	20	17	20	27	34	38	38	36	37	39	36	33	29	26	20	18	13	10	39	38
12/28/2009	10	8	12	16	15	18	22	23	21	21	23	24	26	28	27	27	27	24	19	16	15	12	9	7	28	27
12/29/2009	3	4	5	6	7	8	7	8	12	14	15	18	18	19	19	18	17	20	20	20	18	19	21	24	24	21
12/30/2009	29	27	27	27	25	27	21	15	11	10	8	5	7	9	11	17	20	19	18	22	23	24	24	22	29	27
12/31/2009	19	17	17	15	14	12	11	13	16	18	18	17	22	22	19	21	19	16	12	11	7	11	11	8	22	22

PLEASE NOTE: This data has not been verified by the TCEQ and may change. This is the most current databut it is not official until it has been certified by our technical staff. Data is collected from TCEQ ambient monitoring sites and may include data collected by other outside agencies. This data is updated hourly. All times shown are in Local Standard Time.

Compliance with Eight-Hour Ozone Standard

Area	Monitoring Site	Fourth Highest Annual Average			Three-Year Avg
		2007	2008	2009	
Houston-Galveston-Brazoria					
	Houston East C1/G316	76	73	79	76
	Houston Aldine C8/AF108/X150	86	83	80	83
	Channelview C15/AH115	78	76	80	78
	Northwest Harris Co. C26/A110/X154	90	76	86	84
	Galveston Airport C34/A109/X152	51 *			
	Hou.DeerPrk2 C35/235/1001/AFH139FP239	86	76	82	81
	Seabrook Friendship Park C45	85	71	79	78
	Houston Bayland Park C53/A146	84	83	86	84
	Conroe Relocated C78/A321	76	73	65	71
	Houston Regional Office C81	68	68	80	72
	Manvel Croix Park C84	86	75	91	84
	Clinton C403/C304/AH113	74	71	78	74
	Houston North Wayside C405	78	70	69	72
	Houston Monroe C406	72	72	71	71
	Lang C408	73	71	81	75
	Houston Croquet C409	74	76	80	76
	Houston Westhollow C410	84	82	71	79
	Houston Texas Avenue C411	76	71	79	75
	Park Place C416	85	76	73	78
	HRM-3 Haden Road C603/A114	75	71	76	74
	Wallisville Road C617	92	85	75	84
	Danciger C618	77	77	74	76
	Mustang Bayou C619	86	75	71	77
	Texas City 34th St. C620	80	72	73	75
	Lynchburg Ferry C1015/A165	71	65 *	73	69
	Lake Jackson C1016	72	76	76	74
	Galveston 99th St. C1034/A320/X183	87	69	76	77

* The value shown for this site does not represent an entire year's worth of data.

PLEASE NOTE: This data has not been verified by the TCEQ and may change. This is the most current data but it is not official until it has been certified by our technical staff. Data is collected from TCEQ ambient monitoring sites and may include data collected by other outside agencies. This data is updated hourly. All times shown are in Local Standard Time.

Attachment 3.3.1
Hastings MVA Project Area
Listing of Public Water System Wells

Attachment 3.3.1
Public Water System Wells w/in 2 Miles of Hastings MVA Project Area

Public Water Systems	PWS_ID	Depth
ALVIN PANTRY 261 CITGO	0200302	350
BRAZORIA COUNTY RESOFT PARK	0200552	357
CEDAR GROVE PARK	0200353	585
CHAPLINES MOBILE HOME PARK	0200181	125
CITY OF FRIENDSWOOD	0840002	650
CITY OF FRIENDSWOOD	0840002	602
CITY OF FRIENDSWOOD	0840002	635
CITY OF PEARLAND	0200008	674
COUNTRY CREEK ESTATES WATER SYSTEM	0200337	380
FLORA 6	0200153	349
GENES COUNTRY STORE	0200559	100
HASTINGS HOMEOWNERS WATER SYSTEM	0200218	373
HEIGHTS COUNTRY SUBDIVISION	0200349	375
HEIGHTS COUNTRY SUBDIVISION	0200349	383
KWIK E MART	0200445	328
LA CASITA RESTAURANT	0200266	350
MANSFIELD MOBILE HOME PARK 2	0200191	350
MEADOWLAND SUBDIVISION	0200347	388
MEADOWVIEW SUBDIVISION	0200189	565
MEADOWVIEW SUBDIVISION	0200189	364
MOORELAND SUBDIVISION WATER SYSTEM	0200094	363
MOORELAND SUBDIVISION WATER SYSTEM	0200094	460
MORELAND SUBDIVISION BLOCK 1&2	0200226	375
MORELAND SUBDIVISION BLOCK 3&4	0200227	361
OAK HOLLOW MOBILE HOME PARK	0200055	350
PALMETTO SUBDIVISION	0200242	421
PALMETTO SUBDIVISION	0200242	455
PINE COLONY MOBILE HOME PARK	0200419	300
PLEASANT MEADOWS SUBDIVISION	0200223	451
PLEASANTDALE SUBDIVISION	0200248	395
RYAN LONG SUBDIVISION 2 WATER SYSTEM	0200108	355
SPIN IN MARKET 11	0200406	
VILLAGE TRACE WATER SYSTEM	0200341	622
WELLBORN ACRES	0200211	322

Attachment 3.4.1
Hastings MVA Project Area
Detailed Soil Type Descriptions

Bernard Clay Loam

Bernard-Edna Complex

Lake Charles Clay

Brazoria County, Texas

7—Bernard clay loam

Map Unit Setting

Elevation: 10 to 150 feet
Mean annual precipitation: 35 to 50 inches
Mean annual air temperature: 68 to 70 degrees F
Frost-free period: 250 to 300 days

Map Unit Composition

Bernard and similar soils: 85 percent
Minor components: 15 percent

Description of Bernard

Setting

Landform: Meander scrolls
Landform position (three-dimensional): Talf
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Loamy fluviomarine deposits of late pleistocene age

Properties and qualities

Slope: 0 to 1 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Somewhat poorly drained
Capacity of the most limiting layer to transmit water (Ksat): Very low to moderately low (0.00 to 0.06 in/hr)
Depth to water table: About 6 to 18 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 20 percent
Available water capacity: High (about 9.4 inches)

Interpretive groups

Land capability classification (irrigated): 2w
Land capability (nonirrigated): 2w
Ecological site: Blackland 24-44" PZ (R150AY526TX)

Typical profile

0 to 13 inches: Clay loam
13 to 65 inches: Clay
65 to 69 inches: Silty clay

Minor Components

Edna

Percent of map unit: 10 percent
Landform: Flats
Ecological site: Claypan Prairie 28-44" PZ (R150AY528TX)

Lake charles

Percent of map unit: 2 percent

Bernard
Percent of map unit: 1 percent

Morey
Percent of map unit: 1 percent

Unnamed, hydric minor components
Percent of map unit: 1 percent
Landform: Depressions

Data Source Information

Soil Survey Area: Brazoria County, Texas
Survey Area Data: Version 8, Oct 26, 2009

Brazoria County, Texas

8—Bernard-Edna complex

Map Unit Setting

Elevation: 10 to 150 feet
Mean annual precipitation: 35 to 52 inches
Mean annual air temperature: 68 to 72 degrees F
Frost-free period: 250 to 330 days

Map Unit Composition

Bernard and similar soils: 60 percent
Edna and similar soils: 20 percent
Minor components: 20 percent

Description of Bernard

Setting

Landform: Meander scrolls
Landform position (three-dimensional): Talf
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Loamy fluviomarine deposits of late pleistocene age

Properties and qualities

Slope: 0 to 1 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Somewhat poorly drained
Capacity of the most limiting layer to transmit water (Ksat): Very low to moderately low (0.00 to 0.06 in/hr)
Depth to water table: About 6 to 18 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 20 percent
Available water capacity: High (about 9.3 inches)

Interpretive groups

Land capability classification (irrigated): 2w
Land capability (nonirrigated): 2w
Ecological site: Blackland 24-44" PZ (R150AY526TX)

Typical profile

0 to 12 inches: Clay loam
12 to 60 inches: Clay
60 to 64 inches: Silty clay

Description of Edna

Setting

Landform: Flats
Landform position (three-dimensional): Talf
Microfeatures of landform position: Pimple mounds
Down-slope shape: Linear
Across-slope shape: Linear

Parent material: Loamy fluviomarine deposits of late pleistocene age

Properties and qualities

Slope: 0 to 1 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Somewhat poorly drained
Capacity of the most limiting layer to transmit water (Ksat): Very low to moderately low (0.00 to 0.06 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 10 percent
Maximum salinity: Nonsaline (0.0 to 2.0 mmhos/cm)
Available water capacity: Moderate (about 8.8 inches)

Interpretive groups

Land capability classification (irrigated): 3w
Land capability (nonirrigated): 3w
Ecological site: CLAYEY BOTTOMLAND 25-35" PZ (R150AY527TX)

Typical profile

0 to 9 inches: Fine sandy loam
9 to 48 inches: Clay
48 to 60 inches: Clay

Minor Components

Leton

Percent of map unit: 10 percent
Landform: Deltas
Ecological site: Lowland 35-56" PZ (R150AY537TX)

Lake charles

Percent of map unit: 5 percent

Aris

Percent of map unit: 5 percent

Data Source Information

Soil Survey Area: Brazoria County, Texas
Survey Area Data: Version 8, Oct 26, 2009

Brazoria County, Texas

24—Lake Charles clay, 0 to 1 percent slopes

Map Unit Setting

Elevation: 10 to 100 feet
Mean annual precipitation: 42 to 55 inches
Mean annual air temperature: 68 to 70 degrees F
Frost-free period: 250 to 280 days

Map Unit Composition

Lake charles and similar soils: 95 percent
Minor components: 5 percent

Description of Lake Charles

Setting

Landform: Flats
Landform position (three-dimensional): Talf
Microfeatures of landform position: Gilgai
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Clayey fluviomarine deposits of late pleistocene age

Properties and qualities

Slope: 0 to 1 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Moderately well drained
Capacity of the most limiting layer to transmit water (Ksat): Very low to moderately low (0.00 to 0.06 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 20 percent
Maximum salinity: Nonsaline (0.0 to 2.0 mmhos/cm)
Sodium adsorption ratio, maximum: 5.0
Available water capacity: High (about 10.8 inches)

Interpretive groups

Land capability classification (irrigated): 2w
Land capability (nonirrigated): 2w
Ecological site: Blackland 24-44" PZ (R150AY526TX)

Typical profile

0 to 13 inches: Clay
13 to 40 inches: Clay
40 to 64 inches: Clay
64 to 80 inches: Clay

Minor Components

Bernard

Percent of map unit: 2 percent

Pledger
Percent of map unit: 1 percent

Edna
Percent of map unit: 1 percent
Landform: Flats

Bacliff
Percent of map unit: 1 percent
Landform: Depressions on flats
Microfeatures of landform position: Gilgai

Data Source Information

Soil Survey Area: Brazoria County, Texas
Survey Area Data: Version 8, Oct 26, 2009

Attachment 3.5.1
Hastings MVA Project Area
Listing of State and Federal Rare, Threatened, and Endangered Species
In Brazoria County

Last Revision: 2/2/2010 8:23:00 AM

BRAZORIA COUNTY

BIRDS

		Federal Status	State Status
American Peregrine Falcon	*Falco peregrinus anatum*	DL	T

year-round resident and local breeder in west Texas, nests in tall cliff eyries; also, migrant across state from more northern breeding areas in US and Canada, winters along coast and farther south; occupies wide range of habitats during migration, including urban, concentrations along coast and barrier islands; low-altitude migrant, stopovers at leading landscape edges such as lake shores, coastlines, and barrier islands.

Arctic Peregrine Falcon	*Falco peregrinus tundrius*	DL	

migrant throughout state from subspecies' far northern breeding range, winters along coast and farther south; occupies wide range of habitats during migration, including urban, concentrations along coast and barrier islands; low-altitude migrant, stopovers at leading landscape edges such as lake shores, coastlines, and barrier islands.

Bald Eagle	*Haliaeetus leucocephalus*	DL	T

found primarily near rivers and large lakes; nests in tall trees or on cliffs near water; communally roosts, especially in winter; hunts live prey, scavenges, and pirates food from other birds

Black Rail	*Laterallus jamaicensis*		

salt, brackish, and freshwater marshes, pond borders, wet meadows, and grassy swamps; nests in or along edge of marsh, sometimes on damp ground, but usually on mat of previous year's dead grasses; nest usually hidden in marsh grass or at base of Salicornia

Brown Pelican	*Pelecanus occidentalis*	DL	E

largely coastal and near shore areas, where it roosts and nests on islands and spoil banks

Eskimo Curlew	*Numenius borealis*	LE	E

historic; nonbreeding: grasslands, pastures, plowed fields, and less frequently, marshes and mudflats

Henslow's Sparrow	*Ammodramus henslowii*		

wintering individuals (not flocks) found in weedy fields or cut-over areas where lots of bunch grasses occur along with vines and brambles; a key component is bare ground for running/walking

Peregrine Falcon	*Falco peregrinus*	DL	T

both subspecies migrate across the state from more northern breeding areas in US and Canada to winter along coast and farther south; subspecies (F. p. anatum) is also a resident breeder in west Texas; the two subspecies' listing statuses differ, F.p. tundrius is no longer listed in Texas; but because the subspecies are not easily distinguishable at a distance, reference is generally made only to the species level; see subspecies for habitat.

Piping Plover	*Charadrius melodus*	LT	T

wintering migrant along the Texas Gulf Coast; beaches and bayside mud or salt flats

Reddish Egret	*Egretta rufescens*		T

resident of the Texas Gulf Coast; brackish marshes and shallow salt ponds and tidal flats; nests on ground or in trees or bushes, on dry coastal islands in brushy thickets of yucca and prickly pear

BRAZORIA COUNTY

BIRDS

		Federal Status	State Status
Snowy Plover	*Charadrius alexandrinus*		

formerly an uncommon breeder in the Panhandle; potential migrant; winter along coast

Sooty Tern	*Sterna fuscata*		T

predominately 'on the wing'; does not dive, but snatches small fish and squid with bill as it flies or hovers over water; breeding April-July

Southeastern Snowy Plover	*Charadrius alexandrinus tenuirostris*		

wintering migrant along the Texas Gulf Coast beaches and bayside mud or salt flats

Western Snowy Plover	*Charadrius alexandrinus nivosus*		

uncommon breeder in the Panhandle; potential migrant; winter along coast

White-faced Ibis	*Plegadis chihi*		T

prefers freshwater marshes, sloughs, and irrigated rice fields, but will attend brackish and saltwater habitats; nests in marshes, in low trees, on the ground in bulrushes or reeds, or on floating mats

White-tailed Hawk	*Buteo albicaudatus*		T

near coast on prairies, cordgrass flats, and scrub-live oak; further inland on prairies, mesquite and oak savannas, and mixed savanna-chaparral; breeding March-May

Whooping Crane	*Grus americana*	LE	E

potential migrant via plains throughout most of state to coast; winters in coastal marshes of Aransas, Calhoun, and Refugio counties

Wood Stork	*Mycteria americana*		T

forages in prairie ponds, flooded pastures or fields, ditches, and other shallow standing water, including salt-water; usually roosts communally in tall snags, sometimes in association with other wading birds (i.e. active heronries); breeds in Mexico and birds move into Gulf States in search of mud flats and other wetlands, even those associated with forested areas; formerly nested in Texas, but no breeding records since 1960

FISHES

		Federal Status	State Status
American eel	*Anguilla rostrata*		

coastal waterways below reservoirs to gulf; spawns January to February in ocean, larva move to coastal waters, metamorphose, then females move into freshwater; most aquatic habitats with access to ocean, muddy bottoms, still waters, large streams, lakes; can travel overland in wet areas; males in brackish estuaries; diet varies widely, geographically, and seasonally

Sharpnose shiner	*Notropis oxyrhynchus*	C	

endemic to Brazos River drainage; also, apparently introduced into adjacent Colorado River drainage; large turbid river, with bottom a combination of sand, gravel, and clay-mud

Smalltooth sawfish	*Pristis pectinata*	LE	E

BRAZORIA COUNTY

FISHES		Federal Status	State Status

different life history stages have different patterns of habitat use; young found very close to shore in muddy and sandy bottoms, seldom descending to depths greater than 32 ft (10 m); in sheltered bays, on shallow banks, and in estuaries or river mouths; adult sawfish are encountered in various habitat types (mangrove, reef, seagrass, and coral), in varying salinity regimes and temperatures, and at various water depths, feed on a variety of fish species and crustaceans

MAMMALS		Federal Status	State Status
Jaguarundi	*Herpailurus yaguarondi*	LE	E

thick brushlands, near water favored; 60 to 75 day gestation, young born sometimes twice per year in March and August, elsewhere the beginning of the rainy season and end of the dry season

Louisiana black bear	*Ursus americanus luteolus*	LT	T

possible as transient; bottomland hardwoods and large tracts of inaccessible forested areas

Ocelot	*Leopardus pardalis*	LE	E

dense chaparral thickets; mesquite-thorn scrub and live oak mottes; avoids open areas; breeds and raises young June-November

Plains spotted skunk	*Spilogale putorius interrupta*		

catholic; open fields, prairies, croplands, fence rows, farmyards, forest edges, and woodlands; prefers wooded, brushy areas and tallgrass prairie

Red wolf	*Canis rufus*	LE	E

extirpated; formerly known throughout eastern half of Texas in brushy and forested areas, as well as coastal prairies

West Indian manatee	*Trichechus manatus*	LE	E

Gulf and bay system; opportunistic, aquatic herbivore

MOLLUSKS		Federal Status	State Status
False spike mussel	*Quadrula mitchelli*		T

substrates of cobble and mud, with water lilies present; Rio Grande, Brazos, Colorado, and Guadalupe (historic) river basins

Pistolgrip	*Tritogonia verrucosa*		

stable substrate, rock, hard mud, silt, and soft bottoms, often buried deeply; east and central Texas, Red through San Antonio River basins

Rock pocketbook	*Arcidens confragosus*		

mud, sand, and gravel substrates of medium to large rivers in standing or slow flowing water, may tolerate moderate currents and some reservoirs, east Texas, Red through Guadalupe River basins

Smooth pimpleback	*Quadrula houstonensis*		T

BRAZORIA COUNTY

MOLLUSKS

		Federal Status	State Status

small to moderate streams and rivers as well as moderate size reservoirs; mixed mud, sand, and fine gravel, tolerates very slow to moderate flow rates, appears not to tolerate dramatic water level fluctuations, scoured bedrock substrates, or shifting sand bottoms, lower Trinity (questionable), Brazos, and Colorado River basins

Texas fawnsfoot *Truncilla macrodon* T

little known; possibly rivers and larger streams, and intolerant of impoundment; flowing rice irrigation canals, possibly sand, gravel, and perhaps sandy-mud bottoms in moderate flows; Brazos and Colorado River basins

REPTILES

		Federal Status	State Status

Alligator snapping turtle *Macrochelys temminckii* T

perennial water bodies; deep water of rivers, canals, lakes, and oxbows; also swamps, bayous, and ponds near deep running water; sometimes enters brackish coastal waters; usually in water with mud bottom and abundant aquatic vegetation; may migrate several miles along rivers; active March-October; breeds April-October

Atlantic hawksbill sea turtle *Eretmochelys imbricata* LE E

Gulf and bay system, warm shallow waters especially in rocky marine environments, such as coral reefs and jetties, juveniles found in floating mats of sea plants; feed on sponges, jellyfish, sea urchins, molluscs, and crustaceans, nests April through November

Green sea turtle *Chelonia mydas* LT T

Gulf and bay system; shallow water seagrass beds, open water between feeding and nesting areas, barrier island beaches; adults are herbivorous feeding on sea grass and seaweed; juveniles are omnivorous feeding initially on marine invertebrates, then increasingly on sea grasses and seaweeds; nesting behavior extends from March to October, with peak activity in May and June

Gulf Saltmarsh snake *Nerodia clarkii*

saline flats, coastal bays, and brackish river mouthss

Kemp's Ridley sea turtle *Lepidochelys kempii* LE E

Gulf and bay system, adults stay within the shallow waters of the Gulf of Mexico; feed primarily on crabs, but also snails, clams, other crustaceans and plants, juveniles feed on sargassum and its associated fauna; nests April through August

Leatherback sea turtle *Dermochelys coriacea* LE E

Gulf and bay systems, and widest ranging open water reptile; omnivorous, shows a preference for jellyfish; in the US portion of their western Atlantic nesting territories, nesting season ranges from March to August

Loggerhead sea turtle *Caretta caretta* LT T

Gulf and bay system primarily for juveniles, adults are most pelagic of the sea turtles; omnivorous, shows a preference for mollusks, crustaceans, and coral; nests from April through November

Texas diamondback terrapin *Malaclemys terrapin littoralis*

BRAZORIA COUNTY

REPTILES

Federal Status State Status

coastal marshes, tidal flats, coves, estuaries, and lagoons behind barrier beaches; brackish and salt water; burrows into mud when inactive; may venture into lowlands at high tide

Texas horned lizard *Phrynosoma cornutum* T

open, arid and semi-arid regions with sparse vegetation, including grass, cactus, scattered brush or scrubby trees; soil may vary in texture from sandy to rocky; burrows into soil, enters rodent burrows, or hides under rock when inactive; breeds March-September

Timber/Canebrake rattlesnake *Crotalus horridus* T

swamps, floodplains, upland pine and deciduous woodlands, riparian zones, abandoned farmland; limestone bluffs, sandy soil or black clay; prefers dense ground cover, i.e. grapevines or palmetto

PLANTS

Federal Status State Status

Coastal gay-feather *Liatris bracteata*

Texas endemic; coastal prairie grasslands of various types, from salty prairie on low- lying somewhat saline clay loams to upland prairie on nonsaline clayey to sandy loams; flowering in fall

Giant sharpstem umbrella-sedge *Cyperus cephalanthus*

in Texas on saturated, fine sandy loam soils, along nearly level fringes of deep prairie depressions; also in depressional area within coastal prairie remnant on heavy black clay; in Louisiana, most sites are coastal prairie on poorly drained sites, some on slightly elevated areas surrounded by standing shallow water, and on moderately drained sites; soils include very strongly acid to moderately alkaline silt loams and silty clay loams; flowering/fruiting May-June, August-September, and possibly other times in response to rainfall

Texas meadow-rue *Thalictrum texanum*

Texas endemic; mostly found in woodlands and woodland margins on soils with a surface layer of sandy loam, but it also occurs on prairie pimple mounds; both on uplands and creek terraces, but perhaps most common on claypan savannas; soils are very moist during its active growing season; flowering/fruiting (January-)February-May, withering by midsummer, foliage reappears in late fall(November) and may persist through the winter

Texas windmill-grass *Chloris texensis*

Texas endemic; sandy to sandy loam soils in relatively bare areas in coastal prairie grassland remnants, often on roadsides where regular mowing may mimic natural prairie fire regimes; flowering in fall

Threeflower broomweed *Thurovia triflora*

Texas endemic; near coast in sparse, low vegetation on a veneer of light colored silt or fine sand over saline clay along drier upper margins of ecotone between between salty prairies and tidal flats; further inland associated with vegetated slick spots on prairie mima mounds; flowering September-November

Attachment 7.1
Hastings MVA Project
Qualifications of Key Team Members

Linda Gruver
Denbury Onshore, LLC

Susan Hovorka, Ph.D.
Bureau of Economic Geology, University of Texas at Austin

LINDA M. GRUVER
4320 Oak Knoll Drive
Plano, Texas 75093
(972) 599-4320
gruverlm@yahoo.com

SUMMARY

Regulatory and compliance in oil & gas production. Results oriented professional with strong knowledge and success with regulatory compliance. Unique blend of functional expertise and interpersonal skills, recognized for speed, accuracy and effectiveness of business processes. Major strengths in:

- Mergers and Acquisitions
- Permitting
- Enhanced Recovery Operations
- Staff Development
- Production Analysis
- Increased Productivity

PROFESSIONAL HISTORY

DENBURY ONSHORE, LLC 2007-Present
PLANO, TEXAS
REGULATORY & COMPLIANCE SUPERVISOR

Manage and monitor all aspects of state regulatory compliance for operation areas in Texas, Louisiana and Jackson Dome area in Mississippi of the West Onshore Region.

- Execute all corporate filings mandated by regulatory agencies for acquisitions and divestments.
- Interact with acquisitions group to insure seamless transitions into Denbury's processes and business practices.
- Supervise two regulatory & compliance specialists and two file clerks.

KERR-MCGEE OIL & GAS ONSHORE LP 2004-2006
DALLAS, TEXAS
SENIOR REGULATORY ANALYST

Manage and monitor state regulatory permitting and associated filings for drilling, completions, commingling, annual and semi-annual testing and new field designations for the Permian Basin/Mid-Continent operations area of the Onshore Southern Region.

- Set up administrative and operational processes to insure ease and timeliness of several business mergers and acquisitions.
- Took additional workload with the closing of the Tulsa office.
- Worked within tight time frames for obtaining drilling permits.

WESTPORT OIL AND GAS COMPANY 1990-2004
(formerly Coda Energy, Inc./Belco Energy Corp.)
DALLAS, TEXAS
REGULATORY ADMINSTRATOR

Manage and monitor all aspects of regulatory compliance, both state and federal, for approximately 2500 wells located in Texas, Louisiana and Arkansas. Executed all corporate filings for wells in Texas, Louisiana, Arkansas, Kansas and Oklahoma.

- Hired, trained and managed two production analysts.
- Highly effective communication and rapport established with governmental agencies overseeing oil & gas industry.

DEMINEX U.S. OIL COMPANY 1985-1990
DALLAS, TEXAS
PRODUCTION ANALYST

Production analyst reporting to production records supervisor. Coordinated and monitored regulatory compliance and production accounting for properties located in Texas, Oklahoma, Illinois and New Mexico. Prepared gross production and petroleum excise taxes on enhanced recovery project in Oklahoma.

PRODUCTION ANALYST 1983-1985
WORLD PRODUCERS INC.
DALLAS, TEXAS

Production analyst reporting to VP of Production. Managed regulatory compliance and production accounting for properties in Texas and Louisiana. Audit of severance tax resulted in a refund of approximately $5000.00 from State Comptroller's Office.

PREVIOUS EXPERIENCE

ASSISTANT EDITOR
CTB/MCGRAW-HILL
MONTEREY, CALIFORNA

Assisted project manager in writing test items for the DMI Mathematics System. Prepared final versions of test items, proofread copy and assisted in preparation of ancillary test materials.

ELEMENTARY TEACHER

Teaching positions held in Germany, Okinawa, Iceland, Bermuda, Mesquite, Texas, Midland, Texas and Corpus Christi, Texas.

EDUCATION

BS in Elementary Education
University of North Texas, Denton, Texas

Additional coursework at Texas Tech in Lubbock and University of North Texas.

Susan D. Hovorka

Professional Summary

February 9, 2010

Business address: The University of Texas at Austin
Bureau of Economic Geology
University Station, Box X
Austin, Texas 78713-8924
(512) 471-4863
E-mail address: susan.hovorka@beg.utexas.edu

Academic Background

B.A. Geology, Earlham College, 1974
M.A. Geology, The University of Texas at Austin, 1981
Ph.D. Geology, The University of Texas at Austin, 1990

Areas of Expertise

A. Sedimentology for supporting hydrogeology.
B. Petrography.
C. K-12 outreach.

Professional Work Experience

A. Present Position: Research Scientist, Bureau of Economic Geology, The University of Texas at Austin (1981 - Present).

   CO2 sequestration in saline aquifers (1998–present); Edwards aquifer studies (1993–1995); Austin Chalk study for Superconducting Super Collider project (1990–present); K–12 outreach coordinator; salt cavern studies in the Midland Basin (1996–1999); Montague County saline contamination study (1997–1998); Quaternary studies: geologic analogs for engineered barriers (1995–1997); reservoir characterization, Delaware Mountain Group (1995–1996); playa basin sediment study, Pantex Plant area (1992–1995); San Andres Reservoir Characterization Research Laboratory project (1989–1990); University Lands, Siluro-Devonian reservoirs project (1989–1990); host rock analysis, West Texas Waste Isolation project (1981–1988).

B. Geologist, Bendix Field Engineering Corporation, Austin, TX (April 1979 - April 1981).

   National Uranium Resource Evaluation (NURE) program.

Professional Societies

Austin Geological Society
Geological Society of America
International Association of Sedimentologists
SEPM (Society for Sedimentary Geology)

Awards and Honorary Societies

Award of Excellence, Association for Women in Communications, World of Water Simulation, 2006

Joseph C. Walter Jr. Award, Jackson School of Geosciences, 2005

Committee Responsibilities and Professional Activities

Member, Climate Systems Science Theme Hire Review Panel, Jackson School of Geosciences, 2007

Member, Promotions Advisory Committee, Bureau of Economic Geology, 2007

Chair, K-12 and Public Outreach Committee, John A. and Katherine G. Jackson School of Geosciences, The University of Texas at Austin, 2006 - present

Expert Review Panel Member, Greenhouse Gas Program, Review of Weyburn Phase II, Regina, Saskatchewan, International Energy Agency (Paris), 2006

Member, Expert Review Panel, Edwards Aquifer Authority, 2006

Issue Leader, Monitoring Working Group, International Energy Agency, Greenhouse Gas Program, Rome,, 2005

Member, Organizing Committee, Applied Technology Workshop on CO2 Sequestration, Society of Petroleum Engineers, 2005

Member, Outreach Working Group, Regional Geological Sequestration Partnerships, 2005 - 2006

Member, Organizing Committee, Applied Technology Workshop on CO2 Sequestration, Society of Petroleum Engineers, 2005

Member, Geological Storage Working Group, Regional Geological Sequestration Partnerships, 2004 - 2005

Member, Symposium Coordinating Committee, Symposium on Edwards Resources in Central Texas: Retrospective and Prospective, South Texas Geological Society and Austin Geological Society, 2004

Session Chair, Symposium on Edwards Water Resources in Central Texas: Retrospective and Prospective, South Texas Geological Society and Austin Geological Society, 2004

Chair, Geoscience Alliance, Jackson School K-12 and Public Outreach Committee, John A. and Katherine G. Jackson School of Geosciences, The University of Texas at Austin, Austin, Texas, June, 2002 - 2003

Member, Texas Education Commission Task Force of Geoscience Education in High School, June, 2002 - 2003

Chairman, Evaporite Research Group, Society of Economic Paleontologists and Mineralogists, 1988

Publications

Published Interviews

Price, Lena, and Hovorka, S. D., 2009, UT takes on carbon research, In The Daily Texan, September 11. [Front-page, above-the-fold article in which Hovorka is heavily quoted and features a color photo of her.]

Biello, David, and Hovorka, S. D., 2009, Carbon storage: a few good CO2 reservoirs could go a long way toward making coal 'clean,' in Climatewire, http://www.eenews.net/cw/2009/03/09. [Online article in which Hovorka is heavily quoted.]

Biello, David, and Hovorka, S. D., 2009, Carbon capture and storage: absolute necessity or crazy scheme?: 60-Second Science Blog [Online article in which Hovorka is heavily quoted.]

Hovorka, S. D., 2008, Locked up: Can we solve global warming by storing CO2 underground? Energy Special Report: GOVERNING.com, http://www.governing.com/articles/0809carbon.htm, September (Christopher Swope).

Clayton, Mark, Smyth, R. C., and Hovorka, S. D., 2007, Earth too warm? Bury the CO2, *in* Christian Science Monitor, July 31, http://www.csmonitor.com/2007/0731/po1s05-wogi.html

Article in which Smyth and Hovorka are heavily quoted.

Nowak, Rachel, and Hovorka, S. D., 2007, Biggest carbon-burial test will hunt for leaks: NewScientist Environment, February, NewScientist.com [Hovorka quoted extensively]

Hovorka, S. D., 2006, On-camera interview by Perth, Australia, ABC affilliate on greenhouse gas technologies, fall 2006.

Stowell, Cindy, and Hovorka, S. D., 2005, Solution to warming: go underground: researchers consider storing carbon dioxide beneath Earth's surface: Daily Texan, Focus, February 25 [feature in which Hovorka is quoted extensively].

Hovorka, S. D., 2004, Geologists bury carbon dioxide in test: The State.com: South Carolina's home page, October 5, http://www.thestate.com/mld/thestate/business/9839112.htm [feature in which Hovorka is quoted extensively].

Hovorka, S. D., 2004, Techline: Frio Formation Test Well injected with carbon dioxide: researchers perform small scale, short term carbon sequestration field test: DOE National Technology Laboratory web page, November 19, file://C:\\User/CO2iii\press\NETL%20-%20Carbon%20Sequestration_files\tl_frio_injection [Hovorka prominently featured].

Hovorka, S. D., 2004, CEC environmental exchange: carbon sequestration may be answer to excess greenhouse gas: CEC Newsletter, July, http://www.cechouston.org/newsletter/2004/nl_07-04/carbon.html [feature in which Hovorka is quoted extensively].

Hovorka, S. D., 2004, Texas locks up greenhouse gases—underground: The Christian Science Monitor, December 1 [feature in which Hovorka is quoted extensively].

Hovorka, S. D., 2004, Geologists bury carbon dioxide in test: The Beaumont Enterprise, October 5 [feature in which Hovorka is quoted extensively].

Hovorka, S. D., 2004, Experiment seeks answers on burying carbon dioxide deep underground: The University of Texas at Austin web page, December, http://www.utexas.edu/research/projects/frio.html [feature in which Hovorka is quoted extensively + photo].

Laramée, Valéry, and Hovorka, S. D., 2004, Entretien: La séquestration reste encore trop chère pour les raffineurs: Enerpresse, November [one-on-one interview].

Hovorka, S. D., 2004, A global threat buried: The Times, London, May 20 [feature in which Hovorka is quoted extensively].

Hovorka, S. D., 2004, New technology shows promise for state of Texas: Midland Reporter-Telegram, December 6 [story in which Hovorka is featured].

Berger, Eric, Nowlan, Godfrey, and Hovorka, S. D., 2004, Greenhouse gas goes underground: geologists catch, compress and bury carbon dioxide from smokestacks: Houston Chronicle, City and State, October 5 [feature in which Hovorka is quoted extensively + photo].

Books, Manuals

Farlow, J. O., Langston, W., Jr., Deschner, E. E., Solis, Richard, Ward, William, Kirkland, B. L., Hovorka, Susan, Reece, T. L., and Whitcraft, James, 2006, Texas giants: dinosaurs of the Heritage Museum of the Texas Hill Country: The Heritage Museum of the Hill Country, 105 p.

Reports, Monographs, Brochures, Pamphlets, Bulletins

Hovorka, S. D., 2000, Characterization of bedded salt for storage caverns—a case study from the Midland Basin, Texas: The University of Texas at Austin, Bureau of Economic Geology Geological Circular 00-1, 80 p.

Hovorka, S. D., 1998, Facies and diagenesis of the Austin Chalk and controls on fracture intensity—a case study from North Central Texas: The University of Texas at Austin, Bureau of Economic Geology Geological Circular 98-2, 47 p.

Hovorka, S. D., Mace, R. E., and Collins, E. W., 1998, Permeability structure of the Edwards aquifer, South Texas—implications for aquifer management: The University of Texas at Austin, Bureau of Economic Geology Report of Investigations No. 250, 55 p.

Hovorka, S. D., Dutton, A. R., Ruppel, S. C., and Yeh, J. S., 1996, Edwards aquifer ground-water resources: geologic controls on porosity development in platform carbonates, South Texas: The University of Texas at Austin, Bureau of Economic Geology Report of Investigations No. 238, 75 p.

Hovorka, S. D., 1995, Quaternary evolution of playa lakes on the Southern High Plains—a case study from the Amarillo area, Texas: The University of Texas at Austin, Bureau of Economic Geology Report of Investigations No. 236, 52 p.

Gustavson, T. C., Avakian, A. J., and Hovorka, S. D., 1995, Origin and development of playa basins, sources of recharge to the Ogallala aquifer, Southern High Plains, Texas and New Mexico: The University of Texas at Austin, Bureau of Economic Geology Report of Investigations No. 229, 44 p.

Ruppel, S. C., and Hovorka, S. D., 1995, Chert reservoir development in the Devonian Thirtyone Formation: Three Bar field, West Texas: The University of Texas at Austin, Bureau of Economic Geology Report of Investigations No. 230, 50 p.

Hovorka, S. D., 1994, Water-level controls on halite sedimentation: Permian cyclic evaporites of the Palo Duro Basin: The University of Texas at Austin, Bureau of Economic Geology Report of Investigations No. 214, 51 p., 2 pl.

Paine, J. G., Avakian, A. J., Gustavson, T. C., Hovorka, S. D., and Richter, Bernd, 1994, Geophysical and geochemical delineation of sites of saline-water inflow to the Canadian River, New Mexico and Texas: The University of Texas at Austin, Bureau of Economic Geology Report of Investigations No. 225, 73 p.

Tyler, Noel, Bebout, D. G., Garrett, C. M., Jr., Guevara, E. H., Hocott, C. R., Holtz, M. H., Hovorka, S. D., Kerans, Charles, Lucia, F. J., Major, R. P., and Ruppel, S. C., 1991, Integrated characterization of Permian Basin reservoirs, University Lands, West Texas: targeting the remaining resource for advanced oil recovery: The University of Texas at Austin, Bureau of Economic Geology Report of Investigations No. 203, 136 p.

Fracasso, M. A., and Hovorka, S. D., 1986, Cyclicity in the middle Permian San Andres Formation, Palo Duro Basin, Texas Panhandle: The University of Texas at Austin, Bureau of Economic Geology Report of Investigations No. 156, 48 p.

Gustavson, T. C., Kreitler, C. W., Bassett, R. T., Budnik, R. T, Ruppel, S. C., Baumgardner, R. W., Jr., Caran, S. C., Collins, E. W., Dutton, A. R., Dutton, S. P., Fisher, R. S., Fogg, G. E., Hovorka, S. D., Kolker, Allan, McGookey, D. A., Orr, E. D., Roberts, M. P., Senger, R. K., Smith, D. A., and Smith, D., 1983, Geology and geohydrology of the Palo Duro Basin, Texas Panhandle: a report on the progress of nuclear waste isolation feasibility studies (1982): The University of Texas at Austin, Bureau of Economic Geology Geological Circular 83-4, 156 p.

Gustavson, T. C., Bassett, R. T., Budnik, R. T, Finley, R. J., Goldstein, A. G., McGowen, J. H., Roedder, Edwin, Ruppel, S. C., Baumgardner, R. W., Jr., Bentley, M. E., Dutton, S. P., Fogg, G. E., Hovorka, S. D., McGookey, D. A., Ramondetta, P. J., Simpkins, W. W., Smith, D., Smith, D. A., Duncan, E., Griffin, J. A., Marritt, R. M., and Naiman, E. R., 1982, Geology and geohydrology of the Palo Duro Basin, Texas Panhandle: a report on the

progress of nuclear waste isolation feasibility studies (1981): The University of Texas at Austin, Bureau of Economic Geology Geological Circular 82-7, 212 p.

Guidebooks

Hovorka, S. D., and Mace, R. E., 1997, Interplay of karst, fractures, and permeability in the Cretaceous Edwards aquifer: analogs for fractured carbonate reservoirs: The University of Texas at Austin, Bureau of Economic Geology Field Trip Guidebook, 35 p.

Chapters/Sections

Hovorka, S. D., Doughty, Christine, and Holtz, M. H., 2005, Testing efficiency of storage in the subsurface: Frio Brine Pilot Experiment, *in* Wilson, M., Morris, T., Gale, J., and Thambimuthu, K., eds., Greenhouse gas control technologies: San Diego, Elsevier, Volume II, 1361–1372.

Hovorka, S. D., 1996, Review of Sedimentology and Geochemistry of Modern and Ancient Saline Lakes, R. W. Renault and W. M. Last, eds., *in* Special Publication No. 50 SEPM (Society for Sedimentary Geology): Journal of Sedimentary Research, v. 66, no. 1, p. 294–295.

Hovorka, S. D., Nance, H. S., and Kerans, Charles, 1994, Chapter 19, Parasequence geometry as a control on permeability evolution: examples from the San Andres and Grayburg Formations in the Guadalupe Mountains, New Mexico, *in* Loucks, R. G., and Sarg, J. F., eds., Carbonate sequence stratigraphy: recent developments and applications: American Association of Petroleum Geologists, Memoir 57, p. 493–514.

Hovorka, S. D., 1994, Stratigraphic controls on fracture frequency in the Austin Chalk: data from the near surface and its implications for hydrocarbon production, *in* Austin Chalk Symposium: Texas A&M University, p. 1–19.

Hovorka, S. D., 1989, Depth evolution of the Delaware Basin—Castile/Salado transition, *in* Harris, P. M., and Grover, G. A., eds., Subsurface and outcrop examination of the Capitan Shelf Margin, north Delaware Basin: Society of Economic Paleontologists and Mineralogists, Core Workshop No. 13, p. 441–449.

Hovorka, S. D., and Granger, P. A., 1988, Subsurface to surface correlation of Permian evaporites—San Andres–Blaine–Flowerpot relationships, Texas Panhandle, *in* Morgan, W. A., and Babcock, J. A., eds., Permian rocks of the midcontinent: Midcontinent Society of Economic Paleontologists and Mineralogists, Special Paper No. 1, p. 137–159.

Articles

Peer Reviewed

Lu, Jiemin, Partin, J. W., Hovorka, S. D., and Wong, Corinne, 2009, Potential risks to freshwater resources as a result of leakage from CO2 geological storage: a batch-reaction experiment: Environmental Earth ScienceS, DOI 10.1007/s12665-009-0382-0.

Ambrose, W. A., Breton, C., Holtz, M. H., Nuñez López, V., Hovorka, S. D., and Duncan, I. J., 2009, CO2 source-sink matching in the lower 48 United States, with examples from the Texas Gulf Coast and Permian Basin: Environmental Geology: Environmental Geology, v. 57, p. 1537–1551.

Ambrose, W. A., Lakshminarasimhan, Srivatsan, Nuñez López, Vanessa, Hovorka, S. D., and Duncan, I. J., 2008, Geologic factors controlling CO2 storage capacity and permanence: case studies based on experience with heterogeneity in oil and gas reservoirs applied to CO2 storage: Environmental Geology, v. 54, p. 1619–1633.

Nuñez López, Vanessa, Wood, D. J., Ambrose, W. A., and Hovorka, S. D., 2008, Quick-look assessments to identify optimal CO2 EOR storage sites: Environmental Geology, v. 54, p. 1695–1706.

Hovorka, S. D., Holt, R. M., and Powers, D. W., 2007, Depth indicators in Permian Basin evaporites, *in* Schreiber, B. C., Lugli, S., and Babel, M., Evaporites through space and time: The Geological Society of London, Special Publication 285, p. 335–364.

Kharaka, Y. K., Cole, D. R., Hovorka, S. D., Gunter, W. D., Knauss, K. G., and Freifeld, B. M., 2006, Gas-water-rock interactions in Frio Format on following CO2 injection: implications for the storage of greenhouse gases in sedimentary basins: Geology, v. 34, no. 7, p. 577–580.

Hovorka, S. D., Doughty, Christine, Benson, S. M., Freifeld, B. M., Sakurai, Shinichi, Daley, T. M., Kharaka, Y. K., Holtz, M. H., Trautz, R. C., Nance, H. S., Myer, L. R., and Knauss, K. G., 2006, Measuring permanence of CO2 storage in saline formations: the Frio experiment: Environmental Geosciences, v. 13, no. 2, p. 105–121.

Freifeld, B. M., Trautz, R. C., Kharaka, Y. K., Phelps, T. J., Myer, L. R., Hovorka, S. D., and Collins, D. J., 2005, The U-tube: a novel system for acquiring borehole fluid samples from a deep geologic CO2 sequestration experiment: Journal of Geophysical Research, v. 110, B10203, 10 p.

Hovorka, S. D., Doughty, Christine, Benson, S. M., Pruess, Karsten, and Knox, P. R., 2004, The impact of geological heterogeneity on CO2 storage in brine formations: a case study from the Texas Gulf Coast, *in* Baines, S. J., and Worden, R. H., eds., Geological storage of carbon dioxide: Geological Society, London, Special Publications, 233, p. 147–163.

Mace, R. E., and Hovorka, S. D., 2000, Estimating porosity and permeability in a karstic aquifer using core plugs, well tests, and outcrop measurements, *in* Sasowsky, I. D., and Wicks, C. M., eds., Groundwater flow and contaminant transport in carbonate aquifers: Rotterdam, A. A. Balkema, p. 93–111.

Hovorka, S. D., 1997, Quaternary evolution of ephemeral playa lakes on the Southern High Plains of Texas, USA: cyclic variation, *in* lake level recorded in sediments: Journal of Paleolimnology, v. 17, p. 131–146.

Holliday, V. T., Hovorka, S. D., and Gustavson, T. C., 1996, Lithostratigraphy and geochronology of fills, *in* small playa basins on the Southern High Plains, United States: Geological Society of America Bulletin, v. 108, no. 8, p. 953–956.

Ruppel, S. C., and Hovorka, S. D., 1995, Controls on reservoir development in Devonian chert: Permian Basin, Texas: AAPG Bulletin, v. 79, no. 12, p. 1757–1785.

Gustavson, T. C., and Hovorka, S. D., 1994, Origin of satin spar veins in evaporite basins: Journal of Sedimentary Research, v. A64, no. 1, p. 88–94.

Hovorka, S. D., Nance, H. S., and Kerans, Charles, 1993, Parasequence geometry as a control on permeability evolution: examples from the San Andres and Grayburg Formations in the Guadalupe Mountains, New Mexico, *in* Loucks, R. G., and Sarg, J. F., eds., Carbonate sequence stratigraphy: recent developments and applications: American Association of Petroleum Geologists, Memoir 53, p. 493–514.

Hovorka, S. D., Fisher, W. L., Gao, Guoqiu, and Knauth, L. P., 1993, Marine to non-marine facies transition, *in* Permian evaporites of the Palo Duro Basin, Texas: geochemical response: Geological Society of America Bulletin, v. 105, p. 1119–1134.

Collins, E. W., Hovorka, S. D., and Laubach, S. E., 1992, Fracture systems of the Austin Chalk, North-Central Texas, *in* Schmoker, J. W., Coalson, E. B., and Brown, C. A., eds., Geological studies relevant to horizontal drilling in western North America: Rocky Mountain Association of Geologists, p. 75–88.

Hovorka, S. D., 1992, Halite pseudomorphs after gypsum, *in* bedded anhydrite—clue to gypsum-anhydrite relationships: Journal of Sedimentary Petrology, v. 62, no. 6, p. 1098–1111.

Bein, Amos, Hovorka, S. D., Fisher, W. L., and Roedder, Edwin, 1991, Fluid inclusions in bedded Permian halite, Palo Duro Basin, Texas: evidence for modification of seawater in evaporite brine-pools and subsequent early diagenesis: Journal of Sedimentary Petrology, v. 61, no. 1, p. 1–14.

Gao, Guoqiu, Hovorka, S. D., and Posey, H. H., 1990, Limpid dolomite, *in* Permian San Andres halite rocks, Palo Duro Basin, Texas Panhandle: characteristics, possible origin, and implications for brine evolution: Journal of Sedimentary Petrology, v. 60, no. 1, p. 118–124.

Fisher, W. L., and Hovorka, S. D., 1987, Relations between bromide content and depositional processes, *in* bedded halite, Permian San Andres Formation, Palo Duro Basin, Texas: Carbonates and Evaporites, v. 2, no. 1, p. 67–82.

Fracasso, M. A., and Hovorka, S. D., 1987, First occurrence of a phyllodont tooth plate (Osteichthyes, Platysomidae) from the Permian San Andres Formation, subsurface, Texas Panhandle: Journal of Paleontology, v. 61, no. 2, p. 375–379.

Hovorka, S. D., 1987, Depositional environments of marine-dominated bedded halite, Permian San Andres Formation, Texas: Sedimentology, v. 34, p. 1029–1054.

Hovorka, S. D., 1983, Petrographic criteria for recognizing post-Permian dissolution of evaporites, Donley County, Texas, *in* Gustavson, T. C., and others, Geology and geohydrology of the Palo Duro Basin, Texas Panhandle, a report on the progress of nuclear waste isolation feasibility studies (1982): The University of Texas at Austin, Bureau of Economic Geology, Geological Circular 83-4, p. 66–74.

Hovorka, S. D., 1983, Dissolution and recrystallization fabrics in halite and the timing of their development, Palo Duro Basin, *in* Gustavson, T. C., Kreitler, C. W., Bassett, R. L., Budnik, R. T., Ruppel, S. C., Baumgardner, R. W., Jr., Caran, S. C., Collins, E. W., Dutton, A. R., Dutton, S. P., Fisher, R. S., Fogg, G. E., Hovorka, S. D., Kolker, A., McGookey, D. A., Orr, E. D., Roberts, M. P., Senger, R. K., Smith, Dale A., and Smith, D. Anderson, Geology and geohydrology of the Palo Duro Basin, Texas Panhandle, a report on the progress of nuclear waste isolation feasibility studies (1982): The University of Texas at Austin, Bureau of Economic Geology, Geological Circular 83-4, p. 58–65.

Hovorka, S. D., 1983, Sedimentary structures and diagenetic modifications in halite and anhydrite, Palo Duro Basin, *in* Gustavson, T. C., and others, Geology and geohydrology of the Palo Duro Basin, Texas Panhandle, a report on the progress of nuclear waste isolation feasibility studies (1982): The University of Texas at Austin, Bureau of Economic Geology, Geological Circular 83-4, p. 49–57.

Ruppel, S. C., and Hovorka, S. D., 1983, Stratigraphic section along the northwestern margin of the Palo Duro Basin: core analysis of DOE–Stone and Webster No. 1 Mansfield test well, Oldham County, Texas, *in* Gustavson, T. C., and others, Geology and geohydrology of the Palo Duro Basin, Texas Panhandle, a report on the progress of nuclear waste isolation feasibility studies (1982): The University of Texas at Austin, Bureau of Economic Geology, Geological Circular 83-4, p. 47–48.

Ruppel, S. C., and Hovorka, S. D., 1983, Stratigraphic section along the northeastern margin of the Palo Duro Basin: core analysis of DOE–Stone and Webster No. 1 Sawyer test well, Donley County, Texas, *in* Gustavson, T. C., and others, Geology and geohydrology of the Palo Duro Basin, Texas Panhandle, a report on the progress of nuclear waste isolation feasibility studies (1982): The University of Texas at Austin, Bureau of Economic Geology, Geological Circular 83-4, p. 45–46.

Hovorka, S. D., Naiman, E. R., and McGowen, J. H., 1982, Petrographic summary of Permian rocks from the DOE/Gruy Federal No. 1 Grabbe well, Swisher County, *in* Gustavson, T. C., Bassett, R. L., Budnik, R., Finley, R. J., Goldstein, A. G., McGowen, J. H., Roedder, E., Ruppel, S. C., Baumgardner, R. W., Jr., Bentley, M. E., Dutton, S. P., Fogg, G. E., Hovorka, S. D., McGookey, D. A., Ramondetta, P. J., Simpkins, W. W., Smith, D., Smith, D. A., Duncan, E. A., Griffin, J. A., Merritt, R. M., and Naiman, E. R., Geology and geohydrology of the Palo Duro Basin, Texas Panhandle, a report on the progress of

nuclear waste isolation feasibility studies (1981): The University of Texas at Austin, Bureau of Economic Geology, Geological Circular 82-7, p. 91–100.

Non-Peer-Reviewed

Nicot, J. -P., Choi, Jong-Won, Meckel, Timothy, Chang, C. Y., Hovorka, S. D., and Solano, Silvia, 2009, Results of numerical investigations at SECARB Cranfield, MS field test site, *in* Eighth Annual Conference on Carbon Capture and Sequestration: DOE/NETL, May 4–7, Pittsburgh, Pennsylvania, 11 p.

Hovorka, S. D., 2009, Put it backr, *in* Laubach, S. E., and Tinker, S. W., eds., 2009, Earth's art: celebrating the Centennial of the Bureau of Economic Geology, 1909–2009: The University of Texas at Austin, Bureau of Economic Geology, p. 130–131.

Nicot, J. -P., Hovorka, S. D., and Choi, J. -W., 2009, Investigation of water displacement following large CO2 sequestration operations, *in* Energy Procedia (v. 1, no.1), Proceedings of 9th International Conference on Greenhouse Gas Control Technologies GHGT9, November 16–20, Washington D.C., p. 4411–4418.

Nicot, J. -P., Oldenburg, C. M., Bryant, S. L., and Hovorka, S. D., 2009, Pressure perturbations from geologic carbon sequestration: area-of-review boundaries and borehole leakage driving forces, *in* Energy Procedia (v. 1, no.1), Proceedings of 9th International Conference on Greenhouse Gas Control Technologies GHGT9, November 16–20, Washington D.C., p. 47–54.

Hovorka, S. D., Choi, J. -W., Meckel, T. A., Treviño, R. H., Zeng, H., Kordi, M., Wang, F. P., and Nicot, J. -P., 2009, Comparing carbon sequestration in an oil reservoir to sequestration in a brine formation—field study, *in* Energy Procedia (v. 1, no. 1), Proceedings of 9th International Conference on Greenhouse Gas Control Technologies GHGT9, November 16–20, Washington D.C., p. 2051–2056.

Smyth, R. C., Hovorka, S. D., Lu, J., Romanak, K. D., Partin, J. W., Wong, C., and Yang, C., 2009, Assessing risk to fresh water resources from long term CO2 injection—laboratory and field studies: Energy Procedia, v. 1, p. 1957–1964.

Hovorka, S. D., 2009, Frio Brine Pilot: the first U.S. sequestration test: Southwest Hydrology, v. 8, no. 5, p. 26, 27, 31.

Wong, Corinne, Hovorka, Sue, and Meckel, Tip, 2007, Evaluating the mobilization of cations from aquifer rocks exposed to high CO2 levels: Gulf Coast Association of Geological Societies Transactions, v. 57, p. 797–808.

Kharaka, Y. K., Thordsen, J. J., Hovorka, S. D., Nance, H. S., Cole, D. R., Phelps, T. J., and Knauss, G. K., 2007, Subsurface monitoring of anthropogenic CO2 injected in sedimentary basins: results from the Frio-I brine test, Texas, *in* Bullen, T. D., and Wang, Y., Proceedings, 12th International Symposium on Water-Rock Interaction (WRI-12), v. 1, p. 597–601.

Kharaka, Y. K., Cole, D. R., Thordsen, J. J., Kakouros, E., Pfiffner, S., and Hovorka, S. D., 2007, Environmental implications of toxic metals and dissolved organics released as a result of CO2 injection into the Frio Formation, Texas, USA, *in* Proceedings, International Symposium on Site Characterization for CO2 Geologic Storage, March 20–22, Berkeley, LBNL-59726, p. 214–218.

Ambrose, W. A., Holtz, M. H., Nuñez-Lopez, Vanessa, Breton, C. L., Gülen, Gürcan, Duncan, Ian, Smyth, R. C., Foss, M. M., Lakshminarasimhan, Srivatsan, and Hovorka, S. D., 2006, FutureGen: clean-coal and near-zero-emission power generation technology for the Gulf Coast: Gulf Coast Association of Geological Societies Transactions, v. 56, p. 5–13.

Duncan, I. J., Ambrose, W. A., Holtz, M. H., Hovorka, S. D., Nuñez-Lopez, Vanessa, Esandoh-Yeddu, Joseph, Nicot, J. -P., Smyth, R. C., and Lakshminarasimhan, Srivatsan, 2006, The Gulf Coast Carbon Center: developing a carbon sequestration industry in the Gulf Coast region, *in* Green house gas technology 8, Trondheim, Norway, June 19–22, CD-ROM, 4 p.

Hovorka, S. D., 2006, Frio Brine Storage Experiment—lessons learned, *in* 8th International Conference on Greenhouse Gas Control Technologies, Trondheim, Norway, June 19–22, CD-ROM [6 p.].

Duncan, I. J., Ambrose, W. A., Holtz, M. H., Hovorka, S. D., Esandoh-Yeddu, Joseph, Nuñez López, Vanessa, Nicot, J. -P., Smyth, R. C., and Lakshminarasimhan, Srivatsan, 2006, The Gulf Coast Carbon Center: developing a carbon sequestration industry in the Gulf Coast region, *in* 8th International Conference on Greenhouse Gas Control Technologies, Trondheim, Norway, June 19–22, CD-ROM [4 p.].

Hovorka, S. D., 2005, Put it back—an experiment in returning carbon from burning of fossil fuel to the subsurface as carbon dioxide: Houston Geological Society Bulletin, v. 47, no. 5, p. 34–43.

Hovorka, S. D., 2005, Frio Brine Pilot Experiment—six months after injection: Greenhouse Issues, no. 77, p. 1–3.

Lindgren, R. J., Dutton, A. R., Hovorka, S. D., Worthington, S. R. H., and Painter, Scott, 2005, Conceptualization and simulation of the Edwards aquifer, San Antonio region, Texas, *in* U.S. Geological Survey Karst Interest Group Proceedings, Rapid City, South Dakota, September 12–15: U.S. Geological Survey, Scientific Investigations Report 2005-5160, p. 48–57.

Hovorka, S. D., 2005, Stop 5: 337 Loop roadcut, New Braunfels, *in* Schindel, G. M., Hoyt, J. R., Johnson, S. B., Veni, G., Wilcox, B. P., Munster, C. L., Hovorka, S. D., Kreitler, C. W., and Shade, B. L., eds., An introduction to the Balcones Fault Zone segment of the Edwards Aquifer in South-Central Texas: an event of the 2005 Ground Water Summit: National Ground Water Association and Edwards Aquifer Authority, p. 5-1–5-2 + 2 figs.

Hovorka, S. D., Hotinski, Roberta, and Friedmann, S. J., 2005, Audience-pleasing physical models to support CO2 outreach, *in* Proceedings, Fourth Annual Conference on Carbon Capture and Sequestration: DOE/NETL, Alexandria, Virginia, May 2–5, 9 p., CD-ROM.

McCallum, S. D., Riestenberg, D. E., Cole, D. R., Freifeld, B. M., Trautz, R. C., Hovorka, S. D., and Phelps, T. J., 2005, Monitoring geologically sequestered CO2 during the Frio Brine Pilot Test using perfluorocarbon tracers, *in* Proceedings, Fourth Annual Conference on Carbon Capture and Sequestration DOE/NETL, May 2–5, 9 p., CD-ROM.

Hovorka, S. D., Collins, Dan, Benson, Sally, Myer, Larry, Byrer, Charles, and Cohen, Karen, 2005, Update on the Frio Brine Pilot: eight months after injection, *in* Proceedings, Fourth Annual Conference on Carbon Capture and Sequestration DOE/NETL, 6 p., CD-ROM.

Mace, R. E., Marrett, R. A., and Hovorka, S. D., 2005, Fractal scaling of secondary porosity in karstic exposures of the Edwards aquifer, *in* Beck, B. F., ed., Sinkholes and the engineering and environmental impacts of karst: Proceedings, Tenth Multidisciplinary Conference, San Antonio, September 24–28: American Society of Civil Engineers, Geotechnical Special Publication No. 144, p. 178–187.

Hovorka, S. D., Doughty, Christine, and Holtz, M. H., 2004, Testing efficiency of storage in the subsurface: Frio Brine Pilot Experiment, *in* 7th International Conference on Greenhouse Gas Control Technologies, Vancouver, Canada, September 5–9, unpaginated [5 p.].

Kim, E. M., Hovorka, S. D., and Holtz, M. H., 2004, The Gulf Coast Carbon Center: carbon sequestration opportunities in geologic formations: Gulf Coast Association of Geological Societies Transactions, v. 54, p. 281–288.

Collins, E. W., Tremblay, T. A., Raney, J. A., Paine, J. G., Hovorka, S. D., Gutiérrez, Roberto, Smyth, R. C., and Hepner, Tiffany, 2004, Geologic mapping and construction of digital map data sets of the Edwards aquifer region, Central Texas, *in* Hovorka, Sue, ed., Edwards water resources in Central Texas: retrospective and prospective: South Texas Geological Society and Austin Geological Society, CD-ROM, p. 1–15.

Lindley, A. L., and Hovorka, S. D., 2004, Applying statistical analysis to cave maps to infer controls on conduit development in the Edwards aquifer of Central and South Texas, *in*

Hovorka, S. D., ed., Edwards water resources in Central Texas: retrospective and prospective: South Texas Geological Society and Austin Geological Society, CD-ROM [15 p.]

Hovorka, S. D., and Green, Ron, 2004, Role of conduits in flow in the Edwards aquifer: results and questions, *in* Hovorka, S. D., ed., Edwards water resources in Central Texas: retrospective and prospective, CD-ROM [10 p.]

Hovorka, S. D., 2004, Progress on the Frio Brine Pilot Experiment: Greenhouse Issues, No. 72, May, p. 6–7.

Hovorka, S. D., and Knox, P. R., 2003, Frio brine sequestration pilot in the Texas Gulf Coast, *in* Gale, J., and Kaya, Y., Greenouse gas control technologies: Proceedings, 6th International Conference on Greenhouse Gas Control Technologies, October 1–4, Kyoto, Japan: New York, Pergamon, p. 583–587.

Hovorka, S. D., and Knox, P. R., 2003, Frio Brine Sequestration Pilot in the Texas Gulf Coast, *in* Gale, J., and Kaya, Y., eds., Greenhouse gas control technologies: Proceedings of the 6th International Conference on Greenhouse Gas Control Technologies, Volume I : Amsterdam, Elsevier, p. 583–587.

Dutton, A. R., Hovorka, S. D., and Bennett, P. C., 2002, Effect of Pleistocene depositional heterogeneity on movement of a subsurface crude-oil spill, San Patricio County, South Texas: Gulf Coast Association of Geological Societies Transactions, v. 52, p. 207–216.

Knox, P. R., Hovorka, S. D., and Oldenburg, C. M., 2002, Potential new uses for old gas fields: sequestration of carbon dioxide: Gulf Coast Association of Geological Societies Transactions, v. 52, p. 563–571.

Knox, P. R., and Hovorka, S. D., 2001, Geological sequestration of greenhouse gases: opportunities for industry academe research partnerships: Houston Geological Society Bulletin, v. 43, no. 5, p. 26–33.

Hovorka, S. D., Doughty, C. A., Knox, P. R., Green, C. T., Preuss, K., and Benson, S. M., 2001, Evaluation of brine-bearing sands of the Frio Formation, Upper Texas Gulf Coast for geologic sequestration of CO2, *in* Proceedings, First National Conference on Carbon Sequestration, May 14–17, Washington, D.C., sponsored by National Energy Technology Laboratory, 13 p., 7 figs, on CD.

Doughty, C. A., Preuss, K., Benson, S. M., Hovorka, S. D., and Green, C. T., 2001, Capacity investigation of brine-bearing sands of the Frio Formation for geologic sequestration of CO2, *in* Proceedings, First National Conference on Carbon Sequestration, May 14–17, Washington, D.C., sponsored by National Energy Technology Laboratory, CD-ROM.

Hovorka, S. D., Romero, M. L., Warne, A. G., Ambrose, W. A., Tremblay, T. A., and Treviño, R. H., 2000, A tool to facilitate modeling and pilot projects for sequestration of carbon dioxide in saline formations: American Chemical Society, Division of Fuel Chemistry, 6 p.

Hovorka, S. D., 2000, Deep-water to shallow-water transition in evaporites in the Delaware Basin, Texas, *in* Lindsay, R. F., Trentham, R. C., Ward, R. F., and Smith, A. H., eds., Classic Permian geology of West Texas and southeastern New Mexico: 75 years of Permian Basin oil and gas exploration and development: West Texas Geological Society, Geo 2000 field trip guidebook Publication 00-108, p. 273–299.

Hovorka, S. D., 2000, Understanding the processes of salt dissolution and subsidence, *in* Sinkholes and unusual subsidence over solution mined caverns and salt and potash mines, Technical Session: Solution Mining Research Institute Fall Meeting, p. 12–23.

Paine, J. G., Dutton, A. R., Hovorka, S. D., Blum, Martina, Mahoney, M., and Sullivan, E. J., 1998, Brine in the near-surface environment: determining salinization extent, identifying sources, and estimating chloride mass using surface, borehole, and airborne EM, *in* Bell, R. S., Powers, M. H., and Larson, Timothy, eds., Proceedings, Symposium on the Application of Geophysics to Environmental and Engineering Problems: Environmental and Engineering Geophysical Society, p. 215–219.

Hovorka, S. D., 1996, High-frequency cyclicity during eustatic sea-level rise: Edwards Group of the Balcones Fault Zone: Gulf Coast Association of Geological Societies Transactions, v. 46, p. 179–184.

Hovorka, S. D., Mace, R. E., and Collins, E. W., 1995, Regional distribution of permeability in the Edwards aquifer: Gulf Coast Association of Geological Societies Transactions, v. 45, p. 259–265.

Hovorka, S. D., and Nance, H. S., 1994, Dynamic depositional and early diagenetic processes in a deep-water shelf setting, Upper Cretaceous Austin Chalk, North Texas: Gulf Coast Association of Geological Societies Transactions, v. 44, p. 269–276.

Gustavson, T. C., Holliday, V. T., and Hovorka, S. D., 1994, Development of playa basins, Southern High Plains, Texas and New Mexico, *in* Urban, L. V., and Wyatt, A. W., eds., Proceedings, Playa Basin Symposium: Texas Tech University, Water Resources Center, p. 5–14.

Hovorka, S. D., Dutton, A. R., Ruppel, S. C., and Yeh, Joseph, 1994, Sedimentologic and diagenetic controls on aquifer properties, Lower Cretaceous Edwards carbonate aquifer, Texas: implications for aquifer management: Gulf Coast Association of Geological Societies Transactions, v. 44, p. 277–284.

Scanlon, B. R., Goldsmith, R. S., Hovorka, S. D., Mullican, W. F., III, and Xiang, Jiannan, 1994, Evidence for focused recharge beneath playas in the Southern High Plains, Texas, *in* Urban, L. V., and Wyatt, A. W., eds., Proceedings, Playa Basin Symposium: Texas Tech University, Water Resources Center, p. 87–95.

Hovorka, S. D., 1991, Petrographic and facies study of parasequence 7, upper San Andres, of the Lawyer Canyon area, Algerita Escarpment: development of moldic porosity, *in* Kerans, Charles, Lucia, F. J., Senger, R. K., Fogg, G. E., Nance, H. S., Kasap, Ekrem, and Hovorka, S. D., Characterization of reservoir heterogeneity in carbonate-ramp systems, San Andres/Grayburg, Permian Basin: The University of Texas at Austin, Bureau of Economic Geology, Reservoir Characterization Research Laboratory, final contract report, p. 91–115.

Ruppel, S. C., and Hovorka, S. D., 1990, Controls on reservoir heterogeneity in the Three Bar Devonian chert reservoir, Andrews County, Texas, *in* Flis, J. E., and Price, R. C., eds., Permian Basin oil and gas fields: innovative ideas in exploration and development: West Texas Geological Society Symposium, Publication No. 90-87, p. 57–73.

Kreitler, C. W., Fisher, W. L., Senger, R. K., Hovorka, S. D., and Dutton, A. R., 1985, Hydrology of an evaporite aquitard: Permian evaporite strata, Palo Duro Basin, Texas: International Association of Hydrogeologists Memoires, v. 17, part 1, p. 150–168.

Hovorka, S. D., 1983, Carbonate-anhydrite-halite cycles, San Andres Formation (Permian), Palo Duro Basin, Texas, *in* Shaw, R. L., and Pollan, B. J., eds., Permian Basin cores—a workshop: Society of Economic Paleontologists and Mineralogists Core Workshop No. 2, p. 197–224.

Internet/Web Sites/Modules

Hovorka, S. D., Romero, M. L., Warne, A. G., Ambrose, W. A., Tremblay, T. A., Treviño, R. H., and Sasson, D., 2000, Sequestration of greenhouse gases in brine formations: The University of Texas at Austin, Bureau of Economic Geology, hypertext publication at http://www.beg.utexas.edu/environqlty/co2seq/dispslsaln.htm.

Hovorka, S. D., and Andrews, J. R., 2000, VRML model of the Edwards aquifer: The University of Texas at Austin, Bureau of Economic Geology, hypertext publication at http://activink.net.

Hovorka, S. D., and Andrews, J. R., 2000, Using GIS to examine Earth systems: The University of Texas at Austin, Bureau of Economic Geology, hypertext publication at http://activink.net.

Hovorka, S. D., Andrews, J. R., and Aslan, Andres, 1999, Geo-environmental characterization of the Delta del Orinoco: The University of Texas at Austin, Bureau of Economic Geology, hypertext publication at http://www.beg.utexas.edu/geoenvirn/orinoco/summary/main/front.htm.

Abstracts

Romanak, K. D., Smyth, R. C., Yang, C., and Hovorka, S. D., 2009, Modeling shallow groundwater geochemistry and carbon isotopes: test of methodology for CO2 storage evaluation at an EOR site, West Texas, USA (abs.): Eos, v. 90, no. 22, Abstract V13C-03.

Meckel, Tip, Hovorka, S. D., and Treviño, R. H., 2009, Continuous real-time pressure monitoring during a CO2-EOR project from Cranfield, MS, and relevance for geologic sequestration (abs.): American Association of Petroleum Geologists Annual Convention, v. 18, p. 141.

Hovorka, S. D., 2009, Risks and benefits of geologic sequestration of carbon dioxide—how do the pieces fit? (abs.): American Association of Petroleum Geologists Annual Convention, v. 18, p. 97.

Yang, C., Romanak, K. D., and Hovorka, S. D., 2009, CO2 release experiment in the shallow subsurface at the Brackenridge Field Laboratory and numerical modeling (abs.): Eos, v. 90, no. 52, Fall Meeting Supplement, Abstract No. H21E-0895.

Smyth, R. C., Romanak, K. D., Yang, C., and Hovorka, S. D., 2009, Shallow groundwater monitoring at the SACROC oilfield, Scurry County, TX: good news for geologic storage of CO2 despite a complex hydrogeologic and geochemical setting (abs.): Eos, v. 90, no. 52, Fall Meeting Supplement, Abstract No. H13I-02.

Yang, C., Romanak, K. D., and Hovorka, S. D., 2009, CO2 release experiment in the shallow subsurface at the Brackenridge Field Laboratory and numerical modeling, (abs.): Eos, v. 90.

Smyth, R. C., Romanak, K. D., Yang, C., and Hovorka, S. D., 2009, Shallow groundwater monitoring at the SACROC oilfield, Scurry County, TX: good news for geologic storage of CO2 despite a complex hydrogeologic and geochemical setting, (abs.): Eos, v. 90.

Smyth, R. C., Hovorka, S. D., Romanak, K. D., Partin, J. W., Meckel, Timothy, Wong, Corinne, Nicot, J. -P., and Holt, R. M., 2008, Assessing risk to fresh water resources from long term CO2 injection—laboratory and field studies (abs.), *in* 9th International Conference on Greenhouse Gas Technologies, November 16–20, Washington, D.C.

Nicot, J. -P., and Hovorka, S. D., 2008, Role of geochemical monitoring in geologic sequestration (abs.), *in* 2008 UIC Conference : What's hot in UIC!: Ground Water Protection Council, New Orleans, January 14–16, p. 24.

Kharaka, Yousif, Bullen, T. D., Knauss, Kevin, Cole, D. R., and Hovorka, S. D., 2008, Potential environmental issues of CO2 storage in saline aquifers: metal mobilization from the Frio-II brine test, Texas, USA (abs.): AAPG 2008 Annual Convention and Exhibition Abstracts Volume, v. 17, p. 108.

Choi, J.-W., Nicot, J. -P., Meckel, T. A., Chang, K.-W., and Hovorka, S. D., 2008, Preliminary results of numerical investigations at SECARB Cranfield, MS, field test site (abs.): Eos, v. 89, no. 53, Fall Meeting Supplement, Abstract U41C-22.

Treviño, R. H., Hovorka, S. D., Ambrose, W. A., and Meckel, T. A., 2008, Sequence stratigraphy and reservoir characterization of Cranfield field, Mississippi—an enhanced oil recovery and carbon sequestration study (abs.): Geological Society of America Abstracts with Programs, v. 40.

Meckel, Tip, and Hovorka, S. D., 2007, Gulf Coast stacked storage field test (abs.), *in* Sixth Annual Conference on Carbon Capture & Sequestration: Expediting deployment of industrial scale systems: Can it be done? How? Concerns to be addressed, May 7–10, Pittsburgh, Abstract #085.

Smyth, R. C., Hovorka, S. D., and Meckel, T. A., 2007, Potential saline reservoir sinks for storage of CO2 generated in North and South Carolina (abs.), *in* Sixth Annual Conference on Carbon Capture & Sequestration: Expediting deployment of industrial scale systems: Can it be done? How? Concerns to be addressed, May 7–10, Pittsburgh, Abstract #138.

Kharaka, Y. K., Bullen, T. D., Hovorka, S. D., Cole, D. R., Knauss, K. G., and Freifeld, B. M., 2007, Mobilization of metals as a result of CO2 injection into sedimentary basins: results from the Frio-II Brine Test, Texas (abs.), *in* Sixth Annual Conference on Carbon Capture & Sequestration: Expediting deployment of industrial scale systems: Can it be done? How? Concerns to be addressed, May 7–10, Pittsburgh, Abstract #149.

Hovorka, S. D., Daley, T. M., Freifeld, B. M., Kane, Jeff, Kharaka, Y. K., Benson, S. M., Phelps, T. J., Pope, Gary, and Doughty, C. A., 2007, Testing interactions of buoyancy, multiphase flow, and geochemical interactions: preliminary results for the Frio II Test (abs.), *in* Sixth Annual Conference on Carbon Capture & Sequestration: Expediting deployment of industrial scale systems: Can it be done? How? Concerns to be addressed, May 7–10, Pittsburgh, Abstract #070.

Kharaka, Y. K., Bullen, T. D., Hovorka, S. D., Cole, D. R., Knauss, K. G., and Freifeld, B. M., 2007, Mobilization of metals as a result of CO2 injection into sedimentary basins: results from the Frio-II Brine Test, Texas, USA (abs.), *in* 6th Annual Conference on Carbon Capture and Storage, Pittsburgh, May 7–10.

Kharaka, Y. K., Thordsen, J. J., Cole, D. R., Hovorka, S. D., and Bullen, T. D., 2007, Potential environmental issues of CO2 storage in saline aquifers: geochemical results from the Frio Brine Pilot Tests, Texas, USA (abs.), *in* Proceedings, Goldschmidt Conference, Cologne, Germany, August 19–24.

Smyth, R. C., and Hovorka, S. D., 2006, Potential of subseafloor Atlantic units for geologic sequestration of carbon dioxide (abs.): Geological Society of America Abstracts with Programs, v. 38, no. 7, p. 15.

Nicot, J. -P., Saripalli, Prasad, Hovorka, S. D., and Lakshminarasimhan, Srivatsan, 2006, Leakage pathways from potential CO2 storage sites in the Texas Gulf coast and implications for permitting (abs.), *in* Fifth Annual Conference on Carbon Capture & Sequestration: Taking steps toward deployment utilizing the accumulated knowledge base, May 8–11, Alexandria, Virginia, unpaginated.

Hovorka, S. D., Smyth, R. C., and Paine, J. G., 2006, Downscaling capacity from a regional to a site scale--a case for the southeastern U.S. (abs.), *in* Fifth Annual Conference on Carbon Capture & Sequestration: Taking steps toward deployment utilizing the accumulated knowledge base, May 8–11, Alexandria, Virginia, unpaginated.

Lindgren, Richard, Dutton, A. R., Hovorka, S. D., Worthington, S. R., and Painter, S. L., 2006, Conceptualization and simulation of the Edwards aquifer, San Antonio Region, Texas (abs.), *in* Abstract book of the 2006 Ground Water Summit: National Ground Water Association, p. 153.

Ambrose, W. A., Holtz, M. H., Nuñez López, Vanessa, Hovorka, S. D., Guevara, E. H., Breton, Caroline, and Christopher, Charles, 2006, Structural and stratigraphic controls on storage and CO2 EOR potential in major basins in Texas, California, Illinois, and Michigan (abs.): American Association of Petroleum Geologists Annual Convention, v. 15, p. 4.

Hovorka, S. D., 2006, Update on the Frio Brine Storage Project--progress on estimating permanence (abs.), *in* Fifth Annual Conference on Carbon Capture & Sequestration: Taking steps toward deployment utilizing the accumulated knowledge base, May 8–11, Alexandria, Virginia, unpaginated.

Nicot, J. -P., Hovorka, S. D., and Lakshminarasimhan, Srivatsan, 2006, Impact of carbon storage on shallow groundwater and pressure-controlled regional capacity for brine aquifers (abs.), *in* American Geophysical Union Fall Meeting, San Francisco, California, December 12.

Ambrose, W. A., Breton, C. L., Duncan, Ian, Holtz, M. H., Hovorka, S. D., Nuñez-Lopez, Vanessa, and Lakshminarasimhan, Srivatsan, 2006, Source-sink matching and potential for carbon capture and storage in the Gulf Coast, *in* Proceedings of the 2006 UIC Conference of the Groundwater Protection Council, Abstract 16.

Nicot, J. -P., Hovorka, S. D., Knox, P. R., and Naing, Thet, 2006, Area of review: how large is large enough for carbon storage? in Proceedings of the 2006 UIC Conference of the Groundwater Protection Council, Abstract 17.

Hovorka, S. D., Sakurai, Shinichi, Kharaka, Y. K., Nance, H. S., Doughty, Christine, Benson, S. M., Freifeld, B. M., Trautz, R. C., Phelps, Tommy, and Daley, T. M., 2006, Monitoring CO2 storage in brine formations: lessons learned from the Frio field text one year post injection, *in* Proceedings of the 2006 UIC Conference of the Groundwater Protection Council, Abstract 19.

Ambrose, W. A., Lakshminarasimhan, S., Holtz, M. H., Nuñez-Lopez, V., Hovorka, S. D., and Duncan, I., 2006, Geologic factors controlling CO2 storage capacity and permanence - techniques and case studies based on experience with heterogeneity in oil and gas reservoirs applied to CO2 storage (ext. abs.), *in* Proceedings, CO2SC Symposium, Lawrence Berkeley National Laboratory, Berkeley, California, March 20–22, p. 9–11 + CD-ROM.

Nicot, J. -P., Lakshminarasimhan, Srivatsan, and Hovorka, S. D., 2006, Capillary trapping in the overburden as a defense-in-depth mechanism against leakage from CO2 storage sites: the case of the Tertiary Texas Gulf Coast (ext. abs.), *in* Proceedings, CO2SC Symposium, Lawrence Berkeley National Laboratory, Berkeley, California, March 20–22, p. 173–175 + CD-ROM.

Nuñez Lopez, Vanessa, Holtz, M. H., Wood, D. J., and Hovorka, S. D., 2006, Quick-look assessments to identify optimal CO2 EOR storage sites (ext. abs.), *in* Proceedings, CO2SC Symposium, Lawrence Berkeley National Laboratory, Berkeley, California, March 20–22, p. 245–247 + CD-ROM.

Lindgren, Richard, Dutton, A. R., Hovorka, S. D., Worthington, S. R. H., and Painter, Scott, 2005, Conceptualization and simulation of the Edwards aquifer, San Antonio region, Texas (abs.), *in* The abstract book of the 2005 Ground Water Summit Program, April 17–20, San Antonio, p. 234–235.

Hovorka, S. D., 2005, Frio experiment: CO2 storage in brine-bearing sandstone, Texas, USA (abs.), *in* 1st Indo-US Workshop on Carbon Sequestration souvenir & abstract volume: Hyderabad - 500 007, India, National Geophysical Research Institute, p. 17.

Hovorka, S. D., Doughty, Christine, Sakurai, Shinichi, and Holtz, Mark, 2005, Frio Brine Pilot: field validation of numerical simulation of CO2 storage (abs.): American Association of Petroleum Geologists Annual Convention abstracts volume, v. 14, p. A63.

Hovorka, S. D., Benson, Sally, and Myer, Larry, 2005, Frio Brine Pilot: lessons learned and questions restated (abs.), *in* Proceedings, Fourth Annual Conference on Carbon Capture and Sequestration DOE/NETL, May 2–5, 2 p., CD-ROM.

Freifeld, B. M., Trautz, R. C., Kharaka, Y. K., Phelps, T. J., Myer, L. R., Hovorka, S. D., and Collins, D. J., 2005, The U-tube: a novel system for sampling and analyzing multi-phase borehole fluid samples during the Frio Brine Pilot Test (abs.), *in* Proceedings, Fourth Annual Conference on Carbon Capture and Sequestration DOE/NETL, May 2–5, 2 p., CD-ROM.

Myer, Larry, Benson, Sally, Cole, David, Daley, Tom, Doughty, Christine, Dutton, Alan, Freifeld, Barry, Gunter, William, Holtz, Mark, Hovorka, Susan, Hoversten, Mike, Kennedy, B. P., Mack, B., Kharaka, Yousif, Knauss, Kevin, Knox, Paul, Majer, Ernie, Phelps, Tommy, Pruess, Karsten, and Robinson, J. E., 2004, Subsurface monitoring and verification at the Frio Pilot Text (ext. abs.), *in* 7th International Conference on Greenhouse Gas Control Technologies, Vancouver, Canada, September 5–9, Abstract no. LBNL-54221.

Hovorka, S. D., 2004, Frio Brine Pilot Experiment—update and preliminary results (abs.): Geological Society of America Abstracts with Programs, v. 36, no. 5, p. 542.

Hovorka, S. D., Schindel, G. M., Nicot, J. -P., Worthington, S. R. H., Johnson, S. B., and Lindley, Adrien, 2004, Improving the conceptual model for flow in the Edwards aquifer (abs.): Gulf Coast Association of Geological Societies Transactions, v. 54, p. 251.

Friedmann, S. J., and Hovorka, S. D., 2004, Just do it! Large-scale storage of greenhouse gas in the United States and abroad (abs.): American Association of Petroleum Geologists Annual Convention Abstracts Volume, v. 13, p. A49.

Holtz, Mark, Doughty, Christine, Yeh, Joseph, and Hovorka, Susan, 2004, Modeling of CO2 saline aquifer sequestration and the effects of residual phase saturation (abs.): American Association of Petroleum Geologists Annual Convention Abstracts Volume, v. 13, p. A66.

Hovorka, S. D., 2004, Developing a business plan for carbon sequestration in the Gulf Coast (abs.): American Association of Petroleum Geologists Annual Convention Abstracts Volume, v. 13, p. A66.

Raney, J. A., Hovorka, S. D., Holtz, M. H., and Sakurai, Shinichi, 2004, Underground injection of CO2 as a method of decreasing atmospheric greenhouse gas: a status report (abs.), *in* Underground Injection Control: Environmental Trade Fair and Conference: Texas Commission on Environmental Quality, p. 49.

Hovorka, S. D., Andrews, J. R., Clift, S. J., Hepner, T. L., Gibeaut, J. C., Rodgers, S. D., Jennette, D. C., and Raney, J. A., 2004, Update on public and K-12 programs at the Bureau of Economic Geology, Texas (abs.): Geological Society of America Abstracts with Programs: v. 36, no. 5, p. 349.

Lindley, Adrien, and Hovorka, S. D., 2004, Applying statistical analysis to cave maps to infer controls on conduit development in the Edwards aquifer of Central & South Texas (abs.): Journal of Cave and Karst Studies, December, p. 186.

Myer, Larry, Hovorka, Susan, Hoversten, Mike, Fouad, Khaled, and Holtz, Mark, 2003, Geophysical characterization and monitoring for the Frio Pilot Test (ext. abs.), *in* American Geophysical Union Fall Meeting, San Francisco, December 8–12, Abstract no. LBNS-53637.

Knox, P. R., Doughty, C. A., and Hovorka, S. D., 2003, Impacts of buoyancy and pressure gradient of field-scale geological sequestration of CO2 in saline formations (abs.): American Association of Petroleum Geologists Annual Convention Official Program, v. 12, p. A94.

Hovorka, S. D., Knox, P. R., Holtz, M. H., Yeh, J. S., Fouad, Khaled, and Sakurai, Shinichi, 2003, Tapping the potential for large volume sequestration—update on the Frio brine pilot project (abs.), *in* Briefing book: Second Annual Conference on Carbon Sequestration: developing & validating the technology base to reduce carbon intensity, Alexandria, Virginia, May 5–9, unpaginated.

Kim, E. M., and Hovorka, S. D., 2003, Regional Yates gas resource assessment and reservoir characterization, Permian Basin, Texas (abs.), *in* New methods for locating and recovering remaining hydrocarbons in the Permian Basin: The University of Texas at Austin, Bureau of Economic Geology; Petroleum Technology Transfer Council; and University Lands West Texas Operations, p. 12.

Combs, D. M., Kim, E. M., and Hovorka, S. D., 2003, Stratigraphic characterization of the Yates Formation, Permian Basin, Texas (abs.), *in* Hunt, T. J., and Lufholm, P. H., The Permian Basin: back to basics: West Texas Geological Society Fall Symposium: West Texas Geological Society Publication #03-112, p. 355–356.

Raney, J. A., Collins, E. W., and Hovorka, S. D., 2002, Geologic maps and groundwater resource evaluation and protection, Edwards limestone aquifer, Texas (abs.): AEG News, v. 45, p. 80.

Hovorka, S. D., Knox, P. R., Holtz, M. H., Yeh, J. S., Fouad, Khaled, and Sakurai, Shinichi, 2002, Sequestration pilot site in the Texas Gulf Coast, USA (abs.): Geological Society of America Annual Meeting, Paper No. 135-10, http://gsa.confex.com/gsa/2002AM/finalprogram/abstract_44374.htm.

Kim, E. M., and Hovorka, S. D., 2002, Regional Yates gas resource assessment and reservoir characterization, Permian Basin, Texas (abs.): West Texas Geological Society Fall Symposium, Midland, Texas, CD-ROM.

Hovorka, S. D., Paine, J. G., and Dutton, A. R., 1999, Permeability structure of a North Texas Permian fluvial and Quaternary terrace system delimited by saline plumes (abs.), *in* AAPG Annual Convention official program: American Association of Petroleum Geologists, p. A63.

Hovorka, S. D., 1999, Getting the word out supplying local geologic information to teachers in a large state (abs.): Geological Society of America Abstracts with Programs, v. 31, no. 7, p. A-147.

Dutton, A. R., Hovorka, S. D., and Bennett, P. C., 1999, Heterogeneity control on occurrence and movement of a subsurface plume of crude oil, South Texas (abs.), *in* AAPG Annual Convention official program: American Association of Petroleum Geologists, p. A35.

Hovorka, S. D., and Dutton, A. R., 1999, Exploring for optimal geological environments for carbon dioxide disposal in saline aquifers in the United States (abs.), *in* AAPG Annual Convention official program: American Association of Petroleum Geologists, p. A63.

Hovorka, S. D., 1998, Reconstruction of dissolved evaporite facies (abs.), *in* Bridges to discovery: extended abstracts, volume 1, AAPG Annual Convention: American Association of Petroleum Geologists Bulletin, p. A312.

Cole, A. G., Dutton, S. P., Barton, M. D., Hovorka, S. D., and Asquith, G. B., 1997, Geophysical characterization of Permian deep-water sandstones, Bell Canyon Formation and Cherry Canyon Formation, Geraldine Ford area, West Texas (Delaware Basin) (abs.): American Association of Petroleum Geologists Annual Convention Official Program, v. 6, p. A21.

Dutton, S. P., Barton, M. D., Hovorka, S. D., Cole, A. G., and Asquith, G. B., 1997, Reservoir characterization of Permian deep-water Ramsey sandstones, Bell Canyon Formation, Ford Geraldine Unit, West Texas (Delaware Basin) (abs.): American Association of Petroleum Geologists Annual Convention Official Program, v. 6, p. A31.

Mace, R. E., and Hovorka, S. D., 1997, Quantification and spatial distribution of matrix and conduit porosity and permeability, *in* a karst aquifer, Edwards Group, South-Central Texas (abs.): Geological Society of America Abstracts with Programs, v. 29, no. 7, p. A-183.

Dutton, S. P., Cole, A. G., and Hovorka, S. D., 1996, Application of advanced reservoir characterization, simulation, and production optimization strategies to maximize recovery in slope and basin clastic reservoirs, West Texas (Delaware Basin) (abs.), *in* Improving production shallow shelf carbonate (class 2) reservoirs: Workshop sponsored by the U.S. Department of Energy and BDM Oklahoma, Inc., unpaginated.

Mace, R. E., and Hovorka, S. D., 1996, Karst-conduit characterization of the Edwards aquifer outcrop (abs.): Geological Society of America Abstracts with Programs, v. 28, no. 1, p. 50.

Hovorka, S. D., 1996, Long-term maintenance of playa lakes and lake basins on the Southern High Plains of Texas (abs.): Geological Society of America, South-Central Section, Abstracts with Programs, v. 28, no. 1, p. 19.

Hovorka, S. D., Mace, R. E., and Collins, E. W., 1995, Regional distribution of permeability in the Edwards aquifer (abs.): American Association of Petroleum Geologists Bulletin, v. 79, no. 10, p. 1559.

Hovorka, S. D., 1995, Bedded gypsum in the Edwards Group, Texas: its role in reducing porosity and enhancing permeability (abs.), *in* AAPG Annual Convention Official Program:

petroleum technology of the world: American Association of Petroleum Geologists, p. 44A.

Hovorka, S. D., 1995, Permeability structure of the Edwards aquifer—implications for aquifer management (abs.): South Texas Geological Society Bulletin, v. 36, no. 3, p. 4.

Hovorka, S. D., 1995, Porosity and permeability structure of the San Antonio segment of the Edwards aquifer (abs.): Austin Geological Society Newsletter, v. 30, no. 4, p. 1.

Hovorka, S. D., 1995, Quaternary playa lake evolution on the Southern High Plains of Texas: cyclic variation, *in* lake level recorded in sediments (abs.): Geological Society of America, North-Central–South-Central Sections Abstracts with Programs, v. 27, no. 3, p. 60.

Scanlon, B. R., Xiang, Jiannan, Goldsmith, R. S., Mullican, W. F., III, and Hovorka, S. D., 1994, Unsaturated zone studies to evaluate subsurface water movement in the vicinity of the Pantex Plant, Amarillo, Texas (abs.), *in* Nash, D. J., ed., From the far corners to the Four Corners: Proceedings, 70th Annual Meeting of the Southwestern and Rocky Mountain Division, American Association for the Advancement of Science: American Association for the Advancement of Science, Southwestern and Rocky Mountain Division, Program and Abstracts, v. 34, no. 1, p. 22.

Gustavson, T. C., Paine, J. G., Avakian, A. J., Hovorka, S. D., and Richter, Bernd, 1993, Natural salt-water pollution of the Canadian River, New Mexico and Texas: source identification using chemical, geophysical, and structural data (abs.): Geological Society of America Abstracts with Programs, v. 25, no. 6, p. A-368.

Paine, J. G., Hovorka, S. D., and Gustavson, T. C., 1993, Subsidence beneath a playa basin on the Southern High Plains, U.S.A.: evidence from shallow seismic and stratigraphic data (abs.): Geological Society of America Abstracts with Programs, v. 25, no. 6, p. A-59.

Gustavson, T. C., Hovorka, S. D., Mullican, W. F., III, Scanlon, B. R., and Xiang, Jiannan, 1993, Stratigraphic controls on preferred pathways for recharge to the Ogallala aquifer, Texas and New Mexico (abs.): Eos, v. 74, no. 43, p. 273.

Hovorka, S. D., 1993, Evaporite karst, *in* the Rolling Plains and High Plains of Texas—process and petrographic evidence (abs.): Geological Society of America, South-Central Section, Abstracts with Programs, v. 25, no. 1, p. 15.

Hovorka, S. D., 1993, Evolution of playa basins on the Texas High Plains—evidence from playa-basin fills (abs.): Geological Society of America, South-Central Section, Abstracts with Programs, v. 25, no. 1, p. 15.

Hovorka, S. D., 1993, Geographic and tectonic controls on evaporite sedimentation, Permian Delaware and Palo Duro Basins, Texas, USA (abs.), *in* Carboniferous to Jurassic Pangea: Annual Convention, Canadian Society of Petroleum Geologists with the Global Sedimentary Geology Program, program and abstracts, Canadian Society of Petroleum Geologists, p. 142.

Mace, R. E., Dutton, A. R., and Hovorka, S. D., 1993, Stratigraphic and structural controls on hydraulic conductivity distribution, *in* fractured chalk at the SSC, North-Central Texas (abs.): Geological Society of America Abstracts with Programs, v. 25, no. 6, p. A-208.

Romanak, K. D., Bennett, P. C., and Hovorka, S. D., 1993, Spatial and temporal variations in CO4 and O2, *in* the unsaturated zone of a freshwater playa: implications for geochemical processes (abs.): Geological Society of America Abstracts with Programs, v. 25, no. 6, p. A-201.

Mace, R. E., Dutton, A. R., and Hovorka, S. D., 1993, Stratigraphic and structural controls on hydraulic conductivity distribution in fractured chalk at the SSC, North-Central Texas (abs.): Geological Society of America Abstracts with Programs, v. 25, no. 6, p. A-208.

Hovorka, S. D., 1992, Cyclic sedimentation, synsedimentary volcanism, microfabrics, and fracture intensity, *in* the Austin Chalk, Texas (abs.): Geological Society of America Abstracts with Programs, v. 24, no. 7, p. A67.

Hovorka, S. D., and Kerans, Charles, 1991, Moldic porosity beneath bar crests, Permian San Andres Formation, Algerita Escarpment, New Mexico (abs.): American Association of Petroleum Geologists Bulletin, v. 75, no. 3, p. 598.

Hovorka, S. D., and Ruppel, S. C., 1990, Controls on porosity evolution, *in* Devonian cherts of West Texas (abs.): American Association of Petroleum Geologists Bulletin, v. 74, no. 5, p. 678.

Hovorka, S. D., 1988, Alteration of gypsum to anhydrite—examples from the Permian Basin (abs.): Geological Society of America Abstracts with Programs, v. 20, no. 7, p. A263.

Hovorka, S. D., 1988, Evaporite diagenesis driven by synsedimentary evolution of brines (abs.): Association of American Petroleum Geologists Bulletin, v. 72, no. 2, p. 199.

Hovorka, S. D., and Fisher, W. L., 1987, Transition from marine to nonmarine evaporites, Permian of the Palo Duro Basin, Texas Panhandle (abs.), *in* SEPM Annual Midyear Meeting Abstracts: Society of Economic Paleontologists and Mineralogists, v. 4, p. 36.

Knauth, L. P., Hovorka, S. D., and Fisher, W. L., 1987, Isotope geochemistry of fluid inclusions in relation to sedimentology and bromide geochemistry of halite in the Palo Duro Basin, Texas (abs.), *in* American current research on fluid inclusions: Socorro, New Mexico Institute of Mining and Technology, Program and Abstracts: programs and abstracts, unpaginated.

Hovorka, S. D., and Fisher, W. L., 1986, Use of sedimentological data in interpretation of evaporite geochemistry (abs.), *in* 192nd American Chemical Society National Meeting, abstracts of papers, GEOC35.

Hovorka, S. D., and Granger, P. A., 1986, Subsurface to surface correlation of Permian evaporites: San Andres–Blaine–Flowerpot relationships, Texas Panhandle (abs.): in SEPM 4th Annual Meeting Abstracts: Society of Economic Paleontologists and Mineralogists,

Hovorka, S. D., 1985, Model for deposition of bedded halite, *in* a shallow shelf setting, San Andres Formation, Palo Duro Basin, Texas Panhandle (abs.): Geological Society of America, Abstracts with Programs, v. 17, no. 7, p. 614.

Posey, H. H., Fisher, R. S., Hovorka, S. D., and Elliott. L. A., 1985, Diagenesis of Early Permian evaporites and carbonates, Palo Duro Basin, Texas (abs.): Geological Society of America, Abstracts with Programs, v. 17, no. 7, p. 692.

Gustavson, T. C., Budnik, R. T, Collins, E. W., Dutton, S. P., Hovorka, S. D., and Ruppel, S. C., 1984, Geologic issues in isolating nuclear waste in the Palo Duro Basin, Texas (abs.): Oklahoma Geological Survey, Oklahoma Geology Notes, v. 44, no. 3, p. 78–79.

Hovorka, S. D., 1984, Textures formed during shallow water halite deposition—an example from Permian of Palo Duro Basin, Texas (abs.): American Association of Petroleum Geologists Bulletin, v. 68, no. 4, p. 487–488.

McGookey, D. A., Hovorka, S. D., and Kolker, Allan, 1984, Depositional environments and source areas of Middle and Late Permian terrigenous clastic rocks, Palo Duro Basin, Texas (abs.): Geological Society of America, Abstracts with Programs, v. 16, no. 2, p. 108.

Gustavson, T. C., Budnik, R. T, Collins, E. W., Dutton, S. P., Hovorka, S. D., and Ruppel, S. C., 1983, Geologic issues in isolating nuclear waste in the Palo Duro Basin, Texas (abs.): Geological Society of America, Abstracts with Programs, v. 15, no. 1, p. 3.

Fisher, W. L., and Hovorka, S. D., 1983, Textural and geochemical evidence of primary and altered halite, Permian San Andres Formation, Texas (abs.): Geological Society of America, Abstracts with Programs, v. 15, no. 6, p. 574.

Hovorka, S. D., and Budnik, R. T, 1981, Normal marine–marine marginal sabkha transition, lower Permian, Palo Duro Basin, Texas Panhandle (abs.): Geological Society of America, Abstracts with Programs, v. 15, no. 1, p. 6.

Hovorka, S. D., 1977, Sedimentary textures as clues to the nature of early diagenesis, *in* bedded radiolarian cherts (abs.): Geological Society of America, Abstracts with Programs, South-Central Section, v. 9, p. 1027–1028.

Hovorka, S. D., Luttrell, P. E., and Murphy, T. D., 1976, Facies relationships and depositional history of South Florida carbonate mud banks (abs.): Geological Society of America, Abstracts with Programs, v. 8, p. 23–24.

Proceedings Volumes

Hovorka, S. D., ed., 2004, Edwards water resources in Central Texas: retrospective and prospective, South Texas Geological Society and Austin Geological Society, CD-ROM.

Contract Reports

Hovorka, S. D., 2009, Optimization of geological environments for carbon dioxide disposal in saline aquifers in the United States: The University of Texas at Austin, Bureau of Economic Geology, final report prepared for U.S. DOE, under contract no. DE-AC26-98FT40417, CD-ROM.

Smyth, R. C., Hovorka, S. D., Meckel, T. A., Breton, C. A., Paine, J. G., and Hill, G. R., 2007, Potential sinks for geologic storage of CO2 generated in the Carolinas: The University of Texas at Austin, Bureau of Economic Geology, final report prepared for Southern States Energy Board and Electric Power Research Institute (http://www.beg.utexas.edu/environqlty/co2seq/pubs_presentations/CarolinasSummary_16April07.pdf), 14 p.

Nicot, J. -P., Saripalli, Prasad, Bouroullec, Renaud, Castellanos, Hugo, Hovorka, S. D., Lakshminarasimhan, Srivatsan, Paine, J. G., and Yang, Yiling, 2006, Development of science -based permitting guidance for geological sequestration of CO2 in deep saline aquifers based on modeling and risk assessment: The University of Texas at Austin, Bureau of Economic Geology, final scientific report prepared for U.S. Department of Energy, under DOE Agreement No. DE-FC25-04NT42210, 220 p.

Hovorka, S. D., 2006, Proposed methodology for construction of a 2006 national geological carbon sequestration capacity assessment: Capacity and Fairways Subgroup of the Geologic Working Group of the DOE Carbon Sequestration Regional Partnerships, final report prepared for U.S. Department of Energy, Regional Carbon Sequestration Partnership Program, 35 p.

Hovorka, S. D., Holtz, M. H., Smyth, R. C., Nuñez-Lopez, Vanessa, Kim, E. M., Breton, Caroline, Scanlon, B. R., and Reedy, R. C., 2005, Southeast regional carbon sequestration partnership: The University of Texas at Austin, Bureau of Economic Geology, final report prepared for the U.S. Department of Energy, under DOE award number DE-FC26-03NT41980, 40 p.

Holtz, M. H., Ambrose, W. A., Hovorka, S. D., Nuñez-Lopez, Vanessa, Guevara, E. H., and Breton, C. L., 2005, CO2 sink analysis near U.S. BP refineries: The University of Texas at Austin, Bureau of Economic Geology, report prepared for BP, Charles Christopher, 18 p.

Hovorka, S. D., Phu, Thandar, Nicot, J. -P., and Lindley, Adrien, 2004, Refining the conceptual model for flow in the Edwards aquifer—characterizing the role of fractures and conduits in the Balcones Fault Zone segment: The University of Texas at Austin, Bureau of Economic Geology, final contract report prepared for Edwards Aquifer Authority, under Joint Funding Agreement No. 01-70-AS, 53 p.

Collins, E. W., Tremblay, T. A., Gutiérrez, Roberto, Raney, J. A., Rawlings, Jennifer, Lindley, Adrien, and Hovorka, S. D., 2003, Applications of laser terrain mapping in Central Texas for managing karst aquifers and land use: The University of Texas at Austin, Bureau of Economic Geology, final report prepared for California Institute of Technology, Jet Propulsion Laboratory,, under contract 1247072 for the NASA-AAG Program, 34 p.

Scanlon, B. R., Mace, R. E., Smith, Brian, Hovorka, S. D., Dutton, A. R., and Reedy, R. C., 2002, Groundwater availability of the Barton Springs segment of the Edwards aquifer, Texas—numerical simulations through 2050: The University of Texas at Austin, Bureau of Economic Geology, final report prepared for the Lower Colorado River Authority, under contract no. UTA99-0, 36 p. + figs., tables, attachment.

Hovorka, S. D., Paine, J. G., Reedy, R. C., Collins, E. W., and Lindley, Adrien, 2002, Evaluation of the potential for cross contamination of the Edwards aquifer from dissolved contaminants in the shallow groundwater zone in the vicinity of Kelly AFB via faults and wells: The University of Texas at Austin, Bureau of Economic Geology, final report prepared for U.S. Air Force, Kelly Air Force Base, 47 p.

Hovorka, S. D., 2001, Task 3 milestone: approaches for the recognition and management of sensitive features in the Edwards aquifer recharge zones: The University of Texas at Austin, Bureau of Economic Geology, milestone report prepared for Texas Natural Resource Conservation Commission, 42 p.

Hovorka, S. D., 2001, Task 1 milestone: draft bibliography on karst geomorphology and hydrology relevant to geologic assessment of recharge features in the Edwards aquifer interagency contract on evaluation of the geologic assessment of sensitive features: The University of Texas at Austin, Bureau of Economic Geology, milestone report prepared for Texas Natural Resource Conservation Commission, 10 p.

Hovorka, S. D., 2001, Task 5 milestone: instructions to geologists for geologic assessments on the Edwards aquifer recharge/transition zones: The University of Texas at Austin, Bureau of Economic Geology, milestone report prepared for Texas Natural Resource Conservation Commission, 34 p.

Hovorka, S. D., Romero, M. L., Treviño, R. H., Warne, A. G., Ambrose, W. A., Knox, P. R., and Tremblay, T. A., 2000, Project evaluation: phase II: optimal geological environments for carbon dioxide disposal in brine-bearing formations (aquifers) in the United States: The University of Texas at Austin, Bureau of Economic Geology, final report prepared for U.S. Department of Energy, National Energy Technology Laboratory, under contract no. DE-AC26-98FT40417, 222 p.

Hovorka, S. D., and Nava, Robin, 2000, Characterization of bedded salt for storage caverns—a case study from the Midland Basin, Texas: The University of Texas at Austin, Bureau of Economic Geology, final report prepared for U.S. Department of Energy, National Petroleum Technology Center, under contract no. DE-AF26-97BC15030, 115 p.

Aslan, Andres, Crawford, Melba, Gibeaut, J. C., Guevara, E. H., Hovorka, S. D., Neuenschwander, A. L., Raney, J. A., Smith, Solar, Sullivan, E. J., Warne, A. G., and White, W. A., 1999, 1998 Annual report: year one: geo-environmental characterization of the Delta del Orinoco, Venezuela: The University of Texas at Austin, Bureau of Economic Geology and Center for Space Research, final report prepared for Petróleos de Venezuela, S.A., and Coordinación Desarrollo Armónico de Oriente, 190 p.

Warne, A. G., Aslan, Andres, White, W. A., Gibeaut, J. C., Tremblay, T. A., Smyth, R. C., Guevara, E. H., Gutiérrez, Roberto, Hovorka, S. D., Raney, J. A., Crawford, Melba, Smith, Solar, and Neuenschwander, A. L., 1999, 1999 final report year two: geo-environmental characterization of the Delta del Orinoco, Venezuela: The University of Texas at Austin, Bureau of Economic Geology, final report prepared for Petróleos de Venezuela, S.A., and Coordinación Desarrollo Armónico de Oriente, 99 p. + figures, tables, and appendices.

Hovorka, S. D., Dutton, A. R., Paine, J. G., Nava, Robin, and Blum, Martina, 1999, Site investigation of the Montague salt-water seep, Montague County, Texas (RRC Cleanup No. 09-50211): The University of Texas at Austin, Bureau of Economic Geology, final report prepared for Oil Field Special Response Program, Railroad Commission of Texas, under Interagency Contract No.96-0050, 133 p. + apps.

Hovorka, S. D., 1999, Optimal geological environments for carbon dioxide disposal in saline aquifers in the United States: The University of Texas at Austin, Bureau of Economic

Geology, final report prepared for U.S. Department of Energy, Federal Energy Technology Center, under contract no. DE-AC26-98FT40417, 55 p.

Hovorka, S. D., and Guevara, E. H., 1999, Orinoco Delta bibliography: The University of Texas at Austin, Bureau of Economic Geology and Center for Space Research, final report prepared as part of the Geo-Environmental Characterization of the Delta del Orinoco Project for Petróleos de Venezuela, S.A., and Coordinación Desarrollo Armónico de Oriente, 154 p.

Hovorka, S. D., 1997, Analogs of engineered barriers: natural examples of very long-term performance of layered geologic materials: The University of Texas at Austin, Bureau of Economic Geology, technical report prepared for the Texas Low-Level Radioactive Waste Disposal Authority, under interagency contract no. CON-97-028, 77 p.

Hovorka, S. D., 1997, Salt cavern studies—regional map of salt thickness in the Midland Basin: The University of Texas at Austin, Bureau of Economic Geology, final report performed for Bartlesville Project Office, U.S. Department of Energy, under contract no. DE-AF22-96BC14978, DOE/BC/14978, 31 p.

Hovorka, S. D., Mace, R. E., Parra, S. P., and Porterfield, Susanne, 1997, Lubbock County pilot study for development of a hydrogeologic geographic information system (HGIS) to support TNRCC implementation of risk-reduction rules: The University of Texas at Austin, Bureau of Economic Geology, final technical report prepared for Texas Natural Resource Conservation Commission, under Interagency Contract 72-000000-38, 76 p.

Paine, J. G., Blum, Martina, and Hovorka, S. D., 1997, Status of site investigation and plan for evaluation of remediation alternatives for the Montague County saltwater seep, Montague County, Texas: The University of Texas at Austin, Bureau of Economic Geology, interim technical report prepared for Oil Field Special Response Program, Railroad Commission of Texas, under interagency contract no. 96-0050, 23 p.

Dutton, S. P., Hovorka, S. D., and Cole, A. G., 1996, Application of advanced reservoir characterization, simulation, and production optimization strategies to maximize recovery in slope and basin clastic reservoirs, West Texas (Delaware Basin): The University of Texas at Austin, Bureau of Economic Geology, annual report prepared for U.S. Department of Energy, under contract no. DE-FC22-95BC14936, 81 p.

Gustavson, T. C., Bebout, D. G., Bennett, P. C., Fish, E. B., Fryar, A. E., Hovorka, S. D., Hua, H.-P., Kirschenmann, Kyle, Laun, Scot, Minehardt, T. J., Mullican, W. F., III, Nicot, J. -P., Paine, J. G., Pezzolesi, T. P., Rainwater, Ken, Ramsey, Heyward, Reeduer, Alan, Romanak, K. D., Scanlon, B. R., Thompson, David, Xiang, Jiannan, and Zartman, R. E., 1995, Summary hydrogeologic assessment, U.S. Department of Energy Pantex Plant, Carson County, Texas: The University of Texas at Austin, Bureau of Economic Geology, milestone report prepared for U.S. Department of Energy, 98 p.

Hovorka, S. D., Mace, R. E., and Collins, E. W., 1995, Regional distribution of permeability in the Edwards aquifer: The University of Texas at Austin, Bureau of Economic Geology, final report prepared for Edwards Underground Water District, under contract no. 93-17-FO, 128 p.

Hovorka, S. D., 1995, Quaternary evolution of playa lakes on the Southern High Plains—a case study from the Amarillo area: The University of Texas at Austin, Bureau of Economic Geology, final report prepared for Office of the Governor of Texas using funds provided by the U.S. Department of Energy, under grant no. DE-FG04-90AL65847, 102 p.

Hovorka, S. D., 1995, Stratigraphy of playas in the Pantex area—Playa 5 and Pantex Lake: The University of Texas at Austin, Bureau of Economic Geology, milestone report, activity 1 prepared for U.S. Department of Energy, 22 p.

Dutton, A. R., Collins, E. W., Hovorka, S. D., Mace, R. E., Scanlon, B. R., and Xiang, Jiannan, 1994, Occurrence and movement of ground water in Austin Chalk and Eagle Ford and Ozan Formations at the Superconducting Super Collider (SSC) site, Ellis County, Texas: The University of Texas at Austin, Bureau of Economic Geology, topical report prepared

for the Texas National Research Laboratory Commission, under contract no. IAC(92-93)-0301, 393 p.

Hovorka, S. D., 1994, Evaluation of the ground penetrating radar (GPR) survey at TDCJ playa, Carson County: The University of Texas at Austin, Bureau of Economic Geology, milestone report prepared for the U.S. Department of Energy through the Office of the Governor, State of Texas, 16 p.

Kerans, Charles, Lucia, F. J., Senger, R. K., Fogg, G. E., Nance, H. S., and Hovorka, S. D., 1993, Characterization of facies and permeability patterns in carbonate reservoirs based on outcrop analogs: The University of Texas at Austin, Bureau of Economic Geology, final report prepared for the Assistant Secretary for Fossil Energy, U.S. Department of Energy, under contract no. DE-AC22-89BC14470, 160 p.

Hovorka, S. D., Ruppel, S. C., Dutton, A. R., and Yeh, Joseph, 1993, Edwards aquifer storage assessment: Kinney County to Hays County, Texas: The University of Texas at Austin, Bureau of Economic Geology, final report prepared for Edwards Underground Water District, under contract no 93-04-F0, 51 p., 8 pl.

Hovorka, S. D., 1993, Playa basin fills near the Pantex Plant—stratigraphic and geomorphic analysis: The University of Texas at Austin, Bureau of Economic Geology, milestone report prepared for the U.S. Department of Energy, 16 p.

Xiang, Jiannan, Hovorka, S. D., Goldsmith, R. S., and Scanlon, B. R., 1993, Evaluation of preferential flow in playa settings near the Pantex Plant: The University of Texas at Austin, Bureau of Economic Geology, milestone report prepared for the U.S. Department of Energy, 11 p.

Kerans, Charles, Lucia, F. J., Senger, R. K., Fogg, G. E., Nance, H. S., and Hovorka, S. D., 1992, Characterization of facies and permeability patterns in carbonate reservoirs based on outcrop analogs: The University of Texas at Austin, Bureau of Economic Geology, report prepared for the U.S. Department of Energy, under contract no. DE-AC22-89BC14470, 160 p.

Gustavson, T. C., Avakian, A. J., Hovorka, S. D., and Richter, Bernd, 1992, Canadian River salinity sources, Ute reservoir, New Mexico, to Lake Meredith, Texas: evaporite dissolution patterns and results of February 1992 water quality survey: The University of Texas at Austin, Bureau of Economic Geology, final contract report prepared for the Canadian River Municipal Water Authority, 49 p., 2 pl.

Kerans, Charles, Lucia, F. J., Senger, R. K., Fogg, G. E., Nance, H. S., Kasap, Ekrem, and Hovorka, S. D., 1991, Characterization of reservoir heterogeneity in carbonate-ramp systems, San Andres/Grayburg, Permian Basin: The University of Texas at Austin, Bureau of Economic Geology, Reservoir Characterization Research Laboratory, final contract report, 245 p.

Tyler, Noel, Bebout, D. G., Garrett, C. M., Jr., Guevara, E. H., Hocott, C. R., Holtz, M. H., Hovorka, S. D., Kerans, Charles, Lucia, F. J., Major, R. P., and Ruppel, S. C., 1990, Opportunities for additional recovery in University Lands reservoirs-characterization of University Lands reservoirs: The University of Texas at Austin, Bureau of Economic Geology, final report prepared for the University of Texas System, 255 p.

Hovorka, S. D., Fisher, R. S., and Nance, H. S., 1988, Petrography and geochemistry of the Artesia Group, Palo Duro Basin, Texas Panhandle: The University of Texas at Austin, Bureau of Economic Geology, final report prepared for the U.S. Department of Energy, Salt Repository Project Office, under contract no. DE-AC97-83WM46651, 79 p.

Hovorka, S. D., and McCrary, M. M., 1986, Petrography of the Artesia Group: interim report, volume 1 and volume 2: The University of Texas at Austin, Bureau of Economic Geology, final report prepared for the U.S. Department of Energy, Salt Repository Project Office, under contract no. DE-AC97-83WM46651, Open-File Report OF-WTWI-1985-42, Revision 1, unpaginated.

Droddy, M. J., and Hovorka, S. D., 1982, National uranium resource evaluation, Beeville quadrangle, Texas: Bendix Field Engineering Corporation, report prepared for U.S. Department of Energy, NURE, under contract no. DE-AC07-76GJ01664, Open-File Report No. PGJ/F-066(82), 22 p.

Droddy, M. J., and Hovorka, S. D., 1982, National uranium resource evaluation, Llano quadrangle, Texas: Bendix Field Engineering Corporation, report prepared for U.S. Department of Energy, NURE, under contract no. DE-AC07-76GJ01664, Open-File Report No. PGJ/F-122(82), 24 p.

Atlases/Maps/Cross Sections

Hovorka, S. D., and Dutton, A. R., 2001, Aquifers of Texas: The University of Texas at Austin, Bureau of Economic Geology, Page-Sized Map, 1 p., scale 1 inch = 100 mi.

Collins, E. W., and Hovorka, S. D., 1997, Structure map of the San Antonio segment of the Edwards aquifer and Balcones Fault Zone, south-central Texas: structural framework of a major limestone aquifer: Kinney, Uvalde, Medina, Bexar, Comal, and Hays Counties: The University of Texas at Austin, Bureau of Economic Geology, Miscellaneous Map No. 38, 14-p. text, scale 1:250,000.

Course Notes

Hovorka, S. D., 1999, Water and the environment in Southwest Texas: resources for Summer Institute, Eisenhower Professional Development Workshop: The University of Texas at Austin, Bureau of Economic Geology, course notes and workbook, unpaginated.

Hovorka, S. D., 1997, Salt thickness, in the Midland Basin: regional screening criterion for salt cavern development: The University of Texas at Austin, Bureau of Economic Geology, poster presentation handout for Fall Meeting, 19 p.

Workshop Workbooks

Hovorka, S. D., and Andrews, J. R., 2000, EarthView Texas: high-tech investigation of geology in your backyard: The University of Texas at Austin, Bureau of Economic Geology, at “Think Globally, Learn Locally”, 13 p.

Hovorka, S. D., and Andrews, J. R., 2000, Environmental Assessment of your Town: The University of Texas at Austin, Bureau of Economic Geology, short course workbook and digital data set for teachers, 12 p.

Thesis

Stratigraphy and petrography of the Upper Chert and Shale Member, Caballos Formation, Brewster County, West Texas: The University of Texas at Austin, M.A. thesis, 272 p., 1981.

Dissertation

Sedimentary processes controlling deposition of halite, Permian Basin, Texas: The University of Texas at Austin, Ph.D. dissertation, 394 p., 1990.

Lecturing

BEG Colloquia

Is there really enough space to "put it back"?: Capacity estimation for geologic storage of CO2: presented at Bureau of Economic Geology Research Seminar, The University of Texas at Austin, Austin, Texas, September 8, 2006.

Climate change: the issues and the options: presented at BEG Summer Lecture Series, Austin, Texas, June 10, 2005.

Climate change—issues and answers for Texas: presented at Bureau of Economic Geology seminar with P. R. Knox, M. H. Holtz, K. Fouad, S. Sakurai, J. G. Paine, and J. Yeh, Austin, Texas, October 18, 2002.

Introducing the Jackson School Geoscience Alliance: presented at Bureau of Economic Geology seminar, Austin, Texas, February 22, 2002.

Sedimentary processes: Bureau of Economic Geology research seminar, The University of Texas at Austin, Austin, TX, 2000.

Why should you include an educational element in an applied research project?: present at the Bureau of Economic Geology, University of Texas at Austin, November 1999.

"3-D visualization of the Edwards Aquifer": presented to Bureau of Economic Geology, April 1998, June 1998, February 1999, 1998.

Salt dissolution in the Permian Basin: process and implications: February 1997.

Regional distribution of permeability in the Edwards aquifer: January 1995.

Porosity distribution in the Edwards aquifer—depositional facies, Cretaceous dolomitization, and Cenozoic fresh-water alteration: presented at Bureau of Economic Geology Colloquium, April 1994.

Quaternary playa basin fills on the Southern High Plains, Texas—implications for Pleistocene climate, Ogallala recharge, and playa basin evolution: presented at Bureau of Economic Geology Colloquium, April 1993.

Cyclic sedimentation in deep-water shelf facies of the Austin Chalk: presented at Bureau of Economic Geology Colloquium, April 1992.

Porosity Development in Chert Three Bar Devonian Field: Andrews County, Texas, February 1989.

Early Diagenesis in Sulfates: December 1987.

Update of Depositional Models for Palo Duro Evaporites and Carbonates: November 1986.

Cyclicity in the San Andres Formation, Palo Duro Basin, New Models: presented at a BEG research seminar, March 1984.

Cyclicity in the San Andres Formation: presented at a BEG research seminar, May 1983.

Diagenesis and Dissolution in Evaporites, Donley and Swisher County Cores, West Texas: presented at a BEG research seminar, April 1982.

Corporate Schools, Research Seminars

Denbury Resources Green Pipeline CO2 Sequstration: Video appearance during course of 3½-minute presentation for Denbury Resources, Plana, Texas, September 2009.

Workshops

Monitoring and verification issues for carbon storage: presented as online lecture to Regional Sequestration Partnerships Outreach and Geologic Working Groups, Austin, Texas, 2006.

Workshop on salt core: Solution Mining Research Institute Field Trip to Bureau of Economic Geology Core Research Center (with Steve Seni), Austin, Texas, 2000.

Lectures and Addresses

Investigation of water displacement following large CO2 sequestration operations view boundaries and borehole leakage driving forces: presented at the GHGT-9 (Green House Gas Technology) Conference, Washington, D.C., November 16–20, 2008.

Comparing carbon sequestration in an oil reservoir to sequestration in a brine formation- field study: presented at the GHGT-9 (Green House Gas Technology) Conference, Washington, D.C., November 16–20, 2008.

Pressure perturbations from geologic carbon sequestration: Area-of-review boundaries and borehole leakage driving forces: presented at the GHGT-9 (Green House Gas Technology) Conference, Washington, D.C., November 16–20, 2008.

Continuous pressure monitoring for large volume CO2 injections: presented at the GHGT-9 (Green House Gas Technology) Conference, Washington, D.C., November 16–20, 2008.

Assessing risk to fresh water resources from long term CO2 injection—laboratory and field studies: presented at the GHGT-9 (Green House Gas Technology) Conference, Washington, D.C., November 16–20, 2008.

Recent advances in well-based monitoring of CO2 sequestration: presented at the GHGT-9 (Green House Gas Technology) Conference, Washington, D.C., November 16–20, 2008.

Geochemical modeling of near-surface CO2 interactions: the critical element in cost-effective long-term monitoring: presented at the GHGT-9 (Green House Gas Technology) Conference, Washington, D.C., November 16–20, 2008.

Update on carbon storage field projects: presented at TCEQ Environmental Trade Fair and Conference, Austin, Texas, May 1–3, 2007.

Testing interactions of buoyancy, multiphase flow, and geochemical interactions: preliminary results for the Frio II Test: presented at Sixth Annual Conference on Carbon Capture & Sequestration: Expediting deployment of industrial scale systems: Can it be done? How? Concerns to be addressed, Pittsburgh, Pennsylvania, May 8, 2007.

Role of geochemical interactions in assuring permanence of storage of CO2 in geologic environments: presented to AIChE, Houston, Texas, April 23, 2007.

Downscaling capacity from a regional to a site scale--a case study for the southeastern U.S.: presented at Fifth Annual Conference on Carbon Capture & Sequestration, Alexandria, Virginia, May 8–11, 2006.

Update on the Frio Brine Storage Project--progress on estimating permanence: presented at Fifth Annual Conference on Carbon Capture & Sequestration, Alexandria, Virginia, May 8–11, 2006.

Update on Frio Brine Project—15 months after injection: presented at Workshop on Carbon Capture and Storage, hosted by RITE, Tokyo, Japan, February 18–23, 2006.

Stacked storage field project: presented at SECARB Industry Briefing, Atlanta, Georgia, January 18–19, 2006.

Assessment of geological storage capacity of the southeastern U.S. for CO2 in brines and economic use for EOR: presented at SECARB Industry Briefing, Atlanta, Georgia, January 18–19, 2006.

Monitoring and verification issues for carbon storage pilot experiments: presented at SECARB Industry Briefing, Atlanta, Georgia, January 18–19, 2006.

Verification: does geologic storage really provide environmental benefit?: presented at GCCC 4th Quarter Partners Meeting, Austin, Texas, December 14, 2005.

Frio site visit and Frio Pilot overview: presented to Group from MIBRAG and Anhalt-Saxony, Germany, Dayton, Texas, November 22–23, 2005.

Update on the Frio Brine Pilot: 1 year after injection: presented at Applied Technology Workshop (ATW) CO2 Sequestration, Galveston, Texas, November 16, 2005.

Update on the Frio Brine Pilot: 1 year after injection: presented at IEA Annual Monitoring Network Workshop, Rome, Italy, October 4, 2005.

Frio case study: presented at IEA Annual Monitoring Network Workshop, Rome, Italy, October 5, 2005.

Update on the Frio Brine Pilot: 1 year after injection: presented at Carbon Sequestration Leadership Forum, CSLF Project Exhibits by Policy Group & Technical Group delegates and VIP's, Ministry of Economics and Labor (BMWA), Berlin, Germany, September 28, 2005.

Update on the Frio Brine Pilot: 1 year after injection: presented at Carbon Sequestration Leadership Forum, GeoForschungszentrum, Potsdam, Germany, September 29, 2005.

GCCC plan and scope: presented to GCCC partners, Houston, Texas, August 20, 2005.

Karst and flow in the confined and unconfined Edwards aquifer--key issues and unresolved problems: presented at Edwards Aquifer Workshop, San Antonio, Texas, July 18, 2005.

Update on the Frio Brine Pilot: 8 months after injection: invited talk presented at First India-U.S. CCS Workshop, Hyderabad, India, June 2, 2005.

Frio Brine Pilot: field validation of numerical simulation of CO2 storage: presented at American Association of Petroleum Geologists Annual Meeting, Calgary, Canada, June 23, 2005.

From concept to reality: a systematic management approach for field implementation of the Frio Brine Pilot Test: presented at Fourth Annual Conference on Carbon Capture and Sequestration DOE/NETL, Alexandria, Virginia, May 2–5, 2005.

Review of existing injection well permit regulations and expectations of future geologic sequestration CO2 regulations with monitoring conditions: presented at Fourth Annual Conference on Carbon Capture and Sequestration DOE/NETL, Alexandria, Virginia, May 2–5, 2005.

Frio Brine Pilot: lessons learned and questions restated: presented at Fourth Annual Conference on Carbon Capture and Sequestration DOE/NETL, Alexandria, Virginia, May 2, 2005.

The U-tube: a novel system for sampling and analyzing multi-phase borehole fluid samples during the Frio Brine Pilot Test: presented at Fourth Annual Conference on Carbon Capture and Sequestration DOE/NETL, Alexandria, Virginia, May 2, 2005.

Application of numerical models to development of the Frio Brine Storage Experiment: presented at EPA Modeling Workshop, Houston, Texas, April 6, 2005.

Draft strategic plan: presented to GCCC partners, Houston, Texas, April 11, 2005.

Testing the concepts of sequestration--field demonstration and economic projects: presented at UT CPGE Geological Storage JIP, Austin, Texas, March 22, 2005.

Testing geologic sequestration in high-permeability sandstone of the Frio Formation: 6-month update: presented at AJW CCS Conference, Melbourne, Australia, March 3, 2005.

Testing geologic sequestration in high-permeability sandstone of the Frio Formation: 6-month update: presented at Australian CO2 CRC-Peter Cook Group, Canberra, Australia, March 2, 2005.

Testing geologic sequestration in high-permeability sandstone of the Frio Formation: 6-month update: presented to Society of Petroleum Engineers Perth, Perth, Western Australia, March 8, 2005.

Frio Brine pilot: CO2 outreach: Testing geologic sequestration in high-permeability sandstone of the Frio Formation: 6-month update: presented at the BP Festival, Houston, Texas, February 20, 2005.

Gulf Coast Carbon Center review: presented to GCCC partners, Houston, Texas, November 15, 2004.

Progress update: Developing a science and business plan for carbon storage and use in the Gulf Coast: presented to NETL management, Pittsburg, Pennsylvania, November 22, 2004.

Testing efficiency of storage in the subsurface: Frio Brine Pilot Experiment: presented at MIT CSS Workshop, Boston, Massachusetts, November 4, 2004.

New views of familiar places: elementary geoscience labs: Is dirt just dirt? and How the Earth makes us rich: presented at CAST, Corpus Christi, Texas, November 3, 2004.

Testing efficiency of storage in the subsurface: Frio Brine Pilot experiment: presented at the Gulf Coast Association of Geological Societies Annual Meeting, San Antonio, Texas, October 10, 2004.

Frio Brine Pilot Experiment: update: presented at Geological Society of America Annual Meeting, Denver, Colorado, October 30, 2004.

Texas Gulf Coast: presented to Geologic Working Group of the U.S. Department of Energy Regional Partnerships Program, Dayton, Texas, October 21–22, 2004.

Developing a business plan for carbon use and carbon sequestration in the Gulf Coast: presented at Baker Center, Rice University, Houston, Texas, September 1, 2004.

Subsurface monitoring and verification: presented at the 7th Greenhouse Gas Technology Conference, Vancouver, British Columbia, September 4, 2004.

Monitoring and verification issues for carbon storage: presented at SSEB Annual Meeting, Atlanta, Georgia, September 13, 2004.

Informal update: Frio Brine Pilot: presented to GCCC partners, Houston, Texas, September 15, 2004.

Progress update: Frio Brine Pilot, Texas Gulf Coast: presented at DOE-NETL Program Review, Pittsburg, Pennsylvania, April 18, 2004.

Monitoring and verification issues for carbon storage: invited talk presented to EPA, Washington, D.C., February 2, 2004.

Outreach lecture: CO2 is a gas: presented to BP, CO2 Fest, Houston, Texas, February 21–22, 2004.

Frio Brine Pilot poster: presented to BP, CO2 Fest, Houston, Texas, February 2004.

Partnership kick-off: presented to U.S. Department of Energy, Pittsburg, Pennsylvania, October 29, 2003.

Energy and the environment—tapping the potential for large-volume storage of carbon in the Gulf Coast: presented at Meeting of the Texas PTTC Producers Advisory Group (PAG) and State of Texas Policy Makers, Austin, Texas, May 22, 2003.

The role of map dimension and movement in helping students solve geology problems: presented at the annual meeting of the American Educational Research Association, Chicago, Illinois, April 2003.

Geologic sequestration—case studies in the onshore U.S.: presented at IBC Workshop on Carbon Sequestration, Houston, Texas, October 25, 2002.

Recharge to the BFZ Edwards aquifer—the issues and the unknowns: presented at The University of Texas at Austin, Department of Geological Sciences Hydro Brown Bag Seminar, Austin, Texas, September 6, 2002.

Frio Brine Pilot Project status report: presented to National Energy Technology Laboratory, Pittsburgh, Pennsylvania, August 27, 2002.

Overview of Frio Brine Project: presented to GEO-SEQ advisory panel, Berkeley, California, January 23, 2002.

Reducing atmospheric emissions of greenhouse gasses by injecting them underground: presented to Austin Geological Society, Austin, Texas, April 30, 2001.

Identifying optimal environments for geologic storage of large volumes of CO2, onshore US: presented at Princeton Environmental Institute, Princeton University, Princeton, NJ, April 6, 2001.

Tour of the Edwards aquifer: presented to Honor Society, Southwest Texas Junior College, Uvalde, Texas, September 26, 2000.

Virtual reality tour of the Edwards aquifer: presented at Groundwater Festival 2000, Aquarena Center (with Scott Rodgers and John Andrews), San Marcos, Texas, September 15, 2000.

Virtual reality tour of Earth Science research in Texas: presented to Leakey School (with John Andrews and Dallas Dunlap), Leakey, Texas, April 17-18, 2000.

Rocks from space: meteorites in the classroom: presented at National Science Teachers Association National Convention (with D. F. Lester, M. Walker, R. Stryker, and J. Jackson), Orlando, Florida, April 6, 2000.

Bureau of Economic Geology K-12 outreach: presented to Austin Geological Society, Austin, Texas, February 7, 2000.

Strategies for identification of optimal saline formations for sequestration of carbon dioxide in the United States: presented at ENERGX Conference, Las Vegas, Nevada, 2000.

Flood! : presented at College of Natural Science, The University of Texas at Austin, Science Fun Day (with Bureau staff and Mrs. Hernandez' 6th grade), Austin, Texas, 2000.

Virtual field trip through Texas: presented at Math and Science Technology Conference (with John Andrews), Austin, Texas, 2000.

Virtual field trip through Texas and high-tech investigation of geology in your backyard: presented at Think Globally, Learn Locally Technology Conference (with John Andrews), Jefferson, Texas, 2000.

Exploring for optimal environments for CO2 sequestration, onshore U.S.: presented at International Energy Agency Greenhouse Gas R&D Programme , Leeuwenhorst, Netherlands, 2000.

Edwards Aquifer Issues and Scientific Resolution and Edwards aquifer field trip stop 3 and 4: presented to Commission National del Agua, August 17-18, 1998.

Sysnsedimentary dissolution, a method for determining water depth in evaporites: presented to SEPM Evaporite Research Group, American Association of Petroleum Geologists National Meeting, Salt Lake City, Utah, May 20, 1998.

Determining water depth from evaporite sediments - a key element in modeling basin evolution: presented to Department of Geology, University of Texas at Arlington, March 26, 1998.

Long-term maintenance of playa lakes and lake basins on the Southern High Plains of Texas: presented to the Panhandle Geological Society, Amarillo, TX, October 22, 1996.

Permeability structure of the Edwards aquifer, South Texas—implications for aquifer management: presented to the South Texas Geological Society, San Antonio, Texas, November 8, 1995.

Porosity and permeability structure of the San Antonio segment of the Edwards aquifer: presented to the Austin Geological Society, Austin, Texas, November 6, 1995.

Recognition of evaporite dissolution textures: presented to Evaporite Research Group, March 1995, 1995.

Regional distribution of permeability in the Edwards Aquifer: presented to Edwards Underground Water District Board Meeting, February 1995.

Overview of recent research on the Edwards aquifer: presented to the TNRCC Groundwater Protection Committee, February 1995.

Regional distribution of permeability in the Edwards aquifer: presented to the technical review group of the Edwards Underground Water District, December 1994.

Gypsum in the Edwards group of South Texas: presented to SEPM Evaporite Research Group, Austin, Texas, October 1994.

Austin Chalk at the SSC site—cyclic sedimentation, synsedimentary volcanism, microfabrics, and fracture intensity: presented to Union Pacific Resources, Fort Worth, 1993.

Microfabric influence on fracture intensity, Austin Chalk, shallow subsurface, Ellis County, Texas: poster session presented to the Natural Fracture Workshop, Bureau of Economic Geology, Austin, Texas, 1992.

Origin of Porosity in Chert of the Devonian Thirty-one Formation: presented to Mobil, Midland, Texas, October 1989.

The Sedimentology of Salt, Examples from the Palo Duro and Delaware Basins: presented to Geology Department Technical Sessions, October 1988.

Marine to Non-Marine Transition in Evaporites: presented to Penrose Conference on Marine Evaporites, Windsor, Ontario, August 1988.

San Andres Evaporite Depositional Model: presented at AAPG meeting in New Orleans, Louisiana, April 1988.

Sedimentary Significance of Polyhalite, Glauberite, and Sylvite-A Problem from the Permian of the Texas Panhandle: presented to SEPM Evaporite Research Group, Houston, Texas, March 1988.

Core workshop: Dissolution of Evaporite: Petrologic Evidence of Dissolution and Criteria for Determining Timing: presented to Shell Exploration, February 1988.

Halite Pseudomorphs after Gypsum in Bedded Anhydrite–Clue to Gypsum–Anydrite Relationships: presented to Department of Geological Sciences, January 1988.

Recap of August meeting: presented to U.S. Department of Energy and Nuclear Regulatory Commission in Columbus, Ohio, November 1985.

Core workshop—overview of U.S. Department of Energy cores: U.S. Department of Energy and Nuclear Regulatory Commission, August 1985.

San Andres Evaporite Depositional Model: presented at AAPG meeting, April 1985.

Core workshop—overview of U.S. Department of Energy cores: presented at BEG Core Research Center to U.S. Department of Energy, March 1985.

Distinguishing between Permian and Post-Permian Dissolution: presented at a SWEC-ONWI-BEG Meeting, January 1983.

Short Courses

Geologic assessments of karst areas: presented at the 10th Multidisciplinary Conference on Sinkholes and the Engineering and Environmental Impacts of Karst, San Antonio, Texas, September 2005.

Examples from the Edwards aquifer: using hydrocarbon resource assessment to understand an aquifer/using aquifer tests to understand hydrocarbon resources and Revision to TNRCC Guidance for Geologists Doing Geologic Assessments of the Edwards Aquifer Recharge Zone: presented to South Texas Geological Society, December 11, 2002.

Revision to TNRCC Guidance for Geologists Doing Geologic Assessments of the Edwards Aquifer Recharge Zone: presented to San Antonio College, November 20, 2002.

Revision to TNRCC Guidance for Geologists Doing Geologic Assessments of the Edwards Aquifer Recharge Zone: presented to Government Canyon, August 28, 2002.

Environmental assessment of your town—water, soils, rocks, and pollution: presented as short course to teachers: Conference for the Advancement of Science Teaching (CAST), College Station, TX, October 12-13, 2000.

Public Outreach

BEG virtual reality tour: presented to Whitte Museum staff, Austin, Texas, December 18, 2002.

Water for Texas (assisting Sigrid Clift with workshop): presented at the Conference for Advancement of Science Teaching, El Paso, Texas
Texas, November 7–9, 2002.

Aquifer-in-a-tank and sugar karst: presented at Environmental Science Institute Public Lecture Series, Austin, Texas, October 18, 2002.

Aquifer-in-a-tank: presented at the Aquarena Groundwater Festival, September 20, 2002.

Virtual reality and Bureau tour: presented to the Austin Nature and Science Center staff, Austin, Texas, September 4, 2002.

Introducing the Jackson School Geoscience Alliance: presented to Austin Geological Society, Austin, Texas, February 4, 2002.

Aquifer in a tank: presented at the Southwest Texas State University Groundwater Festival, Aquarena Springs, Texas, September 21, 2001.

GIS 101: Using a computer for environmental assessment: think globally work locally: presented to the River Basin Institute, Jefferson, Texas, August 2001.

GIS 101: Using a computer for environmental assessment: presented to Texas Earth Science Teachers Association, short course, Selah Bamberger Ranch, Johnson City, Texas, February 17, 2001.

Rocks from space: meteorites in the classroom: presented at Workshop Conference for the Advancement of Science Teaching (CAST) (with Roger Stryker and Dan Lester), College Station, Texas, October 14, 2000.

EarthView Texas: high-tech investigation of geology in your backyard: presented at Cyprus Valley Education Center, Jefferson, Texas, July 2000.

Bureau Professional Development Programs: presented to Conference for the Advancement of Science Teaching (CAST) Informal Science Association Showcase, Lubbock, Texas, October 1999.

K-12

All that glitters: demonstration presented at Zilker Geofest, Austin, Texas, August 12, 2006.

All that glitters: demonstration presented at Explore UT, Austin, Texas, March 4, 2006.

Tour through Edwards aquifer: presented at Explore UT, Austin, Texas, March 4, 2006.

All that glitters: demonstration presented at Explore UT, Austin, Texas, March 4, 2006.

Making of "Tour through the Edwards Aquifer" movies: presented at Explore UT, Austin, Texas, March 4, 2006.

Host for shadowing: three "COOL Week" studentsfrom Leander and Cedar Park High Schools, Austin, Texas, February 8–9, 2006.

One-on-one mentoring of high school students Trey Ballman, Jenna Kroman, Tanner Scheneward: Bureau of Economic Geology, Austin, Texas, 2006.

"Sugar karst" demonstration: presented at Cave Week, Austin, Texas, October 27, 2005.

Is dirt just dirt?: presented at CAST meeting, Corpus Christi, Texas, November 6, 2004.

Panning for pyrite: presented at CAST meeting, Corpus Christi, Texas, November 4, 2004.

Geoscience news on global warming: presented at CAST meeting, Houston, Texas, November 1, 2003.

New views of familiar places using GIS in the classroom: presented at CAST meeting, Houston, Texas, October 31, 2003.

Is Dirt Just Dirt Classroom Activity: Laurel Mountain Elementary, April 2003.

New views of familiar places—a GIS program for students: presented at the Conference for Advancement of Science Teaching (CAST), Austin, Texas, November 7–9, 2002.

New views of familiar places short course, Region XIII training: presented to the Round Rock ISD, Round Rock, Texas, June 26–27, 2002.

New views of familiar places—a GIS program for students: presented at the 18th Annual GIS Conference, Education Session, Austin, Texas, February 1, 2002.

Zoom into the environment: presented at a workshop Conference for the Advancement of Science Teaching (CAST), November 2, 2001.

Geoscience looks at global warming: presented at Earth Science Week Career Fair, 7th grade, Austin, Texas, October 9, 2001.

Aquifer in a tank: presented at the Eanes Elementary School Science Night, Austin, Texas, March 27, 2001.

Disaster masters—using GIS in the classroom: presented at Austin Science Fun Day, Parkside Community School, Austin, Texas, March 3, 2001.

Geoscience projects and virtual field trips for K-12 teachers: presented to Department of Geological Sciences Public Outreach program, The University of Texas at Austin (with Sigrid Clift), Austin, Texas, September 15, 2000.

Aquifer in a Tank: presentation of hands-on 4th grade experiment to Earth Camp, City of Austin environmental education training program for teachers, October 1999.

Aquifer in a Tank: presentation of hands-on 4th grade experiment for filming by Texas Education Agency “Eye on Earth” program, 1999.

Field Trips

Leader, Frio Brine Pilot: MIBRAG group, Anhanlt-Saxony, Germany, Dayton, Texas, November 2005.

Leader, Frio Brine Pilot: Toyota site tour, Dayton, Texas, 2004.

Leader, Frio Brine Pilot: Regional Sequestration Partnership Working Group on Geologic Storage, Dayton, Texas, October 2004.

Leader, Frio Brine Pilot: Community and stakeholders tour, Dayton, Texas, October 2004.

Leader, Evolution of conduits in the Edwards Group (and field trip to Edwards outcrops): presented at U.S. Geological Society Fracture Workshop, San Antonio, Texas, September 2002.

Congressional, Legislative, and Special Committee Testimony

January 25, 2007

U.S. Senate Committee on Energy and Natural Resources, Introduction to geologic sequestration of CO2.

2006

National Academy of Science Committee, Earth resources in "Overview of Carbon Storage Field Projects," Washington, DC, April 6.

THE LAKE CHARLES CCS PROJECT
PHASE 1 TOPICAL REPORT

APPENDIX 11

Non-Proprietary Programmatic and Technical Prospectus (Fact Sheet)

Fact Sheet category identification: **Project Facts**
NETL program/product identification: **Industrial Carbon Capture and Sequestration (ICCS)**

Leucadia Energy, LLC: Lake Charles Carbon Capture & Sequestration Project

Background

Carbon dioxide (CO_2) emissions from industrial processes have the potential to contribute to global climate change. Advancing development of technologies that capture and store or beneficially reuse CO_2 that would otherwise reside in the atmosphere for extended periods is of great importance. Carbon capture and storage (CCS) technologies offer great potential for reducing CO_2 emissions and mitigating global climate change without adversely influencing energy use or hindering economic growth.

Under the Industrial Carbon Capture and Sequestration (ICCS) program, the U.S. Department of Energy (DOE) is partnering with industry to demonstrate the next generation of technologies that will capture CO_2 emissions from industrial sources and either sequester those emissions, or beneficially reuse them. The technologies included in the ICCS program represent advanced CCS projects that are ready for operation at a demonstration scale. Once demonstrated, the technologies can be readily deployed at a commercial scale.

Project Description

The DOE selected Leucadia Energy, LLC to receive ICCS program funding through the American Recovery and Reinvestment Act (ARRA) of 2009, for its Lake Charles CCS Project. The ICCS project will demonstrate the capture of CO_2 from a Lake Charles industrial facility for use in an independent enhanced oil recovery (EOR) application. The industrial source of CO_2 will be a petcoke-to-chemicals (methanol and other by-products) plant being developed by Lake Charles Cogeneration LLC (a Leucadia Energy, LLC affiliate) in Lake Charles, Louisiana. Once the CO_2 is captured, it will be purified to remove contaminants and compressed to a pressure suitable for commercial pipeline transport to oil fields in Texas and Louisiana for EOR. The project will also implement a comprehensive monitoring, verification, and accounting (MVA) program to confirm the long-term sequestration of a minimum of one million tons per year of the injected CO_2 at the Hastings and/or Oyster Bayou oil fields.

The project will employ a two-phase approach. During Phase 1, Leucadia Energy, LLC and its team will complete a feasibility study of the CO_2 compression systems to be utilized and conduct a study of the comprehensive MVA program that will be implemented in Phase 2. As part of this process, the team will work towards completing a Phase 2 application in 2010 to seek

CONTACTS

Brad Tomer
Director
Office of Major Demonstrations
National Energy Technology Laboratory
3610 Collins Ferry Road
P.O. Box 880
Morgantown, WV 26507-0880
Phone: (304) 285-4692
brad.tomer@netl.doe.gov

Charles Miller
Project Manager
National Energy Technology Laboratory
626 Cochrans Mill Road
P.O. Box 10940
Pittsburgh, PA 15236-0940
Phone: (412) 386-5745
charles.miller@netl.doe.gov

Hunter Johnston
Participant Project Manager
Leucadia Energy, LLC
New York, NY 10010-3649
Phone: (202) 429-6404
hjohnston@steptoe.com

PROJECT TEAM

Denbury Onshore, LLC
Black & Veatch Corporation
University of Texas Bureau of Economic Geology

PROJECT DURATION (PHASE 1)

Start Date
11/16/2009

End Date
06/16/2010

COST (PHASE 1)

Total Project Value
$600,182

DOE/Non-DOE Share
$390,103/ $210,079

continued funding for the project's construction and early operations. If selected for Phase 2, the project will involve construction of CO_2 compression, pipeline, and monitoring infrastructure followed by the operation of a system to capture, transport, and sequester CO_2 through EOR. A comprehensive MVA program to monitor the injected CO_2 will then be implemented.

Goals/Objectives

The project goal is to advance CCS technologies from the demonstration stage to commercial viability. The project objective is to demonstrate an integrated system of industrial scale CO_2 capture, compression, and sequestration for EOR beneficial reuse.

Benefits

The project will result in the large-scale recovery, purification and compression of more than 4 million tons of CO_2. The sale of CO_2 from the ICCS project for use in independent EOR operations by Denbury affords a cost effective means to increase domestic oil production while using advanced gasification technology to reduce the release of CO_2. On a global scale, petroleum coke currently being exported from the U.S. to regions where little if any environmental controls are required or implemented, will now be used in a domestic chemical project that achieves superior environmental performance and captures CO_2 for beneficial use.

With the completion of the Green Pipeline by Denbury and an affiliate, naturally occurring CO_2 taken from the Jackson Dome in Mississippi will be used for enhanced oil recovery in oil fields in Texas and Louisiana. CO_2 from the project that is compressed and delivered to the Green Pipeline will represent approximately 25 percent of the daily amount of CO_2 that Denbury will use in these oil fields. By using the anthropogenic CO_2 from the Lake Charles plant, Denbury will be able to reduce the amount taken from the Jackson Dome and prolong the life of this naturally occurring source of CO_2 Additionally, a comprehensive MVA program will be implemented in the Hastings and/or Oyster Bayou oil fields that will confirm the long-term sequestration of injected CO_2 in the EOR project application.

The infrastructure developed by the ICCS project could potentially enable other industrial and power plant CO_2 sources in the Lake Charles industrial community to commercially dispose of CO_2 in Gulf Coast EOR operations. Expansion of EOR in the Gulf Region will promote greater energy security by expanding domestic energy supplies. The Lake Charles gasification facility and CCS project alone are expected to provide up to 1,100 construction jobs and 200 permanent operation jobs, as well as millions of dollars in severance taxes and royalties to the States of Louisiana and Texas.

Diagram of the Lake Charles CCS Project