FINAL PROJECT REPORT

Submitted to DOE

July 31, 2017

Advanced Reactor Site Feasibility Evaluation[1]

U.S. Department of Energy

DE-NE-0000531

DUNS # 078466269

NGNP Industry Alliance Limited

NGNP Industry Alliance

Clean, Sustainable Energy for the 21st Century

Project Team Members:

Southern Company

AREVA forward-looking energy

US ULTRA SAFE NUCLEAR

UT PB

SODI SOUTHERN OHIO DIVERSIFICATION INITIATIVE

HEI HighExpectations INTERNATIONAL LLC

Mark Haynes
Executive Director
NGNP Industry Alliance Limited
P.O. Box 3987
Bay Saint Louis, MS 39521
Phone: 202-617-1687
Haynes@concordiapower.us

Martin Owens
Project Manager/Principal Investigator
AREVA Federal Services LLC
7207 IBM Drive
Charlotte, NC 28262
Phone: 704-805-2864
Martin.Owens@areva.com

[1] While the NGNP Industry Alliance Limited supports research and development of any technology that can deliver emission-free energy and lessen the reliance on fossil fuels, the Alliance member organizations understand that the work products generated from this site feasibility evaluation do not constitute a commitment from the DOE to locate an advanced reactor at any or all of the four sites proposed herein. This site feasibility report documents that the four sites proposed are used only as proxy sites for technical feasibility study and that there are no agreements with or plans by DOE to locate such a plant at these sites.

Martin Owens
Project Manager

AREVA-17-01827

July 31, 2017

Mr. Carl Sink
Advanced Reactor Deployment Program Manager
DOE, Office of Nuclear Energy, NE-52
1000 Independence Ave., SW
Washington, DC 20585-1290

Subject: **DE-NE0000531, DUNS# 078466269, NGNP Industry Alliance Limited, Advanced Reactor Site Feasibility Evaluation Project**

Reference 1: Advanced Reactor Site Feasibility Evaluation Project, NGNP Alliance Contract Agreement 10000023 / DOE Contract No. DE-NE-0000531

Dear Mr. Sink:

On the behalf of the NGNP Industry Alliance, AREVA hereby submits the Final Report deliverable in accordance with Reference 1. This report incorporates your comments on the draft report received on July 27.

Thank you in advance for your consideration of this information and please contact me if you have questions.

Sincerely,

Martin Owens
Project Manager

Attachment: NGNP Alliance Final Report deliverable to DOE

cc:

DOE:	John Yankeelov, Jo-Anne Hanners
NGNP Alliance:	J. Mahoney
USNC:	C. Hamilton, M. Richards
AREVA Inc.:	K. Stein, H. Elder, T. Messier, M. Parece, E. Moreno
SNC:	M. Montz, Amir Afzali
SODI:	S. Shepherd, J. Morgan
UTPB:	J. Wright
Concordia Power:	M. Haynes

AREVA INC.
3315 Old Forest Road, Lynchburg, VA 24501
Tel.: 434-832-3000 www.areva.com

AREVA Inc.

ENGINEERING INFORMATION RECORD

Document No.: 51 - 9272172 - 000

NGNP Advanced Reactor Site Feasibility Evaluation – Final Report

Safety Related? ☐ YES ☒ NO

Does this document establish design or technical requirements? ☐ YES ☒ NO

Does this document contain assumptions requiring verification? ☐ YES ☒ NO

Does this document contain Customer Required Format? ☐ YES ☒ NO

Signature Block

Name and Title/Discipline	Signature	P/LP, R/LR, M, A-CRF, A	Date	Pages/Sections Prepared/Reviewed/ Approved or Comments
Theodore A. Messier Principal Scientist	*TA MESSIER* *7/27/2017*	LP		All
Barbara Hubbard Advisory Engineer	*BY HUBBARD* *7/27/2017*	LR		All
Justin Byard First Line Leader	*JN BYARD* *7/27/2017*	A		All

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R/LR designates Reviewer (R), Lead Reviewer (LR)
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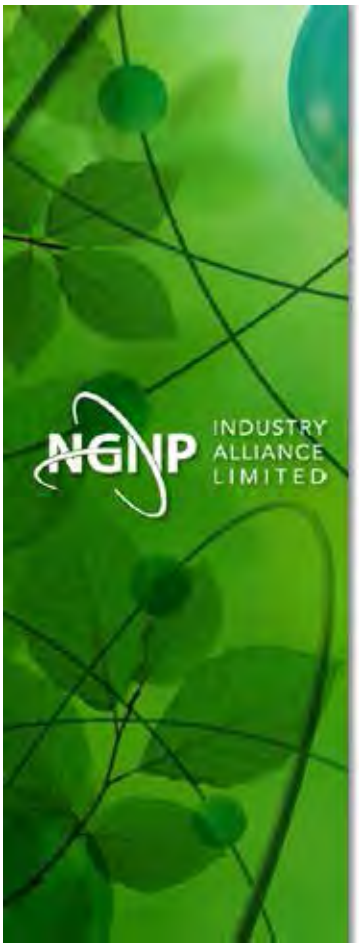
Project Manager Approval of Customer References (N/A if not applicable)

Name (printed or typed)	Title (printed or typed)	Signature	Date
N/A			

Record of Revision

Revision No.	Pages/Sections/ Paragraphs Changed	Brief Description / Change Authorization
000	All	Initial release

Final Report



Advanced Reactor Site Feasibility Evaluation

NGNP Alliance Contract Agreement 10000023
DOE Contract No. DE-NE-0000531

Martin Owens
Project Manager

Approved for Release:

John Mahoney
Project Oversight, NGNP Industry Alliance Limited

Executive Summary

Preliminary site feasibility evaluations were conducted for four proxy sites that bound representative locations within the United States of America:

- Northeast site (Piketon, OH);
- Southeast site (Utility Site, GA);
- Southwest site (Odessa / Midland, TX);
- Northwest site (Red Leaf Seep Ridge Block Site, UT).

Three advanced reactor technologies were also reviewed as a part of the feasibility study and included the Modular High Temperature Gas Reactor (HTGR) / MHR, GE PRISM Sodium Fast Reactor / SFR, TerraPower Molten Salt Reactor / MSR.

Business cases were developed encompassing opportunities for end-user electric generation and industrial process heat applications as determined by geo-economic factors and potential site use. The sites ranged from remote greenfield locations to previously industrialized brownfield settings that are available for reuse.

As a part of the siting study, a framework was developed to include: identification of the technology parameters to be assessed (based upon plant parameter envelope approach used in early site permit applications); business case development format and content objectives that define screening criteria and methodology for qualitative assessment and quantitative ranking for advanced reactor deployment; and exclusionary criteria as a basis for technical acceptance as a feasible option for siting. Site information and business opportunities were collected, compiled and evaluated to identify potential and siting feasibility of the proxy sites.

Preliminary site feasibility evaluations were completed on all four sites with none excluded based upon the framework and technologies within the scope. Resulting business cases can be used to further discussion with stakeholders such as local, state, and federal government, potential investors, industrial partners, and nuclear utilities and vendors.

The following are summary results of the site-specific evaluations for the four proxy sites (order based on quantitative analysis of MHR technology; locations shown on Figure 1-1):

Figure 1-1: Location of Four Proxy Sites

Northeast site (Piketon, OH)

Potential Use: Hydrogen Production (H_2)

Exclusion Evaluation: No criteria were identified to exclude the Northeast site.

The study and analysis indicate that this site is conducive to industrial processes for high temperature heat and cogeneration use. The reactor will integrate with an on-site generator and steam methane reformer to:

- Produce electricity for on-site use by the Demonstration Plant and sale to potential customers;
- Produce hydrogen for use in transportation fuels, polymers, plastics, fertilizer, and H_2 fuel cell market;
- Provide low temperature heat which could support utility processes on the site; and
- Produce CO_2 that could have potential off-site markets within the region.

For the evaluated business case, an existing natural gas pipeline is used. The generated H_2 would be piped to a refinery in Catlettsburg, Kentucky.

The feasibility analysis indicates that this site has the highest near-term potential for an advanced nuclear reactor siting based upon previous use, community redevelopment efforts, and the business case.

Figure 1-2: Northeast Site – Piketon, OH

Southeast site (Utility Site, GA)

Potential Use: Commercial Electricity Generation

Exclusion Evaluation: No criteria were identified to exclude the Southeast site.

The study and analysis indicate that the advanced reactor would be used primarily for electricity generation. Georgia Power Company filed its most recent integrated resource plan with the Public Service Commission in January of 2016. The first year of capacity need is 2024.

The site is a brownfield site of a retired coal fired power plant. This brownfield site offers easy access to existing critical infrastructure such as roads, rail, water and remaining transmission corridors.

The feasibility analysis indicates that this site has the second highest near-term potential for an advanced nuclear reactor siting based upon previous use as a power plant and the existing infrastructure including transmission access and resource plans filed for future use.

Figure 1-3: Southeast Site - Utility Site, GA*

*Before decommissioning.

Southwest site (Odessa / Midland, TX)

Potential Use: Petroleum Refinery / Fracking Water Cleanup

Exclusion Evaluation: No criteria were identified to exclude the Southwest site.

Initially, it was envisioned that the reactor process heat could be used for cleaning fracking water; however, it was determined that this single application would be a challenging business case. The study and analysis indicate that the advanced reactor could also be used in petroleum refining, process steam, hydrogen production, and electricity generation.

A multi-use business case approach is likely required for a positive business plan of the size and complexity for demonstration or full-size production.

Tentatively, bonds for water cleanup may be available in the amount of $1B+ at an interest rate of approximately 5% versus a normal commercial interest rate of 8-9%. This would provide an enormous potential boost to commercial viability.

The Southwest site has potential hazards that would require evaluation before licensing. A potential water source is the subterranean local aquifer. The current distance from the site to either a 230-kV or a 345-kV transmission line has not been determined. There is potential for a future transmission line approximately 15 miles from the site.

The feasibility analysis indicates that this site has the third highest potential for an advanced nuclear reactor siting and would require additional industrial use with a business case to make this a viable opportunity.

Figure 1-4: Southwest Site – Odessa / Midland, TX

Northwest site (Red Leaf Seep Ridge Block Site, UT)

Potential Use: Shale Oil Recovery

Exclusion Evaluation: No criteria were identified to exclude the Northwest site.

The study and analysis indicate that this site, due to its location, is conducive to use of high temperature heat from an advanced reactor for shale oil recovery.

The site is located on the Uintah and Ouray Indian Reservation, just outside the boundary of the tribal lands. The site is very remote and undeveloped with significant infrastructure requirements. The analysis indicates that a business case for nuclear deployment requires an expanded use business plan that involves a large-scale refinery to utilize the hydrogen, methane, and other hydrocarbon byproduct gasses from shale oil recovery.

The feasibility analysis indicates that this site has the lowest near-term potential for an advanced nuclear reactor siting based upon the large infrastructure investment and undeveloped location.

Figure 1-5: NW Site – Red Leaf Seep Ridge Block Site, UT[1]

[1] Figure 1-5 (above) and Figure 1 on page C-5 show the site while it was under construction – the site is no longer under construction.

Table of Contents

Page

List of Tables

Page

List of Figures

Page

List of Acronyms

Acronym	Definition
CFR	Code of Federal Regulations
DOE	Department of Energy
EA	Exclusion Area
EAB	Exclusion Area Boundary
EBR-II	Experimental Breeder Reactor - II
EIS	Environmental Impact Statement
EP	Emergency Planning
EPRI	Electric Power Research Institute
EPZ	Emergency Planning Zone
ERCOT	Electric Reliability Council of Texas
ESP	Early Site Permit
FEMA	Federal Emergency Management Agency
FOAK	First of a Kind
GDP	Gaseous Diffusion Plant
GE	General Electric
GNEP	Global Nuclear Energy Partnership
GPC	Georgia Power Company
HEI	High Expectations International LLC
HTGR	High Temperature Gas Reactor
INL	Idaho National Laboratory
LPZ	Low Population Zone
MHR	Modular High Temperature Gas Reactor
MSR	Molten Salt Reactor
NGNP	Next Generation Nuclear Plant
NIA	NGNP Industry Alliance
NOAK	Nth of a Kind
NRC	Nuclear Regulatory Commission
PE	Probability of Exceedance
PGA	Peak Ground Acceleration
PPE	Plant Parameter Envelope
SFR	Sodium Fast Reactor
SODI	Southern Ohio Diversification Initiative
TPE	Technology Parameter Envelope
TRISO	Tristructural-isotropic
USEC	United States Enrichment Corporation
USNC	Ultra Safe Nuclear Corporation
UTPB	University of Texas of the Permian Basin
WMA	Wildlife Management Area

1.0 INTRODUCTION

This study was performed by the Next Generation Nuclear Plant (NGNP) Industry Alliance Limited as a 50 / 50 cost share to the U.S. Department of Energy (DOE) under DE-NE-0000531. Cost share was in the form of in-kind labor-hours and expenses to support this study.

The goal of this study is to evaluate the viability of investment in a demonstration unit at a site (or sites) including demonstration of the utilization of process heat[2].

The objective was to conduct preliminary site feasibility evaluations for four sites that bound representative U.S. advanced reactor types (Modular HTGR / MHR, GE PRISM Sodium Fast Reactor / SFR, TerraPower Molten Salt Reactor / MSR). Proxy sites, one in each quadrant of the U.S., were pre-selected as representative for potential deployment of a demonstration plant:

- Northeast site (Piketon, OH);
- Southeast site (Utility Site, GA);
- Southwest site (Odessa / Midland, TX);
- Northwest site (Red Leaf Seep Ridge Block Site, UT).

AREVA was selected by the NGNP Industry Alliance Limited to provide project management, as well as to perform some technical work. Other Alliance members include:

- Ultra Safe Nuclear Corporation (USNC);
- High Expectations International (HEI) LLC;
- Southern Nuclear Company (Southern);
- Southern Ohio Diversification Initiative (SODI);
- University of Texas of the Permian Basin (UTPB).

The project is divided into five major technical tasks as follows:

- Technology Parameter Envelope (TPE) and Format Development (Task 1)
  - Developed a list of critical technology parameters from representative advanced (Generation IV) reactor designs appropriate for a site screening / site suitability study.
  - The plant parameter envelope (PPE) approach includes reactor requirements and usable power / heat attributes.
  - Developed bounding values for the critical technology parameters.
- Business Case Format Development (Task 2)

[2] While the NGNP Industry Alliance Limited supports research and development of any technology that can deliver emission-free energy and lessen the reliance on fossil fuels, the Alliance member organizations understand that the work products generated from this site feasibility evaluation do not constitute a commitment from the DOE to locate an advanced reactor at any or all of the four sites proposed herein. This site feasibility report documents that the four sites proposed are used only as proxy sites for technical feasibility study and that there are no agreements with or plans by DOE to locate such a plant at these sites.

- Provides a high level quantitative assessment / ranking for potential deployment of an advanced reactor demonstration plant.
- Defines the screening criteria and methodology.
- Includes some limited financial pro forma assessment.

- Exclusionary Criteria Development (Task 3)
  - Preliminary site exclusionary criteria developed for the potential deployment of an advanced reactor demonstration plant.
  - Preliminary site discretionary criteria developed.
- Site Information Compilation (Task 4)
  - Site information collected.
  - Business opportunities explored.
  - Conceptual business case developed.
- Comparison of Site-Specific Information to Exclusionary Criteria – Final Report (Task 5)
  - Northeast site (Piketon, OH);
  - Southeast site (Utility Site, GA);
  - Southwest site (Odessa / Midland, TX);
  - Northwest site (Red Leaf Seep Ridge Block Site, UT).

2.0 METHODOLOGY

2.1 Technology Parameter Envelope – Task 1

The development of a technology parameter envelope was based on the plant parameter envelope approach used in some early site permit (ESP) applications. A PPE is a set of values of plant design parameters that an ESP applicant projects will bound the design characteristics of a reactor or reactors that might be constructed at a given site, and it serves as a surrogate for actual reactor design information (Reference [1]).

The vendors of the three reactor designs were asked to provide information needed to develop the TPE. AREVA provided information on the MHR, General Electric-Hitachi provided information on the SFR, and TerraPower provided information on the MSR. After receiving input from each vendor and evaluating the available data, the TPE was further modified to include only those parameters for which information was available. The availability of the requested information was limited, to an extent, due to the variability and relative stages of development of these designs. Therefore, the information referenced in this TPE should be considered preliminary and subject to change as each design continues to be advanced and refined.

Bounding values across reactor types were combined in the TPE.

2.2 Business Case Format Development – Task 2

A template was developed for the generalized business case evaluation. This template defines the screening criteria and methodology and provides a high-level quantitative assessment / ranking for potential deployment of an advanced reactor at an arbitrary site within the envelope of the proxy sites. It

includes the basis for the individual ratings for each category / subcategory. The methodology assigns percentage weighting values to each of the screening categories / subcategories.

The template was based on existing materials and studies, including:

- The Next Generation Nuclear Plant (NGNP) Industry Alliance (NIA) Business Plan for Commercialization (Reference [2]).
- Marketing analyses performed by the NIA under previous DOE-funded contract phases (References [3], [4]).
- Siting studies performed by Idaho National Laboratory (INL) for Modular HTGR (MHR) applications (References [5], [6]).
- Studies performed under the Nuclear Energy Research Initiative for assessing deployment of a hydrogen-production MHR at the Savannah River National Laboratory to supply hydrogen to a nearby ammonia production plant (References [7], [8]).
- Legacy studies performed by General Atomics under DOE funding (Reference [9]).

The model used in the NIA Business Plan (Reference [2]) for the MHR had the most quantitative information currently available and was used as the basis for defining cost. At a high level, demonstration module / plant costs can be split into a Development Venture followed by a Deployment Project. These costs are dependent on the technological maturity of the advanced reactor under consideration.

The scope of the Development Venture includes the following:

- Complete design;
- Complete technology development;
- Establish licensing and regulatory requirements;
- Develop equipment supply chain;
- Development of special instrumentation and design features;
- Commitment for initial energy use applications.

The scope of the Development Project includes the following:

- Complete site-specific design;
- Obtain site Nuclear Regulatory Commission (NRC) license and regulatory permits;
- Procure equipment and construct initial demonstration module;
- Startup and testing;
- Perform initial operations.

2.3 Exclusionary Criteria Development – Task 3

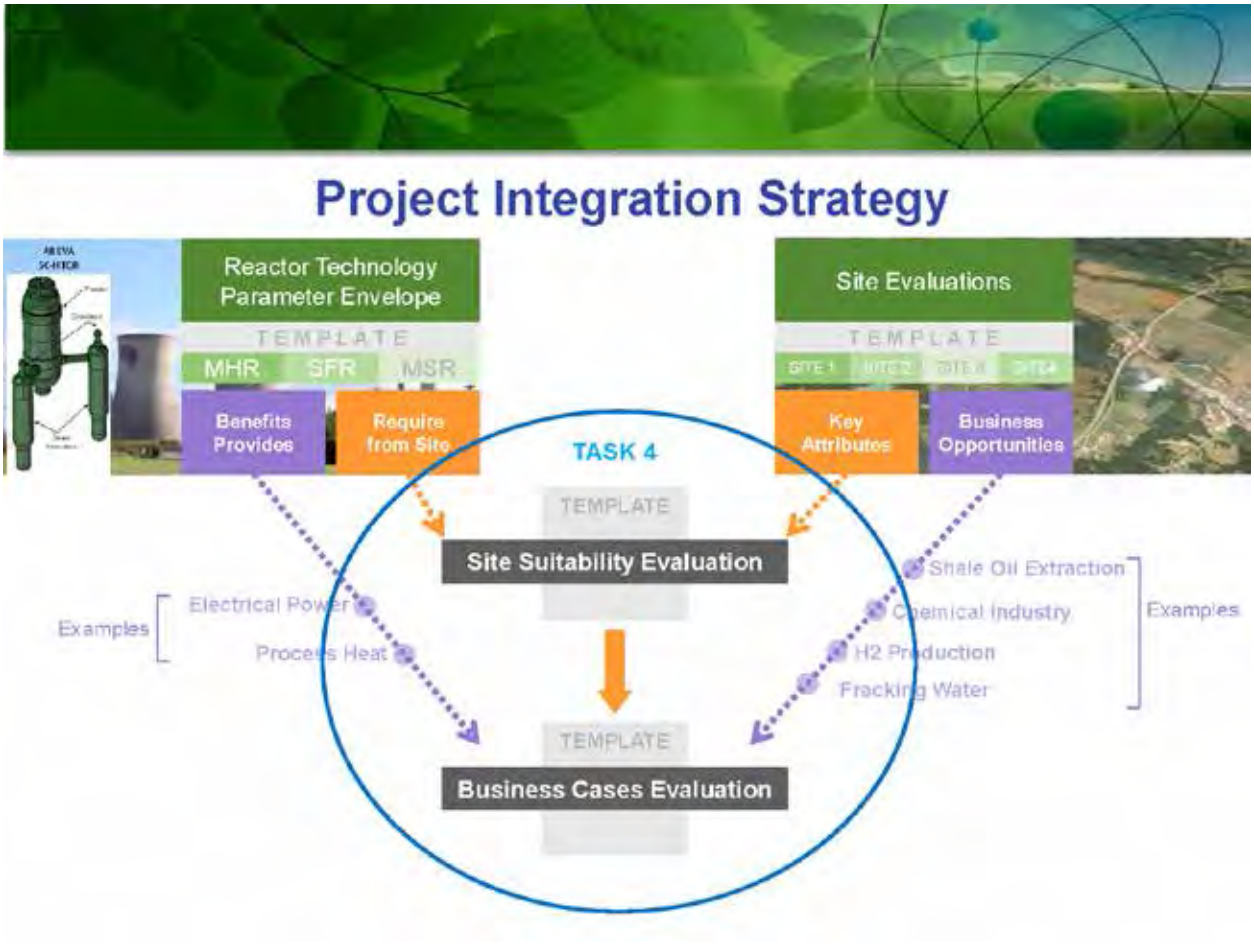
The goals of the Generation IV nuclear plants and Electric Power Research Institute (EPRI) siting guidance (Reference [10]) were considered in the development of exclusionary criteria. The EPRI siting guidance was not followed explicitly because it was not designed specifically for Generation IV reactors. Some criteria that were used to exclude a site for Generation III plants may not be needed, or may be much different, for Generation IV plants. It was proposed that these criteria be designated as discretionary criteria. This information should be gathered and used as part of the business case for potential sites.

2.4 Site Information Compilation – Task 4

Site information was collected and business opportunities were explored to aid in the development of conceptual business cases.

A graphic depicting the integration strategy is presented on Figure 2-1.

Figure 2-1: Project Integration Strategy



2.5 Comparison of Site-Specific Information to Exclusionary Criteria – Task 5

The site-specific information was compared to the exclusionary criteria and a determination was made whether any of the four proxy sites should be excluded from consideration. The potential use of the reactor at each site was determined.

3.0 EVALUATION OF RESULTS

3.1 Technology Parameter Envelope – Task 1

A list of critical technology parameters was developed using information from advanced reactor designs currently under development (Reference [11]). The technology parameters selected are based on available information for each reactor's current design phase and of sufficient detail to be appropriate for

a site screening / site suitability study. The NGNP Industry Alliance collectively provided input on the development of the TPE to ensure inclusion of all relevant parameters.

Once determined, the bounding values from the critical technology parameters from each reactor design were combined into the TPE. This TPE serves as a site screening tool and can be used to compare, at a high level, various sites and assist in determining their suitability as nuclear candidate sites for multiple reactor technologies. Sites meeting the parameters of the TPE demonstrate increased potential to support construction and operation of the selected reactor designs.

The TPE is presented in Table 3-1. More information on the development of the TPE can be found in Reference [11].

Critical Technology Parameters

Seismic / Soil Properties

The seismic characteristics of a potential site are used to determine the plants' ability to survive a seismic event and ability to perform its safety related functions. Standard plant designs shall have analysis performed to determine the maximum design event it can survive and this bounding parameter can be used for the site screening selection. The properties of note are:

- Peak ground acceleration (PGA);
- Minimum bearing capacity;
- Minimum shear wave velocity;
- Maximum depth of construction.

Peak ground acceleration is the maximum earthquake ground acceleration for which a plant is designed. Minimum bearing capacity is the design criteria regarding the capacity of the competent load-bearing layer required to support the loads exerted by plant structures used in the plant design. It is also an important consideration for construction loading that may be experienced if heavy lift cranes are utilized. The minimum shear wave velocity is the baselined limiting propagation velocity of shear waves through the foundation materials used in the plant design. It provides an indication of the severity of the expected shaking in response to an earthquake. Maximum depth of construction is the anticipated depth, from final plant grade, of the lowest plant related structure / foundation. Depth of construction, and the corresponding depth to the load bearing layer, determine the quantities of native material needing removal and, potentially, the quantity of backfill needed to support building foundations.

Emergency Planning / Dose

NRC regulations (10 Code of Federal Regulations (CFR) 52.10 and 10 CFR 52.79 – References [12] and [13]) require consideration of the time required to evacuate, and take other protective actions, for various sectors and distances within the emergency planning zone (EPZ) for transient and permanent populations. Per NRC Regulatory Guide 4.7 (Reference [14]), the recommended EPZ should be evaluated to determine the potential for physical characteristics of the site and surrounding area (within the EPZ) to hinder implementation of an emergency plan (plant evacuation).

A reactor licensee is required by 10 CFR 100.21(a) (Reference [15]) to designate an exclusion area and to have authority to determine all activities within that area, including removal of personnel and property. In accordance with 10 CFR 50.34(a)(1)(ii)(D)(1) (Reference [16]), 10 CFR 52.17(a)(1)(ix)(A) (Reference [17]), and 10 CFR 52.79(a)(1)(vi)(A) (Reference [12]), the exclusion area is required to be of such a size that an individual assumed to be located at any point on its outer boundary would not receive a radiation

dose in excess of 25 rem total effective dose equivalent over any two-hour period following a postulated fission product release.

Construction and Operation

This category can be broken down as follows:

- Construction duration;
- Site size requirements;
- Largest component delivered;
- Plant design life;
- Station capacity factor;
- Megawatts thermal / electric;
- Flexibility of operations.

Construction durations are important considerations for construction financing and should target as short a construction schedule as feasible. Construction 'start' is defined as the placement of the first safety-related concrete and construction 'end' is defined as fuel load. If used for non-generation purposes, the timeline for construction of facilities to use the process heat may factor into the technology selected. Constructability and supply chain capabilities should be considered early in the site process.

Site size for construction is estimated including laydown area(s), temporary construction facilities, and construction parking along with the acreage needed for the plant itself. The acreage needed to support plant operations includes office facilities, parking lots, permanent support facilities, power block and protected areas, cooling towers, and spent fuel storage, if applicable. This acreage should also account for any required buffer zone.

Available transportation options for a selected site are important because large and heavy components and commodities will require a feasible delivery path. This parameter takes into account the estimated weight, in tons, (and dimensions in feet, if known) of the largest component to be delivered.

The plant design life is the anticipated design life, in years, of the facility.

The station capacity factor is the percentage of time that a plant is capable of providing power to the grid. A high capacity factor is important to the financial viability of the technology. The percentage of time that a plant is capable of providing process heat is an important consideration.

The thermal and electrical output of the plant is expressed in units of megawatts.

The adaptability of the facility for responding to load demand (load following) can be an important siting consideration when employing these technologies for providing process heat.

Process Heat Interface

For locations where process heat and / or steam are a desired output, the feasibility of accomplishing this in a cost effective manner must be analyzed. There are logistical limitations to providing process heat and / or steam, especially if the customer's facilities cover large areas of land. Information provided by the end user should be used to compare against design features of the reactor type and the site location relative to the end use location.

For sites requiring process heat and / or steam the evaluator must consider the distance and traverse path for getting the product to the desired location at the required design conditions.

With regards to the process heat interface, important technology limitations to consider in the siting process include:

- Temperature range;
- Pressure;
- Proximity to interface;
- Process heat medium.

Table 3-1: Technology Parameter Envelope

*Only one vendor provided information **Two vendors provided information
A = AREVA GEH = GE Hitachi TP = TerraPower

Report Section	Parameter	Value	Units	Bounding Technology	Notes
2.1.1	Seismic / Soil Properties				
2.1.1.1	Peak Ground Acceleration	0.3	g	A / TP	
2.1.1.2	Minimum Bearing Capacity	833	psi	TP	
2.1.1.3	Minimum Shear Wave Velocity	8000	fps	TP	Note the 8000 fps value, provided by TerraPower, is significantly higher than the 1000 fps provided for the other considered technologies and is consistent with the requirements for a rock site. In this instance, 1000 fps (for a soil site) should be the bounding value.
2.1.1.4	Maximum depth of construction	100	ft	A**	
2.1.2	Emergency Planning / Dose				
2.1.2.1	Recommended Emergency Planning Zone	2	miles	TP	Site boundary
2.1.3	Construction and Operation				
2.1.3.1	Construction Duration	5	yrs	TP**	
2.1.3.2	Site Size Requirements				
	Acreage Needed – Construction	55	acres	A**	Including Laydown, Temporary Construction Facilities, Construction Parking, Crane area, etc.
	Acreage Needed – Plant	31	acres	A	Including Office Facilities, Parking Lots, Permanent Support Facilities, Power Block, Protected Area, Cooling Towers, & Spent Fuel Storage, if applicable, etc.
2.1.3.3	Largest Component Delivered	1500	tons	GEH	Estimated weight of largest component (e.g. final assembly weight of the reactor vessel, containment vessel, closure head, and the fixed internals structures).
2.1.3.4	Plant Design Life	60	yrs	all	
2.1.3.5	Station Capacity Factor	87	%	GEH	

*Only one vendor provided information **Two vendors provided information A = AREVA GEH = GE Hitachi TP = TerraPower					
Report Section	**Parameter**	**Value**	**Units**	**Bounding Technology**	**Notes**
2.1.3.6	Megawatts Thermal / Electric	625/272	MWt/e	A	
2.1.3.7	Flexibility of Operations				Capability of load following
	Reactor operations	Capable		all	
	Secondary side operation	Capable		A / GEH**	
2.1.4	Process Heat Interface				Potential application of the plant for industrial (non-power) uses
2.1.4.1	Temperature range	150-1472	°F	A(low) / TP(high)	Site dependent but lower temperatures available.
2.1.4.2	Pressure	1800-2250	psia	GEH**	Site dependent but lower pressures available.
2.1.4.3	Proximity of the interface	≥ 1313	ft	A**	Measured between steam generator centerline and vehicle barrier to protected area.
2.1.4.4	The medium of the process heat	Steam		A / GEH**	e.g., steam, gas, salt

3.2 Business Case Format Development – Task 2

Four major evaluation categories and several sub-categories were used to rate / score pertinent advanced reactor designs (Reference [18]):

1. Reactor Technology Considerations
   - 1.1. Technology Readiness
   - 1.2. Fuel Qualification
   - 1.3. Safety Considerations
   - 1.4. Process Heat Capability
   - 1.5. Energy Efficiency
   - 1.6. Fuel Cycle Considerations
2. Economics and Commercialization Potential
   - 2.1. U.S. Market Potential
   - 2.2. International Market Potential
   - 2.3. Demonstration Module / Plant Costs
   - 2.4. N^{th} of a Kind (NOAK) Commercial Plant Costs
   - 2.5. Potential for International Collaboration on Reactor Technology
   - 2.6. Impacts on Local Economy
3. Licensing Considerations
4. Site Considerations
   - 4.1. Technology Considerations
   - 4.2. Site-Specific Considerations

The recommended allocations for the evaluation categories are provided in Table 3-2.

Table 3-2 - Recommended Percentage Allocations for Evaluation Categories

Category/Subcategory	Percentage (%)
1. Reactor Technology Considerations	25
1.1 Technology Readiness	4
1.2 Fuel Qualification	4
1.3 Safety Considerations	7
1.4 Process Heat Capability	6
1.5 Energy Efficiency	4
1.6 Fuel Cycle Considerations	0
2. Economics and Commercialization Potential	35
2.1a Market Potential – U.S.	7
2.1b Market Potential – International	7
2.2 Demonstration Module / Plant Costs	3
2.3 NOAK Commercial Plant Costs	5
2.4 Potential for International Collaboration on Reactor Technology	5
2.5 Impacts on Local Economy	8
3. Licensing Considerations	15
4. Siting Considerations	25
4.1 Overall Technology Considerations	10
4.2 Site-Specific Considerations	15
Total	100

Cost from the NIA Business Plan (Reference [2]) for the MHR is presented in Table 3-3. Where appropriate, the cost elements given in Table 3-3 factor in assumed values for annual interest rate, fixed charge rate, indirect costs, and construction time period to account for the time cost of money. Appropriate values for these parameters will be needed if a formal business plan is developed for a particular advanced reactor at a specific site.

Table 3-3 – MHR Cost Estimate

Cost Element	$M (2012)
Development Venture	
Technology Development	245
Complete Preliminary Design	280
Complete Final Design	200
Licensing Activities	165
First Module Modifications for Initial Operations	75
Total – Development Venture	965
Deployment Project	
Site-Specific Design	100
NRC License and Regulatory Permits	65
Equipment Procurement (Including Long-Lead Items)	432
Construction	625
Startup and Testing	55
Initial Operations (3 Years)	348
Revenue (3 Years)	-265
Total – Deployment Project	1,360
Total – Development + Deployment for Demonstration Module	2,325

The costs for technology development are supplemental to the significant costs for MHR TRISO (Tristructural-isotropic) fuel and nuclear-grade graphite qualification that are currently funded by DOE. All of these cost elements are considered to be one-time costs to support development, design, demonstration, and eventual commercialization of an advanced reactor technology. These costs can be evaluated in the context of cost-share models that involve combined U.S. government and U.S. private industry participation, and can include potential cost share from international collaboration.

In terms of evaluating the SFR and MSR, engineering / economic judgments can be made in terms of multipliers on the cost elements provided in Table 3-3. The MSR may require significantly more additional technology development costs than the MHR or the SFR.

More information on business case template development and cost can be found in Reference [18].

A quantitative evaluation of the MHR was made. A rating of 1 (lowest) to 10 (highest) was applied to each category or subcategory. Since fuel cycle considerations are dependent upon national energy policy, no ratings were made. Qualitative remarks were made for the SFR and the MSR. A summary of this process is presented in Table 3-4 and Table 3-5.

Details of the ratings can be found in Appendix A through Appendix D.

Table 3-4 – MHR Reactor Ratings for Each Site

Category No.	Category	Comment	%	Piketon, OH (NE)		Southern Utility Site (SE)		Red Leaf Site, UT (NW)		Odessa, TX (SW)	
				H_2 Production		*Electricity Production*		*Recover Oil from Shale*		*Petroleum Refinery / Fracking Water Cleanup*	
				Rating	Total	Rating	Total	Rating	Total	Rating	Total
Reactor Technology Considerations											
1.1	Technology Readiness		4	6	24	6	24	6	24	6	24
1.2	Fuel Qualification		4	6	24	6	24	6	24	6	24
1.3	Safety Considerations		7	9	63	9	63	9	63	9	63
1.4	Process Heat Capability		6	8	48	8	48	8	48	8	48
1.5	Energy Efficiency		4	8	32	8	32	8	32	8	32
Economics and Commercialization Potential											
2.1a	Market Potential – U.S.	Based on future market competitiveness.	7	8	56	6	42	3	21	3	21
2.1b	Market Potential – International		7	9	63	7	49	4	28	4	28
2.2	Demonstration Module / Plant Costs		3	7	21	8	24	3	9	4	12
2.3	NOAK Commercial Costs	Not evaluated at this time – more work needed to determine these costs.	5	-	-	-	-	-	-	-	-
2.4	Potential for International collaboration on reactor technology	We believe international interest is more focused on reactor technology rather than business application.	5	9	45	8	40	7	35	8	40
2.5	Impacts on Local Economy		8	9	72	9	72	6	48	5	40
Licensing Considerations											
3	Licensing Considerations		15	9	135	8	120	5	75	6	90
Siting Considerations											
4.1	Technology Considerations	Technology is suitable for that site.	10	9	90	8	80	8	80	7	70
4.2	Site-Specific Considerations		15	9.5	142.5	8	120	4	60	5	75
		TOTAL			815.5		738		547		567

Table 3-5: Qualitative Remarks on SFR and MSR for Each Site

Category No.	Category	Piketon, OH (NE)		Southern Utility Site (SE)		Red Leaf Site, UT (NW)		Odessa, TX (SW)	
		H_2 Production		*Electricity Production*		*Recover Oil from Shale*		*Petroleum Refinery / Fracking Water Clean up*	
		SFR	MSR	SFR	MSR	SFR	MSR	SFR	MSR
Reactor Technology Considerations									
1.1	Technology Readiness	Approximately same TRL as MHR.	Much lower TRL than MHR and SFR. Much later deployment time frame.	Same	Same	Same	Same	Same	Same
1.2	Fuel Qualification	Approximately same or slightly lower rating than MHR.	Molten fuel may have significant challenges.	Same	Same	Same	Same	Same	Same
1.3	Safety Considerations	Loss of sodium coolant can lead to severe consequences.	Loss of molten fuel can lead to severe consequences.	Same	Same	Same	Same	Same	Same
1.4	Process Heat Capability	Current design is for electricity only. Lower coolant outlet temperature (~500°C) is less suitable for some process heat applications.	Current design is for electricity only. With its 800°C outlet temperature, design could be adapted for process heat applications.	Same	Same	Same	Same	Same	Same
1.5	Energy Efficiency	Lower thermal efficiency than MHR for electricity generation.	Somewhat higher thermal efficiency for electricity generation than MHR.	Same	Same	Same	Same	Same	Same
1.6	Fuel Cycle Considerations	Fast neutron spectrum allows for breeding fissile fuel. Operation in burner mode allows destruction of transuranics.	Insufficient information to assess fuel cycle considerations.	Same	Same	Same	Same	Same	Same
Economics and Commercialization Potential									
2.1a	Market Potential – U.S.	Co-location with other industries may prove challenging.	May share some of the same potential as MHR.	Well established domestic need and market acceptance for traditional electric	Well established domestic need and market acceptance for traditional electric	Co-location with other industries may prove challenging. Process heat is not	May share some of the same potential as MHR.	Co-location with other industries may prove challenging.	May share some of the same potential as MHR.

Category No.	Category	Piketon, OH (NE)		Southern Utility Site (SE)		Red Leaf Site, UT (NW)		Odessa, TX (SW)	
		H_2 Production		*Electricity Production*		*Recover Oil from Shale*		*Petroleum Refinery / Fracking Water Clean up*	
		SFR	MSR	SFR	MSR	SFR	MSR	SFR	MSR
		Lower coolant outlet temperature (~500°C) is less suitable for process heat applications.	Difficult to assess because of the low Technology Readiness Level compared to the MHR and SFR.	generation facilities. Regulated market, therefore reactor must be competitive with other generation technologies. Lower thermal efficiency for electric power generation.	generation facilities. Regulated market, therefore reactor must be competitive with other generation technologies. Difficult to assess because of the low Technology Readiness Level compared to the MHR and SFR.	an intrinsic design attribute. Additional geologic opportunities to recover oil from shale may be limited.	Difficult to assess because of the low Technology Readiness Level compared to the MHR and SFR.	Process heat is not an intrinsic design attribute.	Difficult to assess because of the low Technology Readiness Level compared to the MHR and SFR.
2.1b	Market Potential – International	Lower coolant outlet temperature (~500°C) is less suitable for some process heat applications. The technology is largely limited to nuclear states with significant export control restrictions. Other nuclear states have SFR design/technology programs that are more advanced than the U.S. program. The travelling wave sodium reactor under development is attempting to address the export control challenges.	May share some of the same potential as MHR. Difficult to assess because of the low Technology Readiness Level compared to the MHR and SFR.	Well established international need and market acceptance for traditional electric generation facilities. Lower thermal efficiency for electric power generation.	Well established international need and market acceptance for traditional electric generation facilities.	Lower coolant outlet temperature (~500°C) is less suitable for some process heat applications Additional geologic opportunities to recover oil from shale may be limited. The technology is largely limited to nuclear states with significant export control restrictions. Other nuclear states have SFR design/technology programs that are more advanced than the U.S. program. The travelling wave sodium reactor under	May share some of the same potential as MHR. Difficult to assess because of the low Technology Readiness Level compared to the MHR and SFR.	Lower coolant outlet temperature (~500°C) is less suitable for some process heat applications The technology is largely limited to nuclear states with significant export control restrictions. Other nuclear states have SFR design/technology programs that are more advanced than the U.S. program. The travelling wave sodium reactor under development is attempting to address the export control challenges.	May share some of the same potential as MHR. Difficult to assess because of the low Technology Readiness Level compared to the MHR and SFR.

Category No.	Category	Piketon, OH (NE)		Southern Utility Site (SE)		Red Leaf Site, UT (NW)		Odessa, TX (SW)	
		H_2 Production		*Electricity Production*		*Recover Oil from Shale*		*Petroleum Refinery / Fracking Water Clean up*	
		SFR	MSR	SFR	MSR	SFR	MSR	SFR	MSR
						development is attempting to address the export control challenges.			
2.2	Demonstration Module / Plant Costs	About the same as the MHR.	Much more uncertain than the MHR.	About the same as the MHR.	Much more uncertain than the MHR.	About the same as the MHR.	Much more uncertain than the MHR.	About the same as MHR.	Much more uncertain than MHR.
2.3	NOAK Commercial Costs	-[2]	-	-	-	-	-	-	-
2.4	Potential for International collaboration on reactor technology	Possibly good. But Russia, France and Japan already have strong national programs.	Unknown, but the U.S. seems to be the country primarily interested in MSR at this stage.	Possibly good. But Russia, France and Japan already have strong national programs.	Unknown, but the U.S. seems to be the country primarily interested in MSR at this stage.	Possibly good. But Russia, France and Japan already have strong national programs.	Unknown, but the U.S. seems to be the country primarily interested in MSR at this stage.	Possibly good. But Russia, France and Japan already have strong national programs.	Unknown, but the U.S. seems to be the country primarily interested in MSR at this stage.
2.5	Impacts on Local Economy	Jobs produced by the construction and operation of an advanced reactor and a Steam Methane Reformer. Local economy could be very positively impacted by the products produced at the site. Ability to reduce supply costs provides the "end users" a competitive advantage for expanding their market share, resulting in additional economic impact.	Jobs produced by the construction and operation of an advanced reactor and a Steam Methane Reformer. Local economy could be very positively impacted by the products produced at the site. Ability to reduce supply costs provides the "end users" a competitive advantage for expanding their market share, resulting in additional economic impact.	Positive and significant. Replaces tax base and jobs lost at previous facility decommissioning.	Positive and significant. Replaces tax base and jobs lost at previous facility decommissioning.	Greenfield project should have strong impacts on local economy.	Greenfield project should have strong impacts on local economy.	Greenfield project should have strong impacts on local economy.	Greenfield project should have strong impacts on local economy.
Licensing Considerations									
3	Licensing Considerations	Less licensing activity to date. Unclear whether NRC will accept fuel	Unclear how NRC will address this very innovative homogeneous fast	Site appears favorable for licensing. Additional info needed re:	Site appears favorable for licensing. Additional info needed re:	SFR should not have any significant licensing issues relative to the MHR;	Less mature technology requires further evaluation to assess realistic	SFR should not have any significant licensing issues relative to the MHR;	Less mature technology requires further evaluation to assess realistic

[2] Not evaluated at this time – more work needed to determine these costs.

Category No.	Category	Piketon, OH (NE)		Southern Utility Site (SE)		Red Leaf Site, UT (NW)		Odessa, TX (SW)	
		H_2 Production		*Electricity Production*		*Recover Oil from Shale*		*Petroleum Refinery / Fracking Water Clean up*	
		SFR	MSR	SFR	MSR	SFR	MSR	SFR	MSR
		experience from EBR-II. Piketon related GNEP studies have looked at breeder reactor and fuel cycle issues.	reactor concept.	flooding, EAB and EP. No certified design.	flooding, EAB and EP. No certified design.	however, licensing/safety evaluation is likely more complex.	licensing case at Red Leaf.	however, licensing/safety evaluation is likely more complex.	licensing case at Odessa.
Siting Considerations									
4.1	Technology Considerations	Extremely well suited for supporting the technical considerations. All Exclusionary Criteria are met or exceeded, and there are no EIS concerns.	Extremely well suited for supporting the technical considerations. All Exclusionary Criteria are met or exceeded, and there are no EIS concerns.	Potential for site to support 4-8 modules (311 MWe each).	Potential for site to support 1-2 Units (1105 MWe each).	Technology less applicable for realistic business case at Red Leaf.	Less mature technology requires further evaluation to assess realistic business case at Red Leaf.	Technology not applicable for realistic business case at southwestern site.	Less mature technology requires further evaluation to assess realistic business case at southwestern site.
4.2	Site-Specific Considerations	Capability to meet all siting requirements exists. The site possesses numerous geological and physical attributes from previous industrial use including mature roads systems, water and waste systems, power distribution systems and on-site facilities such as warehousing, office buildings and parking access. In addition to physical attributes, social and community support for redevelopment of the site and previous missions have	Capability to meet all siting requirements exists. The site possesses numerous geological and physical attributes from previous industrial use including mature roads systems, water and waste systems, power distribution systems and on-site facilities such as warehousing, office buildings and parking access. In addition to physical attributes, social and community support for redevelopment of the site and previous missions have	High site readiness. Pre-existing services (rail, transmission, etc.) make site desirable.	High site readiness. Pre-existing services (rail, transmission, etc.) make site desirable.	Remote site and ancillary services are extremely limited. Technology less applicable for realistic business case at Red Leaf.	Remote site and ancillary services are extremely limited. Less mature technology requires further evaluation to assess realistic business case at Red Leaf.	Technology not currently applicable for realistic business case at Odessa site; however, additional locations should be considered in the southwest.	Technology not currently applicable for realistic business case at Odessa site; however, additional locations should be considered in the southwest.

Category No.	Category	Piketon, OH (NE)		Southern Utility Site (SE)		Red Leaf Site, UT (NW)		Odessa, TX (SW)	
		H_2 Production		*Electricity Production*		*Recover Oil from Shale*		*Petroleum Refinery / Fracking Water Clean up*	
		SFR	MSR	SFR	MSR	SFR	MSR	SFR	MSR
		brought a technical and nuclear professional workforce to Ohio.	brought a technical and nuclear professional workforce to Ohio.						

3.3 Exclusionary Criteria Development – Task 3

The goals of the Generation IV nuclear plants were used to develop exclusionary criteria (Reference [19]). The methodology for the development of exclusionary criteria presented in the EPRI siting guides was not designed for Generation IV reactors, and was therefore used solely as guidance.

The following assumptions were used in the development process for exclusionary criteria:

- The plant exclusion area (EA), as defined in 10 CFR 100.3[3] (Reference [20]), will be much smaller than for Generation III plants. From a dose perspective, the EA could be the outer shell of the building in which the reactor is located. From a security perspective, the EA must provide enough space to implement the regulatory requirements for mitigating potential terrorist attacks.
- The plant low population zone (LPZ), as defined in 10 CFR 100.3[4], will be much smaller than for Generation III plants, and may be the same as the EA.
- Due to the low likelihood and degree of reactor core damage, the plant may be located closer to high population densities than Generation III plants.
- The emergency planning zone can be shortened from that used for Generation III plants such that no offsite emergency response will be necessary.
- Distance to high density population centers will not be used as an exclusionary criterion because while it is expected to be much smaller than what is currently in use, there is no way to predict future regulatory requirements.
- It is assumed that a suitable security program can be developed for any of the proxy sites.
- It is common to include accidents at manufacturing or military facilities as hazards; however, some of these facilities may be in need of process heat. Such potential hazards shall be evaluated and site parameters established such that potential hazards will pose no undue risk to the nuclear plant. Plant design and distance from the potential hazard can be used to mitigate risk.
- While topographic features may be used to screen plant structures from nearby scenic, historical, or recreational resources, features such as hills, mountain ranges, and lake and ocean shorelines can affect the local atmospheric conditions and cause the pollutant dispersion characteristics at a site to be less favorable than those in other parts of the region of interest. In such cases, more stringent plant design or effluent objectives might be required. Therefore, topographic features are not considered to be an exclusionary criterion.

The exclusionary criteria are presented in Table 3-6.

[3] From 10 CFR 100.3: Exclusion area means that area surrounding the reactor, in which the reactor licensee has the authority to determine all activities including exclusion or removal of personnel and property from the area.
[4] From 10 CFR 100.3: Low population zone means the area immediately surrounding the exclusion area which contains residents, the total number and density of which are such that there is a reasonable probability that appropriate protective measures could be taken in their behalf in the event of a serious accident.

Table 3-6 – Exclusionary Criteria

Category	Value	Reason
Seismic	· Peak Ground Acceleration > 0.3g at a probability of exceedance (PE) of two percent in 50 years · Located within five miles (8 km) of a capable fault[5]	Seismic events meeting or exceeding these values have high potential to cause plant accidents.
Flooding	· Located within the 100-year flood zone	High-magnitude flooding events may cause a plant accident and/or impact normal plant operation.
Hazards	· Accidents at nearby industrial or military facilities posing undue risk to the nuclear plant due to shock waves and missiles from explosions (depends on plant design and distance to plant) · Directly in line with runways on high-operations commercial or military airports · Low lying areas downstream of major dams[6]	Hazards may impact the plant or the plant operators in a way that jeopardizes the safety of the plant.
Transmission Lines	· Less than 230 kilo-Volt (kV) capacity and less than two independent sources of off-site power within 30 mi (48.3 km)	An existing power supply is needed to operate the plant and suitable transmission lines are needed to transmit the generated electricity.
Federal and State Lands	Located on one of the following: · National / state parks / wildlife refuges · National / state historic sites · National / state seashores and lakeshores · National / state rivers and scenic riverways · Wilderness areas · National maritime sanctuary areas · Cultural resources (American Indian lands, national landmarks)	Locating a nuclear power plant close to special areas administered by the government for scenic or recreational use, or areas having significant cultural use, may cause unacceptable impacts on land use.

[5] From Appendix A to 10 CFR 100, "Seismic and Geologic Siting Criteria for Nuclear Power Plants," a capable fault is one which has exhibited one or more of the following characteristics: 1) Movement at or near the ground surface at least once within the past 35,000 years or movement of a recurring nature within the past 500,000 years; 2) Macro-seismicity instrumentally determined with records of sufficient precision to demonstrate a direct relationship with the fault; 3) A structural relationship to a capable fault according to characteristics (1) or (2) of this paragraph such that movement on one could be reasonably expected to be accompanied by movement on the other.

[6] For the purposes of plant siting, a major dam is one which threatens the safe operation and shutdown of the nuclear plant due to seismically induced flooding or other cause of major dam failure.

The following discretionary criteria are not to be used to exclude a site from consideration but are envisioned to be important to the business case.

Table 3-7 – Discretionary Criteria

Category	Value	Reason
Cooling/Dilution Water	· Water amount not sufficient to meet plant design · Water source not located nearby[7]	Sufficient water is needed for cooling purposes and to dilute any liquid effluent releases.
Need for process heat	· Need for power / process heat does not exist	The need for power / process heat strengthens the business plan for a site.
Airports, barges, rail lines, and roads	· No preexisting infrastructure within 10 miles (16.1 km)	Infrastructure is needed to facilitate construction and operation of the plant.
Population	· Located within four miles (6.4 km) of a population center of 25,000 or more · Located within 10 miles (16.1 km) of a population center of 100,000 or more · Located within 20 miles (32.2 km) of a population center of 500,000 or more · Located within 30 miles (48.3 km) of a population center of 1,000,000 or more	Title 10, CFR, Part 100.21, "Non-seismic siting criteria," (Reference [15]) states that the population center distance as defined in Part 100.3[8], must be at least one and one-third times the distance from the reactor to the outer boundary of the low population zone. The criteria specified in 10 CFR 100.21 were written for the current generation light-water reactors (LWRs) and may remain applicable for initial deployment of advanced reactor demonstration plants. Less stringent criteria for population centers may be adopted for commercial deployment of advanced reactors that can demonstrate inherent safety for worst-case events.
Wetlands	· Large amount (> five acres) of wetlands impacted by construction	Cost of mitigation may be very high

[7] An acceptable distance to a source of water may depend on the strength of the business case.
[8] From 10 CFR 100.3: Population center distance means the distance from the reactor to the nearest boundary of a densely populated center containing more than about 25,000 residents.

3.4 Site Information Compilation – Task 4

What follows is a summary for each of the four proxy sites. More detailed site information is presented in Appendix A through Appendix D.

Northeast Site (Piketon, OH) - see Reference [21]

SODI is the DOE designated community reuse organization for the DOE Portsmouth Reservation and is working with the DOE to transfer property for their use in attracting private partners to develop and implement strategic plans for the reindustrialization of the Reservation (Reference [21]).

The Reservation is a fully industrialized nuclear enclave. It is comprised of 3,700 acres of land, of which the centrally developed area comprises 1,200 acres. Of those 1,200 acres, 750 acres comprise a controlled access area. Having received a NRC Certificate of Operation for the Gaseous Diffusion Plant (GDP) and two NRC Licenses for the operation of centrifuge technology facilities, the capability to prepare an Environmental Impact Statement (EIS) and obtain licensing for a SODI Demonstration Plant concept is extremely compelling. As a result of the interfaces and studies in support of the Environmental Protection Agencies, both state and federal, and the NRC over the past 30 years, the probability of having any significant unknowns relative to the site is extremely small.

The Reservation does not meet or exceed any of the exclusionary criteria.

There is a skilled nuclear workforce with both DOE and NRC regulatory experience.

Multiple education and training centers are located in the vicinity of the Reservation.

Extensive licensing evaluations have been performed:

- Part 76 Certificate for GDP Operation;
- Part 70 License for the United States Enrichment Corporation (USEC) Lead Cascade;
- Part 70 License for the USEC Commercial Plant;
- DOE Global Nuclear Energy Partnership (GNEP) Detailed Site Report.

The Reservation has extremely strong community support. In addition, there is strong interest within the state of Ohio regarding the future for Hydrogen Fuel Cells. SODI and the NGNP Industry Alliance are pursuing a strategy that incorporates an international partnership to support the deployment (possibly in parallel with Poland) of a first of a kind (FOAK) modern HTGR at Piketon. The strategy would help reduce the costs of deployment and increase political and industrial interest in the project and help provide funding stability through the years necessary to complete the project.

There are several cost savings opportunities associated with the Reservation:

- Existing wells / water treatment / distribution systems;
- Existing sewage treatment facility;
- Existing fire station / emergency response;
- Dry air plant / Nitrogen plant;
- Power to the site;
- Rail access / Spur / On-site Track;
- Administration / Office Buildings.

It is estimated that these cost savings total more than sixty million dollars.

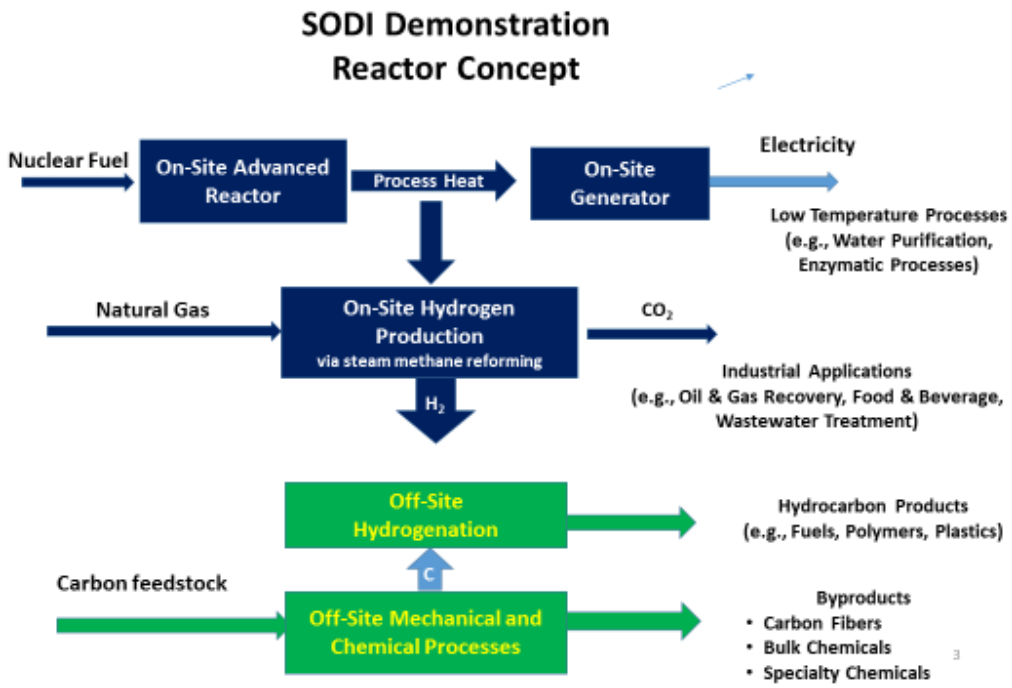
It is envisioned that high temperature heat from the reactor will integrate with an on-site generator and steam methane reformer to:

- Produce electricity for on-site use by the Demonstration Plant and sale to potential customers;
- Produce hydrogen for use in transportation fuels, polymers, plastics, fertilizer, hydrogen fuel cell market;
- Provide low temperature heat which could support utility processes on the site;
- Produce CO_2 that could have potential off-site markets within the region.

For the evaluated business case, a steam methane reformer to produce hydrogen was based upon a feed rate of 100,000 cubic feet per hour. This negates the need to upgrade the existing pipeline to the site and allows ample reserve to address the availability of natural gas for additional site uses. The generated hydrogen would be piped to the Marathon refinery in Catlettsburg, Kentucky.

A graphical presentation of the site process heat usage is presented on Figure 3-1.

Figure 3-1 – Northeast Site Process Heat Usage



Southeast Site (Utility Site, GA) - see Reference [22]

Southern Nuclear Operating Company selected a former Georgia Power Company (GPC) coal site for a pre-conceptual Demonstration Plant analysis of a 'brownfield' site for the southeast region. Located on 3,203 acres adjacent to Lake Sinclair, the plant was the first million-plus-kilowatt electric generating station to operate on the GPC system. The site is located in Putnam County between the towns of Eatonton (population 6,530) and Milledgeville (population 19,256). In April 2015 the facility was closed and demolition began.

The site does not meet or exceed any of the exclusionary criteria.

No nuclear-related licensing evaluations were performed for the site.

It is believed that there will be strong community support.

There are cost savings opportunities associated with the site:

- Existing water supply;
- Power to the site;

- Rail access / Spur / On-site track.

It is envisioned that the reactor would be used primarily for electricity generation. Georgia Power Company filed its most recent integrated resource plan with the Public Service Commission in January of 2016. The first year of capacity need is 2024.

This 'brownfield' site offers easy access to critical infrastructure such as roads, rail, water and existing transmission corridors.

Southwest Site (Odessa / Midland, TX) - see References [23] and [24]

The site is located in Ector County, just south of Interstate 20, approximately 15 miles southwest of Odessa, Texas.

The site does not meet or exceed any of the exclusionary criteria.

Initially, it was envisioned that the reactor process heat could be used for cleaning fracking water; however, it was determined that this single application would be a challenging business case. A multi-use business case approach (petroleum refining, process steam, hydrogen production, and electricity generation) is likely required for a positive business plan.

Tentatively, bonds for water cleanup may be available in the amount of $1B+ at an interest rate of approximately 5% versus a normal commercial interest rate of 8-9%. This would provide an enormous potential boost to commercial viability.

The Southwest site has potential hazards that would require evaluation before licensing. A potential water source is the subterranean local aquifer. The current distance from the site to either a 230-kV or a 345-kV transmission line has not been determined. There is potential for a future transmission line approximately 15 miles from the site.

No nuclear-related licensing evaluations were performed for the site.

It is believed that there will be strong community support.

Northwest Site (Red Leaf Seep Ridge Block Site, UT) - see Reference [25] and [26]

The Seep Ridge Block, a subset of Red Leaf Resources, Inc., Utah oil shale portfolio, is comprised of approximately 1,600 acres of rich, near surface oil shale. It is located in Seep Ridge Canyon, Utah. Seep Ridge is the site of the company's field pilot that was constructed and operated in 2008 - 2009. The pilot successfully exhibited their technology's proprietary heating methods and oil extraction capabilities. The project team is currently in the process of finalizing remaining permits in order to commence mining operations.

The site does not meet or exceed any of the exclusionary criteria.

It is envisioned that high temperature heat from the reactor will be used for the application of the process heat for shale oil recovery.

The site is located on the Uintah and Ouray Indian Reservation, just outside the boundary of the tribal lands. The Red Leaf Site is very remote with significant infrastructure requirements. A business case for nuclear deployment at the Red Leaf Site likely requires a much larger business plan that involves a large-scale refinery to utilize the hydrogen, methane, and other hydrocarbon byproduct gasses from shale oil recovery.

No nuclear-related licensing evaluations were performed for the site.

It is believed that there will be strong community support.

It is envisioned that the reactor would be used to enable expansion of shale oil recovery.

3.5 Comparison of Site-Specific Information to Exclusionary Criteria – Task 5

Northeast Site (Piketon, OH)

The Northeast Site does not meet or exceed any of the exclusionary criteria.

Table 3-8 – Northeast Site-Specific Information Compared to Exclusionary Criteria

Category	Value	Northeast Site-Specific Value
Seismic	· Peak Ground Acceleration > 0.3g at a probability of exceedance (PE) of two percent in 50 years · Located within five miles (8 km) of a capable fault[9]	PGA < 0.3 g at a PE of two percent in 50 years No historical earthquakes within 25 miles
Flooding	· Located within the 100-year flood zone	No portion of the site is located within the 100-year flood plain
Hazards	· Accidents at nearby industrial or military facilities posing undue risk to the nuclear plant due to shock waves and missiles from explosions (depends on plant design and distance to plant) · Directly in line with runways on high-operations commercial or military airports · Low lying areas downstream of major dams[10]	The site is in a rural area. It is not near industrial or military facilities posing undue risk to the nuclear plant due to shock waves and missiles from explosions, is not directly in line with runways on high-operation or military airports, and is not located in a low-lying area downstream of major dams.
Transmission Lines	· Less than 230 kilo-Volt (kV) capacity and less than two independent sources of off-site power within 30 mi (48.3 km)	There is substantial dedicated electricity generation and transmission capacity available to the site. Electrical power is supplied from Ohio Valley Electric Corporation's external 345 kilovolts (kV) power grid at 345 kV. The switching arrangement provides a highly reliable source of power for the proposed Demonstration Plant.
Federal and State Lands	Located on one of the following: · National / state parks / wildlife refuges · National / state historic sites · National / state seashores and lakeshores · National / state rivers and scenic riverways · Wilderness areas · National maritime sanctuary areas · Cultural resources (American Indian lands, national landmarks)	No state or national parks, conservation areas, wild and scenic rivers, or other areas of recreational, ecological, scenic, or aesthetic importance are located within a one-mile radius of the site.

[9] From Appendix A to 10 CFR 100, "Seismic and Geologic Siting Criteria for Nuclear Power Plants," a capable fault is one which has exhibited one or more of the following characteristics: 1) Movement at or near the ground surface at least once within the past 35,000 years or movement of a recurring nature within the past 500,000 years; 2) Macro-seismicity instrumentally determined with records of sufficient precision to demonstrate a direct relationship with the fault; 3) A structural relationship to a capable fault according to characteristics (1) or (2) of this paragraph such that movement on one could be reasonably expected to be accompanied by movement on the other.

[10] For the purposes of plant siting, a major dam is one which threatens the safe operation and shutdown of the nuclear plant due to seismically induced flooding or other cause of major dam failure.

Southeast Site (Utility Site, GA)

The Southeast Site does not meet or exceed any of the exclusionary criteria.

Table 3-9 - Southeast Site-Specific Information Compared to Exclusionary Criteria

Category	Value	Southeast Site-Specific Value
Seismic	· Peak Ground Acceleration > 0.3g at a probability of exceedance (PE) of two percent in 50 years · Located within five miles (8 km) of a capable fault[11]	PGA < 0.3 g at a PE of two percent in 50 years. Not located within five miles of a capable fault.
Flooding	· Located within the 100-year flood zone	The Federal Emergency Management Agency (FEMA) Flood Insurance Rate Map for the site indicates that the site is not located in a flood zone. In addition, since construction in 1961 flooding has not been an issue at the site.
Hazards	· Accidents at nearby industrial or military facilities posing undue risk to the nuclear plant due to shock waves and missiles from explosions (depends on plant design and distance to plant) · Directly in line with runways on high-operations commercial or military airports · Low lying areas downstream of major dams[12]	There are no significant hazards within close proximity to the site. No high-operation commercial or military air traffic occurs at this location. There are no known military bases, industrial / chemical complexes, or pipelines within two miles of the site. Wallace Dam, operated by Georgia Power Company, is located 14 miles northeast of the site. As such, a dam break analysis would be required during licensing.
Transmission Lines	· Less than 230 kilo-Volt (kV) capacity and less than two independent sources of off-site power within 30 mi (48.3 km)	The site has substantial transmission infrastructure in place. There are nine 230kV transmission lines terminating in a switchyard at the site. If additional transmission is required to support the facility, there is a 500kV transmission line (not connected to the existing switchyard) approximately four miles northwest of the site.
Federal and State Lands	Located on one of the following: · National / state parks / wildlife refuges · National / state historic sites · National / state seashores and lakeshores · National / state rivers and scenic riverways · Wilderness areas · National maritime sanctuary areas · Cultural resources (American Indian lands, national landmarks)	The site is owned by Georgia Power Company (GPC) and is not located on, or adjacent to, any federal or state lands. The nearest state-owned lands are the Cedar Creek Wildlife Management Area (WMA) located approximately five miles west of the site (closest boundary).

[11] From Appendix A to 10 CFR 100, "Seismic and Geologic Siting Criteria for Nuclear Power Plants," a capable fault is one which has exhibited one or more of the following characteristics: 1) Movement at or near the ground surface at least once within the past 35,000 years or movement of a recurring nature within the past 500,000 years; 2) Macro-seismicity instrumentally determined with records of sufficient precision to demonstrate a direct relationship with the fault; 3) A structural relationship to a capable fault according to characteristics (1) or (2) of this paragraph such that movement on one could be reasonably expected to be accompanied by movement on the other.

[12] For the purposes of plant siting, a major dam is one which threatens the safe operation and shutdown of the nuclear plant due to seismically induced flooding or other cause of major dam failure.

Southwest Site (Odessa / Midland, TX)

The Southwest Site has potential hazards that would require evaluation before licensing. A potential water source is the local aquifer. The current distance from the site to either a 230-kV or a 345-kV transmission line has not been determined. There is potential for a future transmission line approximately 15 miles from the site.

Table 3-10- Southwest Site-Specific Information Compared to Exclusionary Criteria

Category	Value	Southwest Site-Specific Value
Seismic	· Peak Ground Acceleration > 0.3g at a probability of exceedance (PE) of two percent in 50 years · Located within five miles (8 km) of a capable fault[13]	PGA < 0.3 g at a PE of two percent in 50 years. Not located within five miles of a capable fault.
Flooding	· Located within the 100-year flood zone	The Federal Emergency Management Agency (FEMA) Flood Insurance Rate Map Number 48135C0450E indicates that the site is not located in a flood zone.
Hazards	· Accidents at nearby industrial or military facilities posing undue risk to the nuclear plant due to shock waves and missiles from explosions (depends on plant design and distance to plant) · Directly in line with runways on high-operations commercial or military airports · Low lying areas downstream of major dams[14]	Potential hazards close to the site will require evaluation. No high-operation commercial or military air traffic occurs at this location. There are oil / gas wells located both on-site and within two miles of the site. A cement plant is located approximately 2.7 miles east of the site. Pipelines are within two miles of the site. One sand / gravel surface mine is located approximately two miles east of the site. There are no dams within two miles of the site.
Transmission Lines	· Less than 230 kilo-Volt (kV) capacity and less than two independent sources of off-site power within 30 mi (48.3 km)	The nearest high voltage transmission line to the site is a 69-kV line about 1 mile south of the site. Additional lines are in the area, the next closest being a 138-kV line about 6.8 miles northeast of the site. It is unknown what the distance would be from the site to a 230-kV line. A 345- kV transmission line has been proposed to be constructed north of the site by ERCOT.
Federal and State Lands	Located on one of the following: · National / state parks / wildlife refuges · National / state historic sites · National / state seashores and lakeshores · National / state rivers and scenic riverways · Wilderness areas · National maritime sanctuary areas · Cultural resources (American Indian lands, national landmarks)	The site is not located on, or adjacent to, any federal or state lands. There are no known federal or state lands within two miles of the site.

[13] From Appendix A to 10 CFR 100, "Seismic and Geologic Siting Criteria for Nuclear Power Plants," a capable fault is one which has exhibited one or more of the following characteristics: 1) Movement at or near the ground surface at least once within the past 35,000 years or movement of a recurring nature within the past 500,000 years; 2) Macro-seismicity instrumentally determined with records of sufficient precision to demonstrate a direct relationship with the fault; 3) A structural relationship to a capable fault according to characteristics (1) or (2) of this paragraph such that movement on one could be reasonably expected to be accompanied by movement on the other.

[14] For the purposes of plant siting, a major dam is one which threatens the safe operation and shutdown of the nuclear plant due to seismically induced flooding or other cause of major dam failure.

Northwest Site (Red Leaf Seep Ridge Block Site, UT)

The Northwest Site is located on the Uintah and Ouray Indian Reservation, just outside the boundary of the tribal lands.

Table 3-11 - Northwest Site-Specific Information Compared to Exclusionary Criteria

Category	Value	Northwest Site-Specific Value
Seismic	· Peak Ground Acceleration > 0.3g at a probability of exceedance (PE) of two percent in 50 years · Located within five miles (8 km) of a capable fault[15]	PGA < 0.3 g at a PE of two percent in 50 years. Not located within five miles of a capable fault.
Flooding	· Located within the 100-year flood zone	The Federal Emergency Management Agency (FEMA) Flood Insurance Rate Map Panels 49047C1925D and 49047C1950D indicate that the site is not located in a flood plain.
Hazards	· Accidents at nearby industrial or military facilities posing undue risk to the nuclear plant due to shock waves and missiles from explosions (depends on plant design and distance to plant) · Directly in line with runways on high-operations commercial or military airports · Low lying areas downstream of major dams[16]	There are no significant hazards within close proximity to the site. No high-operation commercial or military air traffic occurs at this location. There are no known military bases, industrial/chemical complexes, or pipelines within two miles of the site. There are no upstream dams, as the site is not located on a water body.
Transmission Lines	· Less than 230 kilo-Volt (kV) capacity and less than two independent sources of off-site power within 30 mi (48.3 km)	The nearest high-voltage transmission line is located 20 miles north of the site.
Federal and State Lands	Located on one of the following: · National / state parks / wildlife refuges · National / state historic sites · National / state seashores and lakeshores · National / state rivers and scenic riverways · Wilderness areas · National maritime sanctuary areas · Cultural resources (American Indian lands, national landmarks)	The site is located on the Uintah and Ouray Indian Reservation, just outside the boundary of the tribal lands. The reservation is located within a three-county area known as the "Uintah Basin". It is the second largest Indian Reservation in the United States and covers over 4.5 million acres. The site is also located just outside of a wilderness area that is under the jurisdiction of the Bureau of Land Management.

[15] From Appendix A to 10 CFR 100, "Seismic and Geologic Siting Criteria for Nuclear Power Plants," a capable fault is one which has exhibited one or more of the following characteristics: 1) Movement at or near the ground surface at least once within the past 35,000 years or movement of a recurring nature within the past 500,000 years; 2) Macro-seismicity instrumentally determined with records of sufficient precision to demonstrate a direct relationship with the fault; 3) A structural relationship to a capable fault according to characteristics (1) or (2) of this paragraph such that movement on one could be reasonably expected to be accompanied by movement on the other.

[16] For the purposes of plant siting, a major dam is one which threatens the safe operation and shutdown of the nuclear plant due to seismically induced flooding or other cause of major dam failure.

4.0 SUMMARY / CONCLUSIONS

Preliminary site feasibility evaluations were conducted for four proxy sites that bound representative United States advanced reactor types (Modular HTGR / MHR, GE PRISM Sodium Fast Reactor / SFR, TerraPower Molten Salt Reactor / MSR):

- Northeast site (Piketon, OH);
- Southeast site (Utility Site, GA);
- Southwest site (Odessa / Midland, TX);
- Northwest site (Red Leaf Seep Ridge Block Site, UT).

A methodology was developed for:

- Advanced reactor technology parameters based on the TPE process;
- Business case format;
- Exclusionary criteria;
- Compilation of site-specific information; and
- Comparison of site information to criteria.

Business cases were developed for electricity generation and varying end user process heat applications. The MHR is the basis for the business case deployment. Other reactor technologies are qualitatively compared and contrasted. Categories evaluated were reactor technology considerations, economics and commercialization potential, licensing and siting considerations.

The final ranking and scoring of the sites for the MHR and associated business case application were as follows:

1. Northeast site (815.5);
2. Southeast site (738);
3. Southwest site (567); and
4. Northwest site (547).

5.0 RECOMMENDATIONS FOR FUTURE WORK

Recommendation #1: Refine NE and SE Business Cases

The most promising deployment sites from the NGNP Site Feasibility Evaluation are the NE (Piketon, OH) and SE (Utility Site, GA) proxy sites. It is recommended that a more detailed business plan is the next logical step as a future work scope.

The deliverable would be a detailed pro-forma business plan for a specific application for reactor needs.

Recommendation #2: Refine SW Business Case

A multi-use business case approach (petroleum refining, process steam, hydrogen production, and electricity generation) is likely required for a positive business plan at the SW site (Odessa / Midland, TX).

Recommendation #3: Refine NW Business Case

Perform some additional scoping assessments to support more detailed business case and marketing evaluations for the NW site (Red Leaf Seep Ridge Block Site, UT).

Maintain contact with the State of Utah, Red Leaf, and other companies in support of MHR process heat applications.

Recommendation #4: Roadmap

Develop a roadmap to an international program to further develop advanced reactor technologies to share in development cost to provide greater market potential.

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APPENDIX A: NE PROXY SITE

SODI – NIA-T0001
Revision 1

SODI

Southern Ohio Diversification Initiative

NGNP Advanced Reactor Site Feasibility Evaluation

Business Case for Evaluation of Advanced Reactor Technologies at DOE Portsmouth Reservation

July 2017

LIST OF CONTRIBUTORS

Name	Organization
Jim Morgan	Innovative Solutions
Mark Haynes	Concordia Power
John Mahoney, PMP	High Expectations International, LLC

Approval:

Steve Shepherd
Executive Director, SODI
Date: 6.29.17

Record of Revision

Revision No.	Pages/Sections/ Paragraphs Changed	Brief Description / Change Authorization
0	All	Initial release
1	Executive Summary/Conclusions	Clarified wording on Exclusionary Criteria and Discretionary Criteria; Modified wording on Site Scoring Summary *J.B.Morgan* 7/17/17

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACRONYMS AND ABBREVIATIONS

ACP	American Centrifuge Plant
CFH	Cubic Feet per Hour
CO_2	Carbon Dioxide
CRES	Competitive Retail Electric Service
CRO	Community Reuse Organization
D&D	Decontamination and Decommissioning
DBEE	Design Basis Earthquake Event
DOE	Department of Energy
EIS	Environmental Impact Statement
EM	Environmental Management
ESP	Early Site Permit
GDP	Gaseous Diffusion Plant
H_2	Hydrogen
HTGR	High Temperature Gas Reactor
IES	Integrated Energy System
km	kilo-meter
kV	kilo-Volt
MOA	Memorandum of Agreement
NGNP	Next Generation Nuclear Plant
NIA	NGNP Industry Alliance Limited
NRC	Nuclear Regulatory Commission
OAC	Ohio Administrative Code
OU	Ohio University
OVEC	Ohio Valley Electric Corporation
PE	Probability of Exceedance
SMR	Steam Methane Reformer
SODI	Southern Ohio Diversification Initiative
SSC	Structures, Systems, and Components
PORTS	Portsmouth Gaseous Diffusion Plant
USEC	United States Enrichment Corporation

1. EXECUTIVE SUMMARY

The information collected for a pre-conceptual Demonstration Plant analysis of a brownfield site at Piketon, Ohio, indicates that the Portsmouth DOE Reservation (PORTS) site would be an excellent site for location of a demonstration plant and an integrated energy system aligned with an advanced reactor technology. There were no Exclusionary Criteria nor Discretionary Criteria identified that would prevent construction of a nuclear reactor on the site. There are no known regulatory issues that would prohibit an application for an early site permit (ESP) and environmental Impact statement (EIS) as the initial stages for licensing and construction at the site. The PORTS site has previously received a NRC Certificate of Operation for the Gaseous Diffusion Plant (GDP) as well as two NRC Licenses for the facility operations of centrifuge technology. As a result of the interfaces and studies in support of Ohio State and Federal Environmental Protection Agencies and the Nuclear Regulatory Commission over the past 30 years, the probability of having any significant unknowns relative to the proposed site are considered low based upon analysis performed.

The fact that the site was designed and operated as a nuclear industrial facility provides assurance that the site is well suited for both a demonstration plant and potentially a larger integrated energy system aligned with an advanced nuclear reactor technology. The future usage of the high temperature process heat from nuclear energy offers significant advantages as the sensitivity to climate change increases throughout the world.

The PORTS reservation possesses numerous geological and physical attributes from previous industrial use including mature roads systems, water and waste systems, power distribution systems and on-site facilities such as warehousing, office buildings and parking access. In addition to physical attributes, social and community support for redevelopment of the site and previous missions have brought a technical and nuclear professional workforce to Ohio[1]. There are two nuclear power stations[2] operating in Ohio less than 180 miles from the PORTS indicating state support and oversight systems are in place and mature.

The design, construction and operation of a demonstration next generation nuclear reactor and an associated Steam Methane Reformer (SMR) for hydrogen production aligns with the goals of the Southern Ohio Diversification Initiative (SODI) to deploy a demonstration project in support of an Integrated Energy System (IES). This represents a significant initial step in SODI's vision of redeveloping the fully industrialized nuclear reservation to address the energy needs of the future, while providing economic development opportunities for the region, state and nation.

[1] In 2017, Thirty-eight companies are listed by the U.S. Nuclear Infrastructure Council supporting the nuclear energy industry.

[2] Perry Station and Davis-Besse Nuclear Power Station owned by FirstEnergy Nuclear Operating Company

BACKGROUND

The PORTS site is a fully industrialized nuclear reservation of approximately 3,700 acres of DOE-owned land. On the PORTS site, Perimeter Road surrounds a 1,200-acre centrally developed industrial use area, which includes a 750-acre controlled access area (DOE 2014a). The portion of the site outside of Perimeter Road comprises approximately 2,500 acres of land, including several contiguous parcels ranging from 1 to more than 1,000 acres. Land uses in this area include a water treatment plant, a private electrical substation, sewage treatment plant, holding ponds, sanitary and inert landfills, cylinder storage yards, parking areas, open fields, and forested buffer areas (DOE 2014a).

Figure 2-1. Aerial View of the DOE Portsmouth Reservation

January 2017

The Southern Ohio Diversification Initiative (SODI) is the DOE designated Community Reuse Organization (CRO) for the DOE Portsmouth (PORTS) Reservation located near Piketon, Ohio. In alignment with their goals of reuse and reindustrialization of the PORTS reservation, the SODI is working with the DOE to transfer property and attract private partners to develop and implement strategic plans for the reindustrialization of the site. Ongoing activities between the SODI and the DOE Site Evaluation Study are aligned with SODI's goals and objectives to:

- Transfer property for redevelopment and reindustrialization;
- Pursue pilot plant and demonstration project deployment;
- Develop and deploy a Piketon Integrated Energy System (IES) Plant concept; and
- Implement and strengthen the Memorandum of Agreement (MOA) with the Next Generation Nuclear Plant (NGNP) Industry Alliance (NIA).

The transfer of real property not required for the government's use of the site would support the DOE objective to reduce the DOE legacy costs for the site. Close coordination among numerous

participants will be required to develop a comprehensive strategic plan for redevelopment of the site while there are ongoing Decontamination and Decommissioning (D&D) activities.

In order to better understand the advantages associated with the use of the process heat, as well as to educate industry on the advantages of the High Temperature Gas Reactor (HTGR), SODI and the NIA are continuing with planned meetings and engagement with interested "end users". Additionally, SODI is working with the NIA to understand the growth, technology and opportunities of the H_2 Energy field, both domestically and internationally.

3. Exclusionary Criteria

Following extensive review, there were no conditions found that would exclude the Piketon site based upon exclusionary criteria identified in Table 3-1.

Table 3-1 Exclusionary Criteria

Category	Value
Seismic	• Peak Ground Acceleration > 0.3 g at a probability of exceedance (PE) of 2 percent in 50 years • Located with five miles (8 Km) of a capable fault
Flooding	• Located within the 10-year flood plain
Hazards	• Accidents at nearby industrial or military facilities posing undue risk to the nuclear plant due to shock waves and missiles from explosions (depends on plant design and distance to plant) • Directly in line with runways on high-operations commercial or military airports. • Low lying areas downstream of major dams
Transmission Lines	• Less than 230 kilo-Volt (kV) capacity and less than two independent sources of off-site power within 30 mi (48.3 km) (minimum requirements to be met)
Federal and State Lands	Located on one of the following: • National/state parks • National/state historical sites • National/state seashores and lakeshores • National/state rivers and scenic river ways • National/state wildlife refuges • Wilderness areas • National maritime sanctuary areas • Cultural resources (American Indian lands, national landmarks)

A summary evaluation of the exclusionary criteria as they relate to the site are described below.

3.1 Seismic

There are no major faults at the site. The nearest fault zone is the Kentucky River Fault Zone located approximately 40 kilometers (25 miles) south of the site. No seismic events have been associated with it. There have been no historical earthquakes within 25 miles of the site.

Ground motion from earthquakes causes damage to buildings and structures. Ground motion is measured as a percent of the acceleration of gravity. At 10 percent gravity (0.1g) some damage may occur in poorly constructed buildings. At 0.1 g to 0.2g most people have trouble keeping their footing. In the 1980's, DOE studied the historical seismicity of the areas surrounding the Portsmouth Plant. Data were developed on probably seismic activity and the intensity levels were converted into acceleration values. They determined that the maximum earthquake likely to occur would produce a ground motion equal to 0.15 gravity and a recurrence of a 1,000 years.

3.2 Flooding

Floodplains are land areas adjacent to streams or rivers susceptible to being inundated by stream-derived waters. The Federal Emergency Management Agency Flood Insurance Rate Map indicates that the 100-year floodplain for Little Beaver Creek extends from the confluence with the Big Beaver Creek upstream to the rail spur. This is within the northwestern portion of the DOE reservation. No portion of the floodplain for Big Beaver Creek is located within the reservation boundary. The DOE reservation has not been affected by flooding of the Scioto River since initial development and site operation. The highest recorded flood elevation of the Scioto River in the vicinity of the site was 570 feet above mean sea level in January 1913. The reservation occupies an upland area at an elevation of 670 feet above mean sea level. Because the entire site is located outside the 100-year floodplain, with the exception of a small area in the northwest portion of the site associated with Little Beaver Creek, no significant floodplain impacts should be associated with any property transfers or ultimate development.

3.3 Hazards

The DOE Reservation located near Piketon is in a rural area and is not near industrial or military facilities. This review for hazards indicates that the rural setting and lack of military or industrial facilities poses no undue risk to the proposed nuclear plant due to shock waves and missiles from explosions. The site is not directly in line with any FAA regulated high-operation airstrips or runways. The site is not directly in line of any military airports and is not located in a low-lying area downstream of major dams.

3.4 Transmission Lines (Electrical Supply)

There is substantial electrical capacity available to the PORTS site. The location of multiple transmission lines on the site, at various voltages from 138 kilovolts (kV) to 765 kV, which in turn are connected to multiple generation resources, could provide a highly reliable source of power for the proposed Demonstration Plant. Electrical power would likely be supplied by the local serving utility, AEP Ohio. Many different electrical configurations are possible to meet the reliability needs required for the proposed Demonstration Plant. A portion of the costs associated with implementing the required configuration could be covered by the serving utility per the serving utilities line extension policy. Additionally, per the Ohio Customer Choice program, potential Demonstration Plant operators could shop for electrical generation among the states Competitive Retail Electric Service (CRES) providers for the most cost effective suppliers of electrical

generation. Large power users may be able to work with various approved CRES providers to negotiate even better rates than average electrical users.

3.5 Federal and State Lands

The PORTS reservation property was purchased by the government is 1952 and has been the topic of many environmental and regulatory evaluations over the years, which emphasizes the fact that no restrictions exist regarding this exclusionary criterion. No state or national parks, conservation areas, wild and scenic rivers, or other areas of recreational, ecological, scenic, or aesthetic importance are located within a 1-mile radius of PORTS site. No Native American Indian burial grounds or historic sites are located within the reservation property[3].

4 Discretionary Criteria

The following discretionary criteria are not to be used to exclude a site from consideration but are envisioned to be important to the business case.

Table 4-1 Discretionary Criteria

Category	Value
Cooling/Dilution Water	• Water amount not sufficient to meet plant design • Water source not located nearby
Need for process heat	• Need for power/ process heat does not exist
Airport, barges, rail lines, and roads	• No preexisting infrastructure with 10 miles (16.1 km)
Population	• Located with four miles (6.4 km) of a population center of 25,000 or more • Located within 10 miles (16.1 km) of a population center of 100,000 or more • Located within 20 miles (32.2 km) of a population center of 500,000 or more • Located within 30 miles (48.3 km) of a population center of 1,000,000 or more
Wetlands	• Large amount (> five acres) of wetlands impacted by construction

4.1 Cooling/Dilution Water

With the termination of enrichment operations at the site, the current water usage and planned future usage is significantly less than the production capacity. The DOE has tasked the Site Contractor with maintaining the status and capacities of all site utilities. The maximum production associated with the well fields is 13 million gallons per day. . There is also a backup system that can draw directly from the Scioto River in the event the wells are unable to produce sufficient water to meet the site demands.

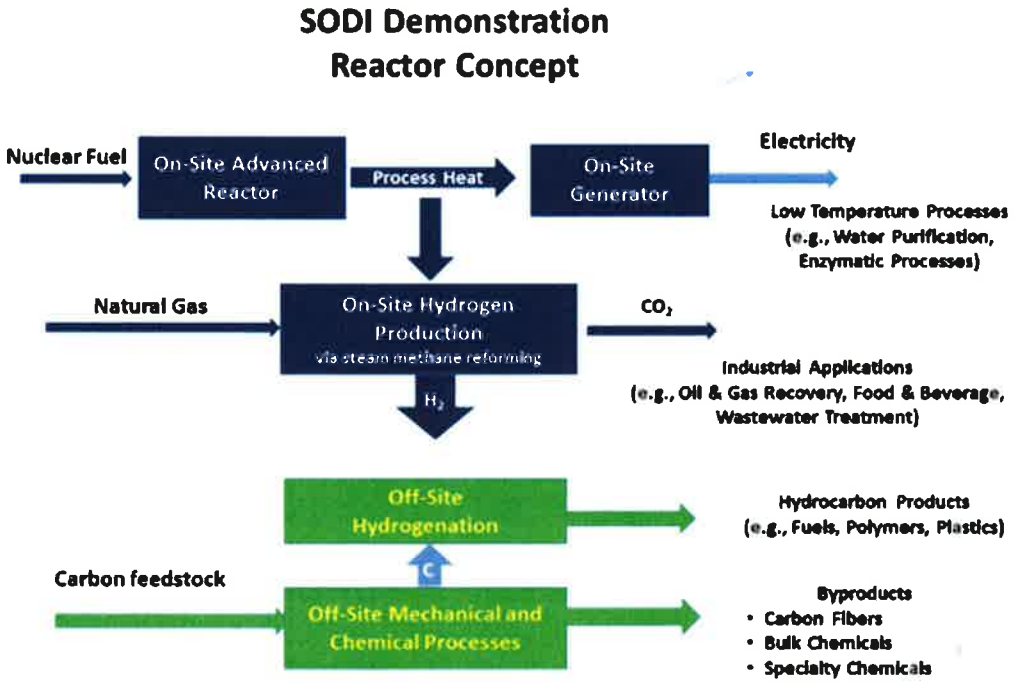
4.2 Need for Process Heat

The SODI Demonstration Reactor Project shown in Figure 4-1 will integrate high temperature heat with an on-site generator and steam methane reformer that will have the capability to:

- Produce electricity for on-site use by the Demonstration Plant and sale to potential customers;
- Produce hydrogen (H_2) for use in transportation fuels, polymers, plastics, fertilizer, and H_2 fuel cell market;
- Provide low temperature heat which could support utility processes on-site; and
- Produce carbon dioxide (CO_2) that could have potential off-site markets regionally.

For the purpose of this evaluation, we are sizing a Steam Methane Reformer (SMR) to produce H_2, based upon a feed rate of 100,000 Cubic Feet per Hour (CFH). Choosing this value negates the need to upgrade the existing pipeline to the site and allows ample reserve to address the availability of natural gas for additional site uses. Our hypothetical H_2 production and sale scenario is to pipe the H_2 to the Marathon refinery in Catlettsburg, Kentucky.

Figure 4-1 SODI Demonstration Plant Project



4.3 Airport, Barges, Rail Lines and Roads

4.3.1 Airports

Three international airports are located within a two-hour drive of the site: 1) Cincinnati/Northern Kentucky International Airport; 2) Dayton International Airport; and 3) Port Columbus International Airport.

With the relatively isolated location of PORTS, local commercial air service is limited. The nearest airport is the Greater Portsmouth Regional Airport, located approximately 15 miles south of the

site. This airport, which has dual runways and T-hangers, mostly serves private aircraft owners and business travelers. There are no regularly scheduled commercial flights; however, charter service is available. Another nearby airport, the Pike County Airport, is located just north of Waverly. This facility is similar in size and makeup to the Greater Portsmouth Regional Airport.

4.3.2 Barges

The site can be served by barge transportation via the Ohio River at the ports of Wheelersburg, Portsmouth, and New Boston. Ocean going ships can access Ohio Great Lakes ports. The Portsmouth barge terminal bulk-materials-handling facility is available for bulk materials and heavy unit loads. All heavy unit loading is by mobile crane or barge mounted crane at an open-air terminal. The Ohio River provides barge access to the Gulf of Mexico via the Mississippi River or the Tennessee-Tombigbee Waterway. Travel time to New Orleans is 14 to 16 days; to St. Louis, seven to nine days; and to Pittsburgh, three to four days. The U.S. Army Corps of Engineers maintains the Ohio River at a minimum channel width of 800 feet and a depth of 9 feet.

4.3.3 Rail Lines

An existing rail system is located on-site with several track configurations possible. Two rail carriers, CSX and Norfolk Southern service Pike County. The Norfolk Southern rail line is connected to the Portsmouth Site rail line system via a rail spur entering the northern portion of the site. Norfolk Southern track near Piketon allows a maximum speed of 60 miles per hour.

4.3.4 Roads

An existing road system and access to the site has been used and upgraded over the life of the reservation. The site is 3.5 miles south of the intersection of the U.S. Route 23 and Ohio SR 32 interchange. Both routes are four lanes with U.S. Route 23 traversing north-south and Ohio SR 32 traversing east-west. Principal access to the site is by the Main Access Road (also called the West Access Road), a four-lane road connecting with U.S. Route 23. Employees of the proposed facilities would utilize the Main Access Road for access from and traveling to U.S. Route 23.

Figure 4-2 Roadmap Showing Intrastate, Federal and State Highways

U.S. Route 23 intersects I-270, I-70, and I-71 approximately 70 miles north of the site. Trucks also may access I-64 approximately 20 miles southeast of Portsmouth. SR 32 runs east-west from Cincinnati and through Piketon to Parkersburg, West Virginia. To the west, SR 32 provides access to Cincinnati's three interstate highways, I-71, I-4, and I-75. To the east, SR 32 is linked with I-77. Refer to Figure 6-18 Roadmap Showing Intrastate, Federal and State Highways, for a graphic representation of the regional roads.

U.S. Route 23 is at approximately 60 percent of design capacity with Ohio SR 32 at approximately 40 percent of design capacity. The Ohio Department of Transportation supplied these data from a 1999 traffic study. Load limits on these routes are controlled by the Ohio Revised Code (85,000 pounds) gross vehicle weight. Special overload permitting is available.

4.4 Population

Population concentrations are below the Discretionary Criteria Table 4-1. The major population centers in the four-county region of influence are as follows:

- **Piketon** is the nearest residential center to the DOE reservation. Located in Pike County, this town is approximately 4 miles north of the DOE reservation on U.S. Route 23. In 2010, the population of Piketon was 2,181.

- **Waverly** is the largest town in Pike County. Located 8 miles north of the DOE reservation, the population of Waverly was 4,408 in 2010.
- The largest population center in the region of influence is **Chillicothe**, which is located in Ross County. Chillicothe is 27 miles north of the DOE reservation, and had a population of 21,901 in 2010.
- **Portsmouth** is in Scioto County and is 27 miles south of the DOE reservation. The population of Portsmouth was 20,226 in 2010.
- **Jackson** is located in Jackson County and is 26 miles east of the DOE reservation. In 2010, Jackson's population was 6,397.

4.5 Wetlands

A wetland survey of the Portsmouth site was conducted in 1995. There are forty-one wetlands designations, which total approximately 34 acres of land on the site, excluding retention ponds. Forty-one of these wetlands meet the criteria for jurisdictional wetlands, while four wetlands are non-jurisdictional. Wetlands on the site primarily support emergent vegetation that includes cattail, great bulrush, and rush. Palustrine forested wetlands occur on the site along Little Beaver Creek.

Wetland field assessments inside Perimeter Road were updated in the fall of 2014[4]. This wetland assessment followed the same methodology used in the previous study of the northeastern portion of PORTS. Field surveys identified 69 total wetlands, totaling less than 15 acres, inside Perimeter Road. Thirty-six of the wetlands were categorized as Category 1[5], 10 were categorized as Category 2[6], and the remaining 23 wetlands were classified as Category 1 or 2 or Modified Category 2. Like the previous study, no high-quality Category 3 wetlands[7] were identified. The locations and categories of the wetlands that have been identified at PORTS in previous studies and maintained in a database are presented in Figure 9. The wetland assessments have identified 148 wetlands covering approximately 36 acres. Most of the acreage (approximately 23 acres) is identified as Category 2.

5 Business Case

5.1 Reactor Technology Considerations

The reactor technologies considered for this study are the Modular High Temperature Gas-Cooled Reactor (MHR), the Sodium Fast Reactor (SFR), and the Molten Chloride Fast Reactor

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[4] Wastren Advantage Inc. [WAI] and Stantec Consulting Services, Inc.

[5] Ohio Administrative Code (OAC) Rule 3745-1-54(C)(1) defines Category 1 wetlands as wetlands that support minimal wildlife habitat, and minimal hydrological and recreational functions, and as wetlands do not provide critical habitat for threatened or endangered species or contain rare, threatened or endangered species.

[5] OAC Rule 3745-1-54(C) states Category 2 wetlands constitute the broad middle category that support moderate wildlife habitat, or hydrological or recreational functions, but also include wetlands which are degraded but have a reasonable potential for reestablishing lost wetland functions.

[7] Wetlands that are assigned to Category 3 have superior habitat, or superior hydrological or recreational functions. They are typified by high levels of diversity, a high proportion of native species, and/or high functional values. Category 3 wetlands include wetlands which contain or provide habitat for threatened or endangered species, are high quality mature forested wetlands, vernal pools, bogs, fens, or which are scarce regionally and/or statewide.

(MCFR). Reactor technology descriptions and considerations for deployment are discussed in the Task 2 report "Business Case Template for Evaluation of Advanced Reactor Technologies at Candidate Sites," [USNC 2017]. Reactor technology considerations include:

1. Technology Readiness
2. Fuel Qualification
3. Safety Considerations
4. Process Heat Capability
5. Energy Efficiency
6. Fuel Cycle Considerations

These considerations and recommended approaches for evaluating these considerations are discussed in [USNC 2017].

The NGNP Industry Alliance (NIA) has the expertise and design information to quantitatively evaluate the MHR for deployment at the four candidate sites. However, because the NIA supports MHR technology, the NIA does not intend to quantitatively evaluate the SFR and MCFR with respect to the MHR, since inherent biases may result. Instead, the NIA will make qualitative remarks on these technologies based on the judgments of those performing the screening evaluations and project review of the screening evaluations.

The Task 2 report describes a screening methodology for the four candidate sites under consideration and includes a Business Case Screening Evaluation Template. For these higher-level business case assessments, it is assumed that most reactor technology considerations are independent of the site under consideration, with some allowance for exceptions at sites that may favor a particular reactor technology. The Task 2 template provides the NIA assessment of the MHR site-independent technology considerations with qualitative remarks for the SFR and MCFR, and includes site-specific allowances under a separate category.

5.2 Economics and Commercialization Potential

5.2.1 Market Potential – U.S. and International

Increasing the market potential within the US and internationally will require further analysis of data and markets. Goals and objectives this include, but are not limited to:

- Serving existing markets;
- Creating new markets, both domestic and "off-shore" opportunities;
- Utilizing the hydrogen generated to satisfy the demands created by aggressive programs to utilize hydrogen in the future; and
- Developing "flexible" processes that can adapt to shifts in markets.

"Flexible" processes are those that can be utilized to accommodate alternate feedstocks and alternate products. It is not credible to predict future markets; however, what is achievable is to develop the flexibility of the process plant industries, utilizing the co-generated energy from high temperature heat source, to remain economically viable and adaptable to dramatic changes in

both the energy and product markets. A viable energy future requires demonstration of innovative and flexible technologies that can adjust to market changes.

5.2.2 Demonstration Module/Plant Costs

Table 3-1 provides the cost elements from the NIA Business Plan [NIA 2015] for the AREVA SC-HTGR 625 MWt MHR design. Where appropriate, the cost elements given in the table factor in assumed values for annual interest rate, fixed charge rate, indirect costs, and construction time period to account for the time cost of money.

Table 5-1: Development Venture and Deployment Project Cost Elements

Cost Element	$M (2012)
Development Venture	
Technology Development	245
Complete Preliminary Design	280
Complete Final Design	200
Licensing Activities	165
FOAK Modifications for Initial Operations	75
Total – Development Venture	965
Deployment Project	
Site – Specific Design	100
NRC License and Regulatory Permits	65
Equipment Procurement (Including Long-Lead Items)	432
Construction	625
Startup and Testing	55
Initial Operations (3 Years)	348
Total – Deployment Project	1360
Total – Development + Deployment for Demonstration Module	2325

Table 5-2: Steam Methane Reformer Deployment Project Cost

Cost Element	$M (2017)
Construction of SMR	
Initial Operation (3 Years)	
Natural Gas supplied to the Site	
Hydrogen delivered to End Users	
Total – Deployment Cost for Steam Methane Reformer	

Table 5-3: Cost Avoidance Opportunities at PORTS

Cost Element	$M (2017)
Existing Water/Wells System (X-6609 & X-608B)	7.8
Existing Sewage Treatment Facility (X-6619)	.7
Existing Fire Station/Emergency Response (X-1007 & X-1020)	3.8
Dry Air Plant (X-670)	4.3
OVEC Switchyard/Power to the Site (X-530B)	31.5
Site Preparation/Construction Roads	*TBD*
Facilities to house Construction Workers/Management Team (X-1000)	12
Rail Access/Spur	*TBD*
Total – Cost Avoidances for Existing Infrastructure/Utilities	*>60.1*

Figure 5-1 Water Treatment Facility at PORTS

5.2.3 NOAK Commercial Plant Costs

The capital and energy production costs for a NOAK commercial plant are an important consideration before deciding to proceed with a demonstration plant/module. At a minimum, these costs must be competitive with existing LWRs (for electricity) and fossil fuels (for electricity and process heat) and uncertainties in these costs should be minimized.

Expansion of nuclear energy in the U.S. is significantly inhibited because of the currently low price of fossil fuels and the absence of a national carbon-emission pricing policy. For deployment of new LWRs, [DOE 2016] recommends a production subsidy/payment of approximately $0.027/kWe-hr for generation of carbon-free electricity for a time period to be

determined. This subsidy/payment may also be required for advanced reactors if fossil fuel prices remain low out to the time frame of their deployment.

For this study, it is recommended the MHR, SFR, and MCFR be treated equally for evaluation with respect to NOAK commercial plant costs.

5.2.4 Potential for International Collaboration

The SODI Piketon Integrated Energy System (IES) Plant concept has several parallels with the goals/objectives being pursued by other nations including Poland, Korea, Japan and the EU generally:

- Primary interest in utilizing the Process Heat for supplying energy intensive industrial users;
- Use of high temperature advanced reactors for to produce hydrogen; and
- Developing an approach that utilizes both a Nuclear Energy source and a Natural Gas Fired Energy source for the operation of their IES concept.

There is strong interest within the state of Ohio regarding the future for Hydrogen Fuel Cells. SODI and the NGNP Industry Alliance are pursuing a strategy that incorporates an international partnership to support the deployment (possibly in parallel with Poland) of a FOAK modern HTGR at Piketon. The strategy would help reduce the costs of such deployment and increase political and industrial interest in the project and help provide funding stability through the years necessary to complete the project.

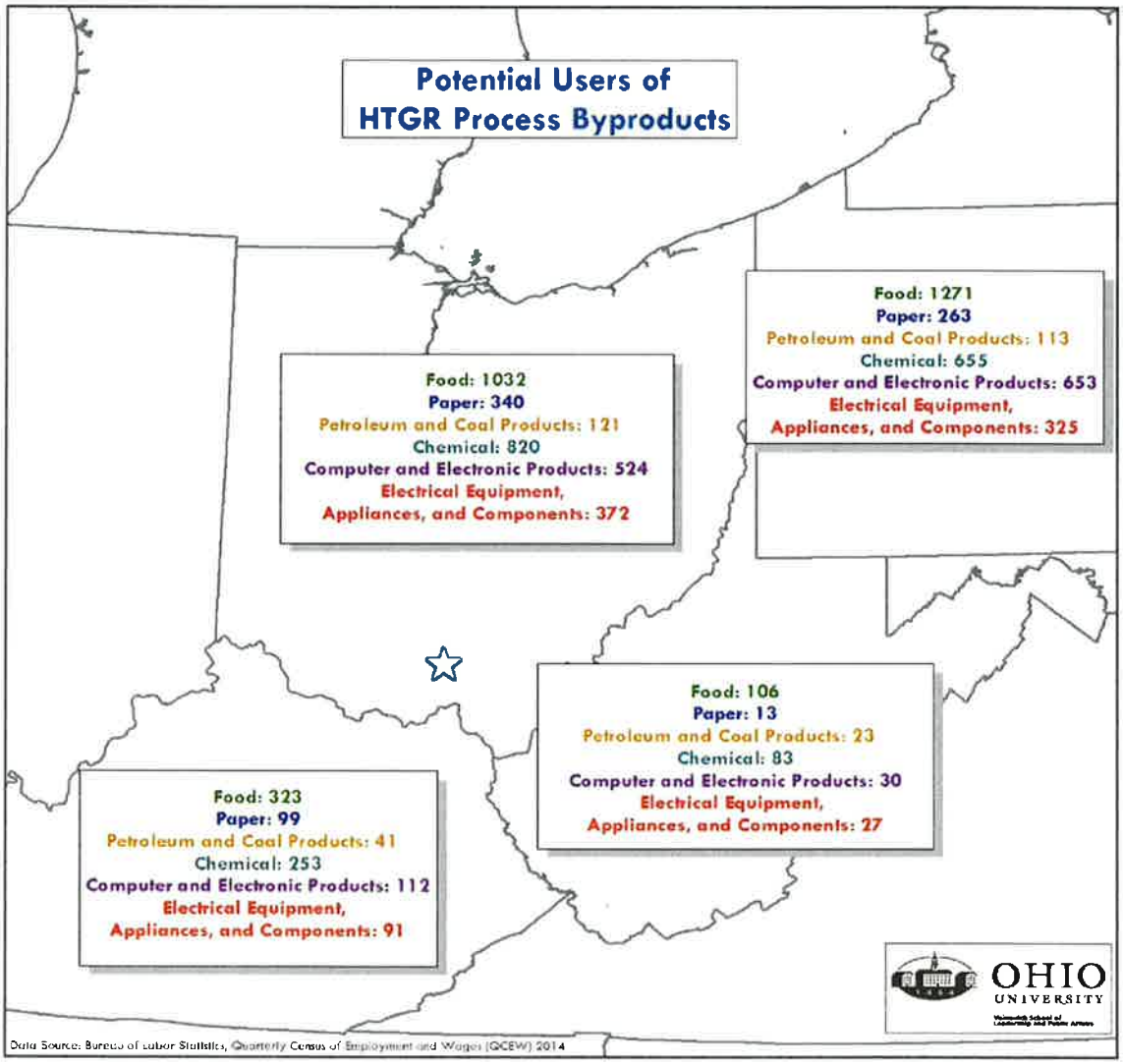
5.2.5 Impacts on Local Economy

The SODI Demonstration Plant Project diagram shown in Figure 4-2 depicts the integration of high temperature heat with an on-site generator and steam methane reformer to:

- Produce electricity for on-site use by the Demonstration Plant and sale to potential customers;
- Produce hydrogen for use in transportation fuels, polymers, plastics, fertilizer, hydrogen fuel cell market; and
- Produce CO_2 that could have potential off-site markets within the region.

The primary markets initially being evaluated as part of the Demonstration Project are the sale of electricity within the region and the supplying of hydrogen to an oil refining facility. However, as the diagram below illustrates, there are various markets that exist within the four-state region surrounding the DOE PORTS Reservation that could utilize the products that could be produced from the deployment of the advanced reactor and a Steam Methane Reformer (SMR):

Figure 5-2: Potential Markets for Demonstration Plant Products



The potential monetary benefits can be seen in the table below:

Table 5-4: Potential Demonstration Plant Economic Benefits

Vended Product	End User	Value per unit	Total Value
H_2	Marathon, Air Products, etc.	$ /Million Liters	$/ML x Production
E	Grid	$/MW hour	
CO_2	…		

5.3 Licensing Considerations

For over half of a century, the Piketon community and the surrounding counties have provided overwhelming support to the government's successful nuclear energy initiatives including construction and operation of the Portsmouth Gaseous Diffusion Plant, construction and start-up of the DOE Gaseous Centrifuge Enrichment Plant, Environmental Restoration, the DUF_6 Processing Facility, and the United States Enrichment Corporation (USEC) Advanced Centrifuge Project. The Piketon plant has a lengthy history of safe nuclear facility operations, and already has proven its ability to meet environmental and regulatory standards for other facilities. The results of the OU Voinovich Outreach Program are overwhelmingly in favor of nuclear power and energy production

The site has experience with both NRC and DOE regulation and oversight:

- Part 76 Certificate of Operation for the GDP;
- Part 70 License for the USEC Lead Cascade;
- Part 70 License for the USEC American Centrifuge Plant (ACP); and
- Numerous Environmental Impact Statements (EISs) have been completed for the site (Lead Cascade/American Centrifuge Plant, etc.).

With numerous siting studies performed at the PORTS site since the original construction of the Gaseous Diffusion Plant in 1952, PORTS is very well characterized in terms of the specific siting requirements associated with the proposed nuclear facilities. Regulatory driven services including emergency preparedness, environmental and radiological monitoring, emergency medical, fire and hazmat responders, and security are already present on the site. PORTS has a continuing nuclear mission with the operation of the DOE owned DUF_6 Facility and has a history of providing overwhelming support to the government's successful nuclear energy initiatives. Future nuclear industrialization is a good fit with existing site uses and the workforce in the area. No site environmental characteristics or regulatory requirements would prevent siting an advanced nuclear reactor at PORTS.

Figure 5-3: PORTS Site Fire Station

5.4 Siting Considerations

The capability to meet all the requirements for the location of an advance reactor have been highlighted in the other chapters of this document. An equally important siting consideration is the ability to hire, train and maintain a qualified workforce. The four-county region of influence has a skilled nuclear workforce with both DOE and NRC regulatory experience. Training and education centers offer extensive capabilities – 6 public universities within 75 miles of the DOE reservation, two with nuclear engineering programs; 13 public community colleges within 75 miles of the DOE reservation; Battelle Memorial Institute located 60 miles north in Columbus, Ohio;, National Composite Center located 75 miles northwest in Dayton, Ohio;, Edison Welding Institute located 60 miles north in Columbus, Ohio;, Cincinnati Machining Company located 75 miles west in Cincinnati;, and the University of Cincinnati Center of Robotics located 75 miles west in Cincinnati.

6 Conclusions/Recommendations

The design, construction and operation of a nuclear reactor and a Steam Methane Reformer (SMR) at a Demonstration Plant aligns with the goals of the Southern Ohio Diversification Initiative (SODI) to deploy a demonstration project in support of an Integrated Energy System (IES). This represents a significant initial step in SODI's vision of redeveloping the fully industrialized nuclear reservation to address the energy needs of the future, while providing economic development opportunities for the region, state and nation. Having received a NRC Certificate of Operation for the Gaseous Diffusion Plant (GDP) and two (2) NRC Licenses for the operation of centrifuge technology facilities, the capability to prepare an Environmental Impact Statement (EIS) and obtain licensing for a SODI Demonstration Plant concept is extremely compelling. As a result of the interfaces and studies in support of the Environmental Protection Agencies, both state and federal, and the Nuclear Regulatory Commission over the past 30 years, the probably of having any significant unknowns relative to the site is extremely small. The information collected during this site evaluation activity demonstrates that the Portsmouth DOE Reservation (PORTS) site would be an excellent site for location of a SODI Demonstration Plant. The PORTS site possesses numerous physical attributes that would benefit the siting, construction, and operations of the facilities, and there are no regulatory issues that would prohibit siting it on the DOE reservation.

There were no Exclusionary Criteria nor Discretionary Criteria identified that would prevent the construction of a nuclear reactor on this site. The fact that the site was designed and operated as a nuclear industrial facility provides assurance that the site is well suited for both a demonstration plant and an integrated energy system centered around and advanced reactor technology. The future usage of the high temperature process heat from the advanced reactor offers significant advantages as the sensitivity to climate change increases throughout the world.

To better understand the advantages associated with the use of the process heat, as well as to educate industry on the advantages of the AREVA High Temperature Gas Reactor (HTGR), it is recommended that the Southern Ohio Diversification Initiative (SODI) and the Next Generation Nuclear Plant (NGNP) Industry Alliance (NIA) continue with their planned meetings with "end users".

References

DOE GNEP Detailed Site Report Portsmouth Reservation, Piketon, Ohio Affected Environment And Regulatory and Environmental Permitting/Licensing Requirements, May 1, 2007

NGNP Advanced Reactor Site Feasibility Evaluation – Technology Parameter Envelope

NGNP Advanced Reactor Site Feasibility Evaluation Business Case Template for Evaluation of Advanced Reactor Technologies at Candidate Sites, USNC-NIA-G00008 Revision 0, February 2017

Exclusionary Criteria for Deployment of Advanced Reactors in the United States, AREVA Document No.: 51-9266268-000, January 25, 2017

Ohio Rapid Assessment Method for Wetlands v. 5.0 User's Manual and Scoring Forms, February 1, 2001, State of Ohio Environmental Protection Agency

Environmental Impact Statement for the Proposed American Centrifuge Plant in Piketon, Ohio, Final Report (NUREG-1834, Vol. 1)

Site Location/Description: DOE Portsmouth Reservation near Piketon, OH
Business Application: Production/Sale of Electricity and Hydrogen (H_2)

Category/Subcategory	(%)	MHR			SFR	MCFR
		Rating	Score	Basis	Qualitative Remarks	Qualitative Remarks
1.0 Reactor Technology Considerations (25)						
1.1 Technology Readiness	4	6	24	Overall TRL rating. See Section 5.1.1.	Approximately same TRL as MHR.	Much lower TRL than MHR and SFR. Much later deployment time frame.
1.2 Fuel Qualification	4	6	24	AGR program. See Section 5.1.2.	Approximately same or slightly lower rating than MHR.	Molten fuel may have significant challenges.
1.3 Safety Considerations	7	9	63	Complete loss of coolant does not impact safety case. See Section 5.1.3.	Loss of sodium coolant can lead to severe consequences.	Loss of molten fuel can lead to severe consequences.
1.4 Process Heat Capability	6	8	48	Can replace fossil fuels and transition to higher temperatures. See Sections 2 and 5.1.4.	Current design is for electricity only. Lower coolant outlet temperature (~500°C) is less suitable for process heat applications.	Current design is for electricity only. With its 800°C outlet temperature, design could be adapted for process heat applications.
1.5 Energy Efficiency	4	8	32	High coolant outlet temperatures increase thermal efficiency. Direct utilization of process heat also increases efficiency. See Section 5.1.5.	Lower thermal efficiency than MHR for electricity generation.	Somewhat higher thermal efficiency for electricity generation than MHR.
1.6 Fuel Cycle Considerations	0	N/A	N/A	Dependent on national fuel cycle policy. Per Section 7.2, good fuel cycle synergy with fast reactors.	Fast neutron spectrum allows for breeding fissile fuel. Operation in burner mode allows destruction of transuranics.	Insufficient information to assess fuel cycle considerations.
1.0 Subtotal			191			
2.0 Economics and Commercialization Potential (35)						
2.1a Market Potential – U.S.	7	9	63	Growing market for Hydrogen production in the US, as well as a potential market for electricity from the future use of electric cars. Site is strategically located for power distribution and supporting industries using the Hydrogen.	Co-location with other industries may prove challenging. Lower coolant outlet temperature (~ 500° C) is less suitable for process heat applications.	May share some of the same potential as MHR Difficult to assess because of the low Technology Readiness Level compared to the MHR and SFR.
2.1b Market Potential - International	7	9	63	Growing global interest in hydrogen production, particularly in Japan and Korea. Foreign interest in future Hydrogen markets. Deployment of MHRs can be extremely important in countries with limited natural resources. Safety factors have increased sensitivity	Lower coolant outlet temperature (~ 500° C) is less suitable for process heat applications. The technology is largely limited to nuclear states with significant export control restrictions. Other nuclear states have SFR design/technology programs that are more advanced than the U.S. program.	May share some of the same potential as MHR Difficult to assess because of the low Technology Readiness Level compared to the MHR and SFR.

				in countries with limited land availability and population densities	The traveling wave sodium reactor under development is attempting to address export control challenges.	
2.2 Demonstration Module/Plant Costs	3	7	21	Site cost avoidances and schedule advantages due to the existing infrastructure, utilities and support facilities. Difficult to estimate the significance of total value of the electrical distribution system supporting site. It may be necessary to provide additional piping for product distribution.	About the same as the MHR.	Much more uncertain than the MHR.
2.3 NOAK Commercial Plant Costs	5		0			
2.4 Potential for International Collaboration on Reactor Technology	5	9	45	Demonstration Plant aligns well with the proposed Polish national program. High level of Japanese and Korean interest in a partnership for FOAK HTGR deployment in the U.S. High interest globally in utilizing the process heat to produce Hydrogen and drive other energy intensive industries. Demo Plant positions US to lead Energy development.	Possibly good. But Russia, France and Japan already have strong national programs.	Unknown, but the U.S. seems to be the country primarily interested in MCFR at this stage
2.5 Impacts on Local Economy	8	9	72	Jobs produced by the construction and operation of an advanced reactor and a Steam Methane Reformer. Local economy could be very positively impacted by the products produced at the site. Ability to reduce supply costs provides the "end users" a competitive advantage for expanding their market share, resulting in additional economic impact.	Jobs produced by the construction and operation of an advanced reactor and a Steam Methane Reformer. Local economy could be very positively impacted by the products produced at the site. Ability to reduce supply costs provides the "end users" a competitive advantage for expanding their market share, resulting in additional economic impact.	Jobs produced by the construction and operation of an advanced reactor and a Steam Methane Reformer. Local economy could be very positively impacted by the products produced at the site. Ability to reduce supply costs provides the "end users" a competitive advantage for expanding their market share, resulting in additional economic impact.
2.0 Subtotal			264			
3.0 Licensing Considerations (15)	15	9	135	Significant past licensing and regulatory review/approval activities. The site meets and/or exceeds all exclusionary requirements>	Less licensing activity to date. Unclear whether NRC will accept fuel experience from EBRII. Piketon related GNEP studies have looked at breeder reactor and fuel cycle issues	Unclear how NRC will address this very innovative homogeneous fast reactor concept.
4.0 Siting Considerations (25)						

4.1 Technology Considerations	10	9	90	Extremely well suited for supporting the technical considerations of deploying a HTGR. No Exclusionary Criteria exists that negatively affect the site, and there are not EIS concerns	Extremely well suited for supporting the technical considerations. No Exclusionary Criteria exists that negatively affect the site, and there are not EIS concerns	Extremely well suited for supporting the technical considerations of deploying a HTGR. No Exclusionary Criteria that negatively affect the site, and there are not EIS concerns
4.2 Site-Specific Considerations	15	9.5	142.5	Capability to meet all siting requirements exists. The PORTS reservation possesses numerous geological and physical attributes from previous industrial use including mature roads systems, water and waste systems, power distribution systems and on-site facilities such as warehousing, office buildings and parking access. In addition to physical attributes, social and community support for redevelopment of the site and previous missions have brought a technical and nuclear professional workforce to Ohio	Capability to meet all siting requirements exists. The PORTS reservation possesses numerous geological and physical attributes from previous industrial use including mature roads systems, water and waste systems, power distribution systems and on-site facilities such as warehousing, office buildings and parking access. In addition to physical attributes, social and community support for redevelopment of the site and previous missions have brought a technical and nuclear professional workforce to Ohio	Capability to meet all siting requirements exists. The PORTS reservation possesses numerous geological and physical attributes from previous industrial use including mature roads systems, water and waste systems, power distribution systems and on-site facilities such as warehousing, office buildings and parking access. In addition to physical attributes, social and community support for redevelopment of the site and previous missions have brought a technical and nuclear professional workforce to Ohio
4.0 Subtotal			232.5			
Total			822.5			

APPENDIX B: SE PROXY SITE

Date: 07/25/2017
ND-17-1162
R-Type SND.BD.L06

Signature Block 1: Matthew T Montz

Signature Block 2:

Version Summary

Version	Description
0	Issued as final
1	Editorial changes to Table on pages 17-19

Southeastern Demonstration Plant Site

1. Executive Summary

A retired coal fired power plant site was selected for the Southeastern proxy site. This 'brownfield' site was used to evaluate the potential for other retired electric generating plant and industrial sites to host advanced reactor (Gen IV) technologies currently under development.

Brownfield sites, due to the nature of their previous development, often offer easy access to critical infrastructure such as roads, rail, water and transmission. Similarly, redevelopment of these sites typically result in significantly less environmental impacts compared to new construction at undisturbed 'greenfield' sites. And finally, brownfield redevelopment can reduce or even eliminate the negative economic impacts associated with the closure of the facility originally located at the site.

Siting Gen IV reactors at brownfield sites is not, however, without its challenges, since the Nuclear Regulatory Commissions (NRC's) strict site and safety requirements must still be met. Site soil and seismic properties, nearby population centers, water availability and numerous other site and environmental characteristics must be considered.

2. Background

Southern Nuclear Operating Company (SNC) selected a former Georgia Power Company (GPC) coal site for a pre-conceptual Demonstration Plant analysis of a brownfield site within the southeast region. Located on 3,203 acres adjacent to Lake Sinclair, the plant was the first million-plus-kilowatt electric generating station to operate on the GPC system. The site is in Putnam County between the towns of Eatonton (population 6,530) and Milledgeville (population 19,256).

Figure 1 – Site Location

Construction on the plant began in 1961, and by the summer of 1969, four units were in operation.

- Plant Nameplate Capacity: 1,746 Megawatts (MW)
- Units and In-Service Dates: 299 MW (1965), 359 MW (1967), 544 MW (1968), 544 MW (1969)
- Location: 1100 Milledgeville Rd., Milledgeville, GA 31061
- Located in Putnam County. Adjacent Counties are Morgan (N), Greene (E), Hancock (E), Baldwin (S), Jones (S), and Jasper (W).

In April, 2015 the facility was closed and demolition began.

Figure 2 – Site Prior to Plant Decommissioning

3. Exclusionary Criteria

Site values for the following criteria cannot be met or exceeded. None of these values are met or exceeded by this site.

Category	Value (not to exceed)
Seismic	• Peak Ground Acceleration > 0.3 g at a probability of exceedance (PE) of 2 percent in 50 years • Located within five miles (8 Km) of a capable fault
Flooding	• Located within the 100-year flood plain
Hazards	• Accidents at nearby industrial or military facilities posing undue risk to the nuclear plant due to shock waves and missiles from explosions (depends on plant design and distance to plant) • Directly in line with runways on high-operations commercial or military airports. • Low lying areas downstream of major dams
Transmission Lines	• Less than 230 kilo-Volt (kV) capacity and less than two independent sources of off-site power within 30 mi (48.3 km)
Federal and State Lands	Located on one of the following: • National/state parks • National/state historical sites

	• National/state seashores and lakeshores • National/state rivers and scenic riverways • National/state wildlife refuges • Wilderness areas • National maritime sanctuary areas • Cultural resources (American Indian lands, national landmarks)

A summary and evaluation of these exclusionary criteria as they relate to the site are described below.

3.1. Seismic

Regulatory requirements are established for nuclear power plant structures, systems, and components important to safety must be designed to withstand the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, floods, tsunami, and seiches without loss of capability to perform their safety functions. From analysis performed for this site, it is worthy of additional consideration for a demonstration plant.

To fully evaluate a potential site for seismic hazards, a great deal of information is needed – including subsurface (soil/rock) investigations and analysis of seismic hazard information. Methodologies required for nuclear facility siting are different from those methodologies used for fossil power plant sites. Techniques for determining seismic hazards for nuclear plants have evolved over the last ten to fifteen years consistent with U. S. Nuclear Regulatory Commission (NRC) guidance[1].

There are useful industry and public information available to further evaluate the feasibility of this site for a nuclear demonstration project. This same information would be useful as site specific seismic hazards are developed. Some examples identified are below:

- Plant Vogtle Electric Generating Plant located south of Augusta, Georgia, currently a two-unit pressurized water reactor (PWR) site, is approximately 100 miles east from the site. The original investigation of historical seismic activity in the Plant Vogtle region is described in the Plant Vogtle Final Safety Analysis Report (FSAR). That document section states that detail studies have revealed no seismological or geological evidence for capable faults within 200 miles of the site. (VEGP 2011) (VEGP 2014)
- The 2012 Central and Eastern United States Seismic Source Characterization (EPRI 2012) and 2013 Electric Power Research Institute (EPRI) ground motion study (EPRI 2013) performed extensive research and analysis using seismic background source inputs that lie within 400 miles of Plant Vogtle. In addition, Repeated Large Magnitude Earthquake sources representing additional sources of seismic hazard to the background sources were included that are within 625 miles of Plant Vogtle. While these studies were not specific to this siting study, the research and analysis was inclusive of the general site area, and provides useful information for seismologist to use in developing site specific seismic hazard information.
- There is historical, site specific geotechnical information dating from the 1960s including boring logs, groundwater information and soil information.

[1] 10 CFR 100 Appendix A —Seismic and Geologic Siting Criteria for Nuclear Power Plants

- In 2009, a subsurface investigation report was prepared in support of the construction of a Selective Catalytic Reduction (SCR) project at the site (Southern 2009).
- An EPRI investigation was performed to develop S-wave velocity (Vs) models to a depth of 30 m, or more, and to estimate the average shear wave velocity of the upper 30 m (VS,30) at 33 earthquake recording stations located in Central and Eastern United States. (EPRI 2013). One of the sites was located at Eatonton, Georgia approximately 12 miles from the site. The $V_{S,30}$ was determined to be 990 ft/s. This information, reported in 2013, would be useful to seismologists and engineers in determining the Peak Ground Acceleration using present day techniques for nuclear plants.

3.2. Flood Zone

As mentioned above, the site is located adjacent to Lake Sinclair. Lake Sinclair is an impoundment (Sinclair Dam) of the Oconee River and was created in 1953. The lake is approximately 15,330-acres.

Floodplains are land areas adjacent to streams or rivers susceptible to being inundated by stream-derived waters. The Federal Emergency Management Agency (FEMA) Flood Insurance Rate Map was obtained for the site (Panel 0275C) and indicates the location of the 100-year floodplain. The Flood Zone map shows that the site is not located in a flood zone (See Attachment 1 - FEMA Flood Map) and lists Lake Sinclair as Zone A 'No Base Flood Determination'. (FEMA 2017)

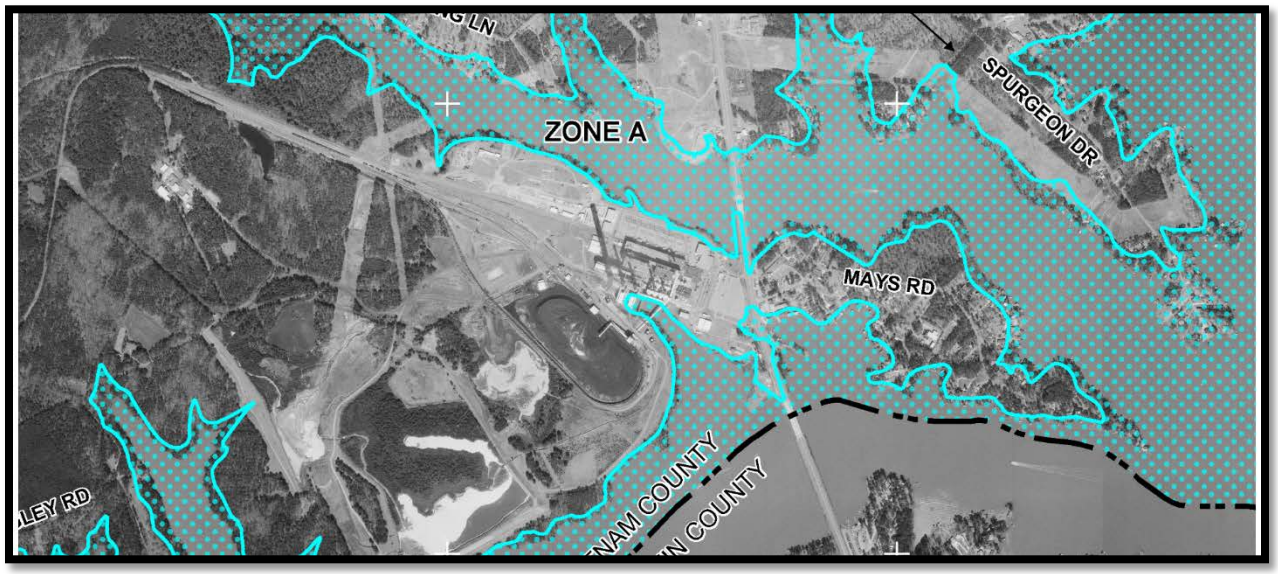


Figure 3 – Site Flood Map

3.3. Hazards

There are no significant hazards within close proximity to the plant. The following facilities were noted in the area:

- Airports
    - The Baldwin County Airport is located approximately 4.3 miles southeast of the site. The Baldwin County Airport is a county owned, public use airport and is included in the

National Plan of Integrated Airport Systems for 2011–2015, which categorizes it as a general aviation facility. (Wikipedia, 2017)

- Deerfield Landing is a grass landing strip located 2 miles north of the site. No additional information was available for this facility; however, no high-operations commercial or military air traffic occurs at this location. (Google 2017)

- Military Bases – there are no known military installations within 2 miles of the site.
- Industrial/Chemical Sites – there are no known industrial/chemical complexes within 2 miles of the site.
- Pipelines - Per the National Pipeline Mapping System website (NPMS 2017) there are no pipelines located within 2 miles of the site. The nearest pipelines are:
  - Natural gas pipeline located 9 miles south of the site in Baldwin Co. It is operated by Atlanta Gas Light Co.
  - Natural Gas pipeline located 12 miles south in Baldwin Co. It is operated by Southern Natural Gas.
  - Liquefied Petroleum Gas (LPG) line operated located 13 miles north of the site in Putnam Co. It is operated by Dixie Pipeline Company.
- Upstream Dams
  - Wallace Dam, operated by Georgia Power Company, is located 14 miles northeast of the site. The project reservoir, Lake Oconee, covers 19,000 acres. (GPC 2017)

    A dam break analysis would be required during licensing.
- Subsurface Mining
  - No surface or subsurface mining operations were identified within 5 miles of the site. Numerous sand and gravel mining operations were noted approximately 20 miles south of the site.

3.4. Transmission Lines

The site has substantial transmission infrastructure in place. There are nine 230kV transmission lines terminating in a switchyard at the site. While in operation, the previous plant was capable of generating approximately 1700 MW. If additional transmission capability is required to support the facility, there is a 500kV transmission line (not connected to the existing switchyard) approximately 4 miles northwest of the site.

3.5. Federal and State Lands

The site is owned by GPC and is not located on or adjacent to federal or state lands. The nearest state owned lands is the Cedar Creek Wildlife Management Area (WMA) located approximately 5 miles west of the site (closest boundary). (Google 2017)

The wildlife management area extends over 37,820 acres and allows activities including camping, fishing, hiking, picnicking, and hunting. (CCWMA 2017)

Also, located nearby is the Bartram Forest WMA (13 miles south); the Piedmont Nation Wildlife Refuge (20 miles west); and Oconee National Forest (24 miles north). (Google 2017)

4. Discretionary Criteria

The following discretionary criteria are not to be used to exclude a site from consideration, but are envisioned to be important to the business case.

Category	Value
Cooling/Dilution Water	• Water amount not sufficient to meet plant design • Water source not located nearby
Need for process heat	• Need for power/ process heat does not exist
Airport, barges, rail lines, and roads	• No preexisting infrastructure with 10 miles (16.1 km)
Population	• Located with four miles (6.4 km) of a population center of 25,000 or more • Located within 10 miles (16.1 km) of a population center of 100,000 or more • Located within 20 miles (32.2 km) of a population center of 500,000 or more • Located within 30 miles (48.3 km) of a population center of 1,000,000 or more
Wetlands	Large amount (> five acres) of wetlands impacted by construction

4.1. Cooling/Dilution Water

The source water for the facility comes from Lake Sinclair. During operation of the coal fired plant, the site was permitted to withdraw approximately 1254 million gallons per day (mgd) for cooling. Additionally, the plant successfully operated under a National Pollutant Discharge and Elimination System (NPDES) permit utilizing once through cooling with mechanical draft 'helper towers' to reduce thermal impacts to the lake. Previous commercial power plant needs at the site were identified and monitored during the operational phase and early analysis indicates the requirements for cooling and dilution water can be accommodated. Note that only one of the three nuclear technologies in this study identified specific water requirements and the remaining two were incomplete in their definitive input in this area.

4.2. Need for Power/Process Heat

SNC's interest in evaluating a demonstration plant site lies primarily in electric power generation. Therefore, this evaluation focuses on the geographic area serviced by GPC and their need for increased electrical generation rather than focus on process heat or steam for industrial processes.

In the state of Georgia, GPC is fully regulated by the Georgia Public Service Commission (PSC). Through an Integrated Resource Plan (IRP) submitted to the PSC by GPC, an evaluation of the need for power within the system is evaluated and justified. The PSC has established detailed regulatory requirements for IRPs. Those requirements include the following:

- Energy and demand forecasting – The plan must report and use 3 years of historic data and address each of the next 20 years. Forecasting must be weather-normalized and address the jurisdictional area, retail and wholesale loads, customer classes, and annual load factors. The regulation specifies forecasting methodology and determinants, and standards for data inputs. Finally, the plan must include an evaluation of the sensitivity of the results to changes in major

assumptions and estimates used. The sensitivities must include a reasonable range of sales and demand and include base growth, high-growth, and low-growth scenarios.

- Capacity resource identification – The plan must identify existing resources, including power purchases, sales and exchanges, demand-side programs, cogeneration, standby generation, interruptible service, pooling or coordination agreements, generation, and transmission. It must address potential new supply- and demand-side resources and the associated decision making process (the regulation details the process for securing long-term new supply-side options).
- Integrated plan development and filing – In addition to energy and demand forecasting and capacity resource identification, the plan must address alternatives to proposed generation; environmental impact of proposed and alternative generation; economic, environmental, and other benefits to the state and consumers; and financial information. The plan must identify the integrated combination of demand- and supply-side resources selected to satisfy future energy demands. Periodically after plan approval, the utility must report on actions taken to implement the plan and any deviations from the plan. A new plan must be filed every 3 years.4

The Georgia integrated resource planning process satisfies the NRC's Need for Power analysis and meets the NRC's criteria for an acceptable state plan through a systematic, comprehensive approach that is subject to confirmation and responsive to forecasting uncertainty. (VEGP 2008)

Georgia law and PSC regulations, orders, and requests prescribe the Georgia integrated resource planning process (Official Code of Georgia Annotated [O.C.G.A.] 515-3-4) that includes evaluation of the need for additional electric generation capacity. Planning is updated every three years. Each triennial review culminates in a PSC order approving (with modifications as necessary) and adopting the plan. The PSC approval process involves prescribed reviews and hearings and typically takes 150 days. SNC has concluded that the statutory, regulatory, and administrative requirements that make up the Georgia process comprise a methodical state process for regularly reviewing, in a thorough fashion, the need for power that GPC is responsible for satisfying.

The State of Georgia's planning encompasses energy and demand forecasting, capacity resource identification, integrated plan development, supply-side and demand-side resource evaluation, renewable resource assessment, and includes comparisons of historic forecasted versus actual load results. The plan looks forward 10 years for transmission and 20 years for demand and energy planning. SNC has concluded that the Georgia need-for-power planning process encompasses all the components that NRC would cover if NRC had to perform a detailed review, covering the subject completely.

The utility prepares the plan. The PSC staff and outside experts review the plan and perform their own analyses, as needed. The PSC solicits public comment and utility, staff, and public testimony, and maintains supporting documentation on a publicly available website. A division of the Governor's Office represents state residents and small commercial customers in the proceedings. The Georgia integrated resource planning process is subject to confirmation in multiple ways; several entities review the utility-prepared plan, the PSC review is conducted in a public forum, and the PSC requires interim reviews on plan implementation. SNC concludes that the resultant need-for-power analysis is fully corroborated, including supporting evidence.

Planning begins with an evaluation of the accuracy of past forecasts and incorporates lessons-learned into current forecasting. The plan also must include an analysis of the sensitivity of all major

assumptions and estimates used and include, at a minimum, base case, high-growth, and low-growth scenarios. Uncertainty factors evaluated include population and demand growth, customer mix changes, weather normalization, gas fuel cost volatility, reserve margins, unit retirements, conservation impacts, and environmental compliance costs. SNC concludes that Georgia's use of established models capable of performing sensitivity analyses, together with PSC-required uncertainty analysis, ensures that the state process responds appropriately to uncertainty that is inherent in the forecasting process.

SNC concludes that Georgia, having opted to retain traditional regulation of its investor-owned utility, has the kind of integrated resource planning process that meets the NRC need for power evaluation and satisfies their criteria for an acceptable state need for power analysis. (VEGP 2008)

4.2.1. Load and Energy Forecast

GPC filed its most recent IRP with the PSC in January of 2016 and included predictions on future energy needs.

A twenty-year forecast of energy sales and peak demand was developed to meet the planning needs of GPC. The 2016 energy budget includes the retail classes of residential, commercial, industrial, Metropolitan Atlanta Rapid Transit Authority (MARTA), and governmental lighting.

Both the U.S. and Georgia economies have recovered from the Great Recession and are experiencing growth. However, this growth is well below that experienced in previous economic recoveries. Since the recession ended in mid-2009, real U.S. Gross Domestic Product growth has averaged 2.2% per year. Georgia's growth, however, has lagged that of the U.S. over this period, with its corresponding real Gross State Product growing by an average of just 1.4% per year. The national unemployment rate has fallen from a peak of 10.0% to 5.0% at the end of 2015, while the state's unemployment rate declined from a peak of 10.5% at the end of 2010 to 5.6% as of November 2015.

The modest economic recovery has been reflected in GPC's energy sales statistics for the past few years. Weather normalized total energy sales for 2015 were 1.2% above the prior year's level and remain 1.6% below the previous peak in 2007. The major drop since the recession has been in industrial sales, which remain nearly 6.4% below their pre-recession level on a weather-normalized basis despite growth since 2013. After eight years, residential and commercial energy sales surpassed their pre-recession levels, up 0.8% and 0.2% respectively, in 2015 compared to 2007.

Although underperforming for the past few years, Georgia's economy is expected to regain significant strength over the next several years. Surveys show that the state remains an attractive place to do business and that living costs remain favorable relative to those in many other states. Recent announcements of companies' plans to locate or expand in the state are expected to add numerous jobs to the state. Strong demographic trends are expected to propel Georgia into the top tier of states with respect to economic growth. As the economy improves, energy sales will follow suit. Total energy sales are projected to grow at an average annual rate of 1.2% from 2016 to 2025. Industrial sales will be the strongest of the three major customer classes with growth averaging 1.4% per year; commercial and residential sales will average 1.3% and 1.1%, respectively. Peak demand is expected to grow an average of 1.1% per year from 2016 to 2025.

The electric generation system carries reserves to maintain a desired level of reliability in the face of many uncertainties, the most significant of which are load growth, weather, and generating unit outages. GPC recommends a long-term system target planning reserve margin of 17% (which results in an operating company target of 15.4%) and a short-term system target planning reserve margin of 15.5% (which results in an operating company target of 14%). Without reserve sharing with the other retail operating companies, the Company's first year of capacity need is 2024. Even with the recommended increased target planning reserve margin, the Company's first year of capacity need remains at 2024. (GPC 2016)

4.3. Airports, Barges, Rail lines, Roads

The site has access to roads, rail and air. Below is a list of the various transportation options at the site.

- Airports – As discussed above, the closest airport is the Baldwin County Airport, located approximately 4.3 miles southeast of the site.
- Rail – The site is serviced by an existing GPC owned rail spur which connects to the Eatonton District branch line. Access to the Savannah District mainline rail is via the Eatonton District branch line, both are operated by Norfolk Southern. (OpenRail 2017) The existing rail spur was used to support operations (fuel and equipment) of the now decommissioned coal fired plant.
- Roads – Access to the site is via Highway 441. Access to I-75 and I-16 is approximately 40 road miles southwest of the site. Access to I-20 is approximately 28 road miles north. (Google 2017) Georgia State law (O.G.C.A 32-6-26) allows for max grass weight for transport by designated highway not to exceed 80,000 lbs. unpermitted and up to 100,000 lbs. with proper permit.
- Barge Access – there is no barge access to the site. The closest major port, with access to rail, is the Port of Savannah.

Figure 4 – Area Rail Map

4.4. Population

The major population centers in the seven-county region of influence are as follows:

- Milledgeville, Georgia, population 19,256, located in Baldwin County, approximately 5 miles south of the site.
- Eatonton, population 6,530, located in Putnam County, approximately 10 miles northwest of the site.
- Gray, Georgia, population 3,268, locates in Jones County, approximately 18 miles southwest of the site.
- Sparta, Georgia, population, 1,334, located in Hancock County, approximately 20 miles east of the site.
- Monticello, Georgia, population 2,613, located in Jasper County, approximately 24 miles northwest of the site.
- Greensboro, Georgia, population 3,461, located in Greene County, approximately 27 miles northeast of the site.
- Maddison, Georgia, population 3,973, located in Morgan County, approximately 29 miles north of the site.

Other Population Centers

- Macon, Georgia, population 89,981, located in Bibb County, approximately 32 miles southwest of the site.
- There are no Native American lands on or near the site. (BIA 2017)

4.5. Wetlands

Current wetland delineations have not been performed at the site. However, National Wetland Inventory Maps (Attachment 3) were reviewed and do not indicate any wetlands on the site.

There are several small freshwater ponds located just to the south of the site and wetland features associated Beaverdam creek to the northwest of the site. (FWS 2017) Based on a review of the NWI maps and the site being previously developed, impacts to wetlands are expected to be small.

Figure 5 – National Wetland Inventory Map

4.6. Sites on the National Historic Register

Cultural and historic resource surveys have not been performed at the site. An online search was performed of the National Register of Historic Places for documented resources at or near the site. No historic sites were listed on or within 5 miles of the site. (NRHP 2017)

5. Business Case

5.1. Reactor Technology Considerations

See Task 2

5.2. Economics and Commercialization Potential

5.2.1. Market Potential – U.S. and International

See Task 2

5.2.2. Demonstration Module/Plant Costs

See Task 2 - Table 3-1. SC-HTGR Development Venture and Deployment Project Cost Elements

5.2.3. NOAK Commercial Plant Costs

See Task 2

5.2.4. Potential for International Collaboration

See Task 2

5.2.5. Impacts on Local Economy

The impacts of station operation on the local and regional economy are dependent on the region's current and projected economy and population. Although future impacts cannot be predicted with certainty, some insight can be obtained for the projected economy and population by consulting with county planners and population data. Over the projected 40-year life of a plant, social and economic impacts would occur from additional operation workforce jobs, tax revenue impacts, increased population because of in-migrating workers and their families and increased demand for goods and services. Of these, by far the largest impact is associated with plant property tax revenues.

Baldwin County, because of nearby Milledgeville, would likely receive the largest population and workforce increase as a percentage of its base population and workforce. However, the site is in Putnam County, which would likely receive the substantial property tax benefits from a project.

Property taxes that would be paid during facility operations depend on many factors, most of which are unknown now, including future millage rates. However, rough estimates can be made using information developed during the licensing of the two new nuclear units (Vogtle Electric Generating Plant, Units 3 and 4) currently under construction in Burke County, Georgia. In that case, facility tax payments represent 80 to 82 percent of the total property taxes received by Burke County. Table 1 below provides an estimate of the tax payments for the Vogtle, Units 3 and 4 throughout the life of the plant. (VEGP 2008)

Table 1 - Range of Estimated Annual Property Taxes Paid to Burke County Generated by Plant Vogtle, Units 3 and 4

Years of Operation	Lower Range ($)	Upper Range ($)
2015-2024	20,000,000	29,000,000
2025-2034	16,000,000	23,000,000
2035-2044	10,000,000	14,000,000
2045-2054	3,500,000	5,000,000

Though not as long term as operational economic effects, plant construction has a similarly positive impact on local economies. Construction of new units can employ thousands of construction workers for 7-10 years. These workers, in turn, indirectly support area commerce and pay state and local taxes.

5.3. Licensing Considerations

Licensing of a nuclear facility requires interactions between the prospective applicants and the wide range of federal, state, and local agencies for application and permits. Standardization of the licensing approach for conducting pre-application interactions also adds significant value while establishing common expectations.

Detail site specific environmental and geotechnical evaluations have not been performed at this site. However, based on what is known about the site, several key licensing considerations can be conferred. Specific areas for further consideration include, but not limited to, Geology and Seismology, Emergency Planning and Establishment of the Exclusion Area Boundary, and Flooding.

5.3.1. Geology and Seismology

As required by 10 CFR Part 100 - “Each applicant shall evaluate all siting factors and potential causes of failure, such as, the physical properties of the materials underlying the site, ground disruption, and the effects of vibratory ground motion that may affect the design and operation of the proposed nuclear power plant.” This site-specific information is needed to support numerous evaluations, including the Safe Shutdown Earthquake Ground Motion estimate and other related characteristics such as soil and rock stability, and liquefaction potential.

5.3.2. Emergency Planning and Establishment of the Exclusion Area Boundary

Federal law requires nuclear operating companies to develop emergency response plans for their nuclear energy facilities and to ensure that emergency preparedness plans are in place to protect the public. An effective emergency response is the product of mutually supportive planning and preparedness among several parties: companies that operate the facilities; local, state and federal agencies; and private and nonprofit groups that provide emergency services.

NRC regulations require a facility to establish an EPZ and to consider the time required to evacuate the population, and take other protective actions, for various sectors and distances within the EPZ. These requirements extend to both transient and permanent populations.

Establishment of an EPZ requires coordination with state and local emergency management agencies and first responders, and evaluations to determine the potential for physical characteristics of the site and surrounding area to hinder implementation of an emergency plan.

Additionally, an exclusion area must be designated around the facility. While transportation corridors (highways, railroads, and waterways, etc.) are permitted to traverse the exclusion area, they must not interfere with the normal operation of the facility and must be effectively controlled in case of emergency to protect public health and safety.

State Highway 441 runs adjacent to the east of the site and is the major north/south corridor for the area. Therefore, consideration must be given to the potential impacts associated with including Highway 44 within the EAB.

5.3.3. Flooding

This site is located adjacent to Lake Sinclair and downstream of Wallace Dam and Lake Oconee. The NRC requires applicants to evaluate site for all appropriate external flooding sources, including the effects from local intense precipitation on the site, probable maximum flood on streams and rivers, storm surges, seiche, tsunami, and dam failures.

As a result of the Fukushima event, the NRC is placing greater emphasis on a site susceptibility to floods and Beyond Design Basis Flooding.

5.4. Siting Considerations

5.4.1. Technology

All the advanced reactor technologies discussed in this report can generate electricity, therefore, all are viable technologies for this site. Primary drivers for technology considerations are external market factors, primarily, Need for Power. It is assumed that the site can support the approximately 1700 MW's, equal to the power generated by the previous facility.

5.4.2. Site Specific

As discussed above, the use of a 'brownfield' power plant site to host advanced reactor (Gen IV) technologies currently under development has significant advantages. One of the greatest is access to existing site infrastructure, primarily water and transmission. Additionally, redevelopment of these sites typically result in significantly less environmental impacts compared to new construction at undisturbed 'greenfield' sites. And finally, brownfield redevelopment can offset or even eliminate the economic impacts associated with the closure of the facility originally located at the site.

Site Location/Description: SE Proxy Site						
		Advanced Reactor Technologies				
		MHR			SFR	MCFR
Category/Subcategory	(%)	Rating	Score	Basis	Qualitative Remarks	Qualitative Remarks
1. Reactor Technology Considerations (25)						
1.1 Technology Readiness	4	6	24	Overall TRL rating. See Section 5.1.1.	Approximately same TRL as MHR.	Much lower TRL than MHR and SFR. Much later deployment time frame.
1.2 Fuel Qualification	4	6	24	AGR program. See Section 5.1.2.	Approximately same or slightly lower rating than MHR.	Molten fuel may have significant challenges.
1.3 Safety Considerations	7	9	63	Complete loss of coolant does not impact safety case. See Section 5.1.3.	Loss of sodium coolant can lead to severe consequences.	Loss of molten fuel can lead to severe consequences.
1.4 Process Heat Capability	6	8	48	Can replace fossil fuels and transition to higher temperatures. See Sections 2 and 5.1.4.	Current design is for electricity only. Lower coolant outlet temperature (~500°C) is less suitable for process heat applications.	Current design is for electricity only. With its 800°C outlet temperature, design could be adapted for process heat applications.
1.5 Energy Efficiency	4	8	32	High coolant outlet temperatures increase thermal efficiency. Direct utilization of process heat also increases efficiency. See Section 5.1.5.	Lower thermal efficiency than MHR for electricity generation.	Somewhat higher thermal efficiency for electricity generation than MHR.
1.6 Fuel Cycle Considerations	0	N/A	N/A	Dependent on national fuel cycle policy. Per Section 7.2, good fuel cycle synergy with fast reactors.	Fast neutron spectrum allows for breeding fissile fuel. Operation in burner mode allows destruction of transuranics.	Insufficient information to assess fuel cycle considerations.
2. Economics and Commercialization Potential (35)						
2.1a Market Potential – U.S.	7	6	42	Well established domestic need and market acceptance for traditional electric generation facilities. Regulated market, therefore reactor must be competitive with other generation technologies.	Well established domestic need and market acceptance for traditional electric generation facilities. Regulated market, therefore reactor must be competitive with other generation technologies. Lower thermal efficiency for electric power generation.	Well established domestic need and market acceptance for traditional electric generation facilities. Regulated market, therefore reactor must be competitive with other generation technologies. Difficult to assess because of the low Technology Readiness Level compared to the MHR and SFR.
2.1b Market Potential - International	7	7	49	Well established	Well established international need and	Well established international need and

				international need and market acceptance for traditional electric generation facilities.	market acceptance for traditional electric generation facilities. Lower thermal efficiency for electric power generation.	market acceptance for traditional electric generation facilities.
2.2 Demonstration Module/Plant Costs	3	8	24	Requires large gov't funding regardless of technology. Category rating is judged to be low for this particular high relative to the other sites because surrounding infrastructure is well developed.	About the same as the MHR.	Much more uncertain than the MHR.
2.3 NOAK Commercial Plant Costs	5	N/A	N/A	Not Evaluated	Not Evaluated	Not Evaluated
2.4 Potential for International Collaboration	5	8	40	Several existing international programs.	Possibly good. But Russia, France and Japan already have strong national programs.	Unknown, but the U.S. seems to be the country primarily interested in MSR at this stage.
2.5 Impacts on Local Economy	8	9	77	Positive and significant. Replaces tax base and jobs lost at previous facility decommissioning.	Positive and significant. Replaces tax base and jobs lost at previous facility decommissioning.	Positive and significant. Replaces tax base and jobs lost at previous facility decommissioning.
3. Licensing Considerations (15)	15	8	120	Site appears favorable for licensing. Additional info needed re: flooding, EAB and EP. No certified design.	Site appears favorable for licensing. Additional info needed re: flooding, EAB and EP. No certified design.	Site appears favorable for licensing. Additional info needed re: flooding, EAB and EP. No certified design.
4. Siting Considerations (25)						
4.1 Technology Considerations	10	8	80	Site previously supported ~1700 MW's. Appears favorable for all technologies. Potential for site to support 4-8 modules (272 MWe each).	Potential for site to support 4-8 modules (311 MWe each).	Potential for site to support 1-2 Units (1105 MWe each).
4.2 Site-Specific Considerations	15	8	120	High site readiness. Pre-existing services (rail, transmission,	Same	Same

				etc.) make site desirable.		
Total	100	**Total**	743			

References:

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(VEGP 2011) U.S. Nuclear Regulatory Commission, "NUREG-2124, Final Safety Evaluations Report Related to the Combined Licenses for Vogtle Electric Generating Plant, Units 3 and 4", March, 2011,

(VEGP 2014) Southern Nuclear Operating Company, "Vogtle Electric Generating Plant – Units 1 and 2 Seismic Hazard and Screening Report for CEUS Sites", March, 2014, NL-14-0344, ML140292A019.

(Wikipedia, 2017) Wikipedia website https://en.wikipedia.org/wiki/Baldwin_County_Airport, accessed April, 2016.

Abbreviations:

EPRI	Electric Power Research Institute
FEMA	U.S. Federal Emergency Management Agency
FSAR	Final Safety Analysis Report
GPC	Georgia Power Company
IRP	Integrated Resource Plan
Km	kilometer
kV	kilovolt
LPG	Liquefied Petroleum Gas
MARTA	Metropolitan Atlanta Rapid Transit Authority
mgd	million gallons per day
MW	megawatt
NPDES	National Pollutant Discharge and Elimination System
NRC	U.S. Nuclear Regulatory Commission
NWI	National Wetland Inventory
PE	probability of exceedance
PSC	Public Service Commission
PWR	pressurized water reactor
SNC	Southern Nuclear Operating Company
Vs	S-wave velocity
WMA	Wildlife Management Area

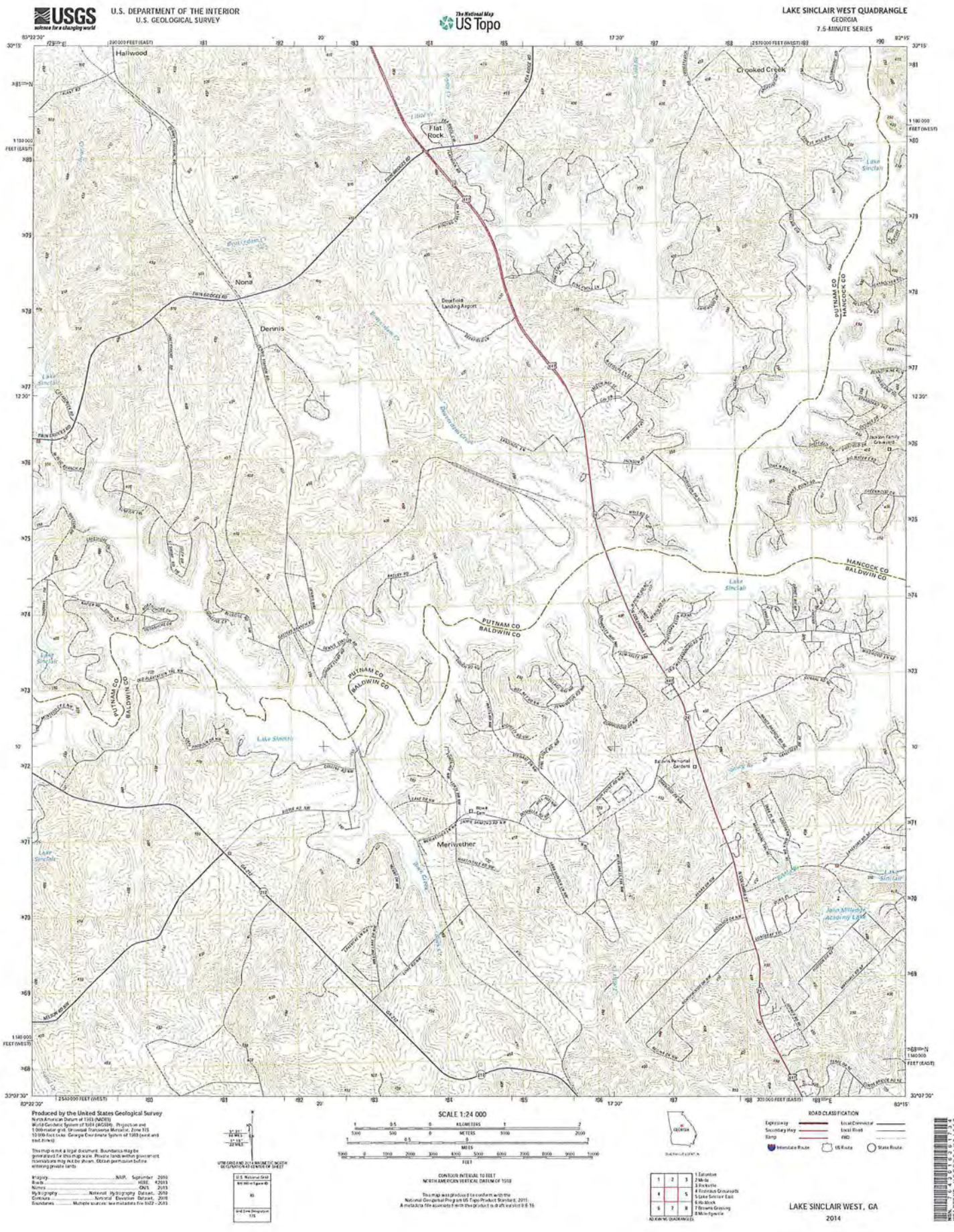
Attachments

Attachment 1 – Topographic Site Map

Attachment 2 – FEMA Floodplain Map

Attachment 3 – National Wetland Inventory Map

ATTACHMENT I



ATTACHMENT 2

NOTES TO USERS

This map is for use in administering the National Flood Insurance Program. It does not necessarily identify all areas subject to flooding, particularly from local drainage sources of small size. The **community map repository** should be consulted for possible updated or additional flood hazard information.

To obtain more detailed information in areas where **Base Flood Elevations** (BFEs) and/or **floodways** have been determined, users are encouraged to consult the Flood Profiles and Floodway Data and/or Summary of Stillwater Elevations tables contained within the Flood Insurance Study (FIS) Report that accompanies this FIRM. Users should be aware that BFEs shown on the FIRM represent rounded whole-foot elevations. These BFEs are intended for flood insurance rating purposes only and should not be used as the sole source of flood elevation information. Accordingly, flood elevation data presented in the FIS Report should be utilized in conjunction with the FIRM for purposes of construction and/or floodplain management.

Boundaries of the **floodways** were computed at cross sections and interpolated between cross sections. The floodways were based on hydraulic considerations with regard to requirements of the National Flood Insurance Program. Floodway widths and other pertinent floodway data are provided in the Floodway Data table shown on this FIRM.

The **projection** used in the preparation of this map was Georgia State Plane West Zone (FIPS zone 1002). The **horizontal datum** was NAD 83, GRS 80 spheroid. Differences in datum, spheroid, projection or State Plane zones used in the production of FIRMs for adjacent jurisdictions may result in slight positional differences in map features across jurisdiction boundaries. These differences do not affect the accuracy of this FIRM.

Flood elevations on this map are referenced to the North American Vertical Datum of 1988. These flood elevations must be compared to structure and ground elevations referenced to the same **vertical datum**. For information regarding conversion between the National Geodetic Vertical Datum of 1929 and the North American Vertical Datum of 1988, visit the National Geodetic Survey website at http://www.ngs.noaa.gov or contact the National Geodetic Survey at the following address:

NGS Information Services
NOAA, N/NGS12
National Geodetic Survey
SSMC-3, #9202
1315 East-West Highway
Silver Spring, Maryland 20910-3282
(301) 713-3242

To obtain current elevation, description, and/or location information for **bench marks** shown on this map, please contact the Information Services Branch of the National Geodetic Survey at **(301) 713- 3242**, or visit its website at http://www.ngs.noaa.gov.

Base map information shown on this FIRM was provided for Putnam County by Pond and Company dated February 2001 and captured at a resolution of 1-foot within Putnam County and .5-foot within the City of Eatonton.

The **profile baselines** depicted on this map represent the hydraulic modeling baselines that match the flood profiles in the FIS report. As a result of improved topographic data, the profile baseline, in some cases, may deviate significantly from the channel centerline or appear outside the Special Flood Hazard Area.

Corporate limits shown on this map are based on the best data available at the time of publication. Because changes due to annexations or de-annexations may have occurred after this map was published, map users should contact appropriate community officials to verify current corporate limit locations.

Please refer to the separately printed **Map Index** for an overview map of the county showing the layout of map panels; community map repository addresses; and a Listing of Communities table containing National Flood Insurance Program dates for each community as well as a listing of the panels on which each community is located.

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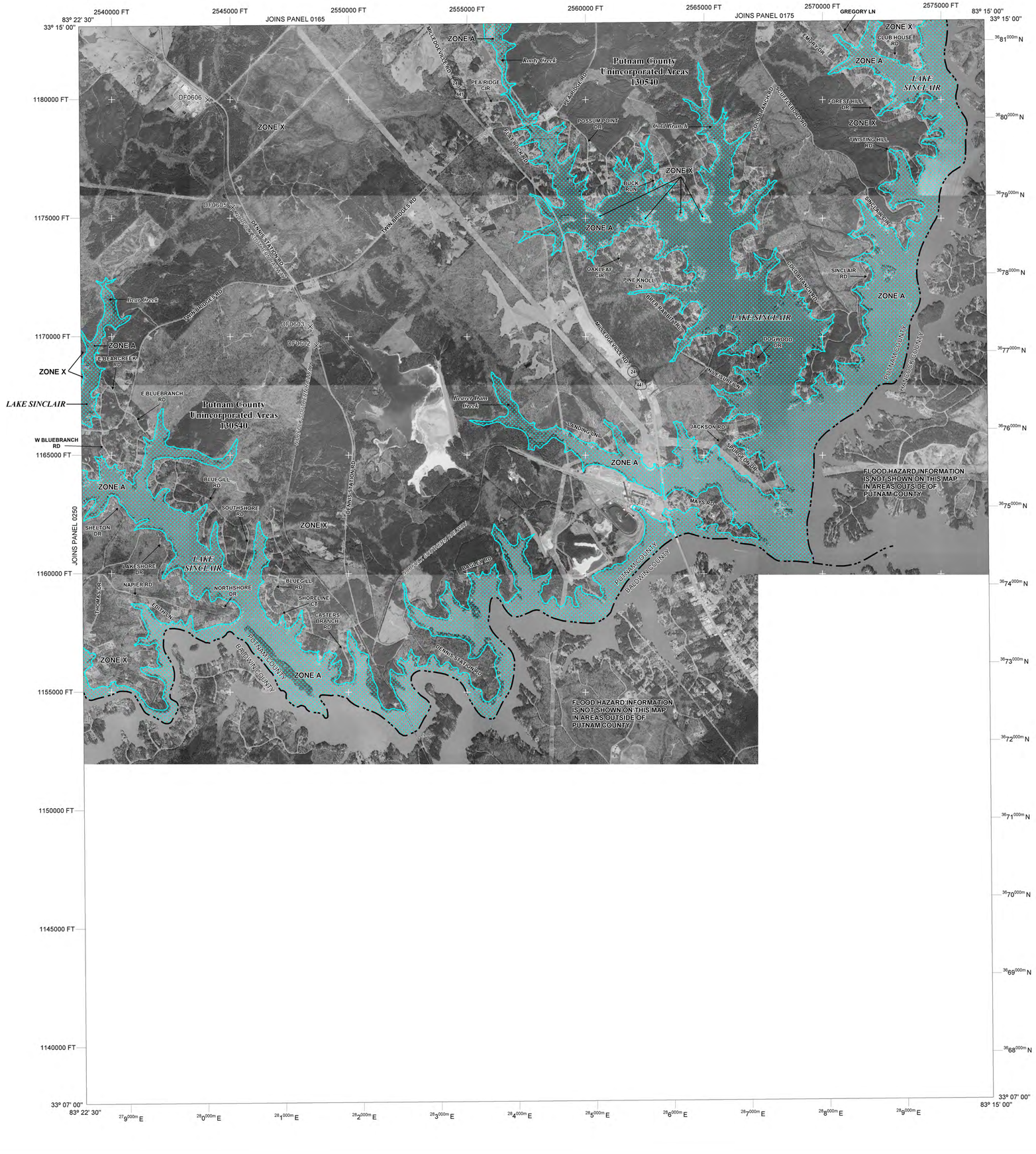

LEGEND

SPECIAL FLOOD HAZARD AREAS (SFHAs) SUBJECT TO INUNDATION BY THE 1% ANNUAL CHANCE FLOOD

The 1% annual chance flood (100-year flood), also known as the base flood, is the flood that has a 1% chance of being equaled or exceeded in any given year. The Special Flood Hazard Area is the area subject to flooding by the 1% annual chance flood. Areas of Special Flood Hazard include Zones A, AE, AH, AO, AR, A99, V, and VE. The Base Flood Elevation is the water-surface elevation of the 1% annual chance flood.

ZONE A	No Base Flood Elevations determined.
ZONE AE	Base Flood Elevations determined.
ZONE AH	Flood depths of 1 to 3 feet (usually areas of ponding); Base Flood Elevations determined.
ZONE AO	Flood depths of 1 to 3 feet (usually sheet flow on sloping terrain); average depths determined. For areas of alluvial fan flooding, velocities also determined.
ZONE AR	Special Flood Hazard Areas formerly protected from the 1% annual chance flood by a flood control system that was subsequently decertified. Zone AR indicates that the former flood control system is being restored to provide protection from the 1% annual chance or greater flood.
ZONE A99	Area to be protected from 1% annual chance flood by a Federal flood protection system under construction; no Base Flood Elevations determined.
ZONE V	Coastal flood zone with velocity hazard (wave action); no Base Flood Elevations determined.
ZONE VE	Coastal flood zone with velocity hazard (wave action); Base Flood Elevations determined.

FLOODWAY AREAS IN ZONE AE

The floodway is the channel of a stream plus any adjacent floodplain areas that must be kept free of encroachment so that the 1% annual chance flood can be carried without substantial increases in flood heights.

OTHER FLOOD AREAS

ZONE X	Areas of 0.2% annual chance flood; areas of 1% annual chance flood with average depths of less than 1 foot or with drainage areas less than 1 square mile; and areas protected by levees from 1% annual chance flood.

OTHER AREAS

ZONE X	Areas determined to be outside the 0.2% annual chance floodplain.
ZONE D	Areas in which flood hazards are undetermined, but possible.

COASTAL BARRIER RESOURCES SYSTEM (CBRS) AREAS

OTHERWISE PROTECTED AREAS (OPAs)

CBRS areas and OPAs are normally located within or adjacent to Special Flood Hazard Areas.

	1% annual chance floodplain boundary
	0.2% annual chance floodplain boundary
	Floodway boundary
	Zone D boundary
	CBRS and OPA boundary
	Boundary dividing Special Flood Hazard Areas of different Base Flood Elevations, flood depths or flood velocities.
513	Base Flood Elevation line and value; elevation in feet*
(EL 987)	Base Flood Elevation value where uniform within zone; elevation in feet*

*Referenced to the North American Vertical Datum of 1988

A — A	Cross section line
23 — 23	Transect line
45° 02' 08", 93° 02' 12"	Geographic coordinates referenced to the North American Datum of 1983 (NAD 83) Western Hemisphere
4989000FT	5000-foot grid ticks: Georgia State Plane coordinate system, West zone (FIPS Zone 1002), Transverse Mercator
3689000m N	1000-meter Universal Transverse Mercator grid values, zone 16
DX5510 ×	Bench mark (see explanation in Notes to Users section of this FIRM panel)
M1.5	River Mile

MAP REPOSITORY
Refer to listing of Map Repositories on Map Index

EFFECTIVE DATE OF COUNTYWIDE
FLOOD INSURANCE RATE MAP
SEPTEMBER 26, 2008

EFFECTIVE DATE(S) OF REVISION(S) TO THIS PANEL

For community map revision history prior to countywide mapping, refer to the Community Map History table located in the Flood Insurance Study report for this jurisdiction.

To determine if flood insurance is available in this community contact your insurance agent or call the National Flood Insurance Program at 1-800-638-6620.

MAP SCALE 1" = 2000'

1000 0 2000 4000 FEET
600 0 600 1200 METERS

NFIP

PANEL 0275C

FIRM

FLOOD INSURANCE RATE MAP

PUTNAM COUNTY, GEORGIA

AND INCORPORATED AREAS

PANEL 275 OF 275

(SEE MAP INDEX FOR FIRM PANEL LAYOUT)

CONTAINS:

COMMUNITY	NUMBER	PANEL	SUFFIX
PUTNAM COUNTY	130540	0275	C

Notice to User: The **Map Number** shown below should be used when placing map orders; the **Community Number** shown above should be used on insurance applications for the subject community.

MAP NUMBER
13237C0275C
EFFECTIVE DATE
SEPTEMBER 26, 2008

Federal Emergency Management Agency

NATIONAL FLOOD INSURANCE PROGRAM

U.S. Fish and Wildlife Service
National Wetlands Inventory

Plant Branch Site

ATTACHMENT 3

February 21, 2017

- Estuarine and Marine Deepwater
- Estuarine and Marine Wetland
- Freshwater Emergent Wetland
- Freshwater Forested/Shrub Wetland
- Freshwater Pond
- Lake
- Other
- Riverine

This map is for general reference only. The US Fish and Wildlife Service is not responsible for the accuracy or currentness of the base data shown on this map. All wetlands related data should be used in accordance with the layer metadata found on the Wetlands Mapper web site.

National Wetlands Inventory (NWI)
This page was produced by the NWI mapper

APPENDIX C: NW PROXY SITE

Date: 06/30/2017
ND-17-1174
R-Type SND.BD.L06

Signature Block 1: Matthew T Montz

Signature Block 2:

Version Summary

Version	Description
0	Issued as final

Western Demonstration Plant Site

1. Executive Summary

TBD – Common for all sites.

2. Background

The Seep Ridge Block, a subset of Red Leaf's Utah oil shale portfolio, is comprised of approximately 1,600 acres of rich, near surface oil shale. It is located in Seep Ridge Canyon, Utah. Supported by recent drilling and engineering resource reports, the Seep Ridge Block is estimated to hold approximately 120 million barrels of oil that can be recovered using Red Leaf's EcoShale® technology. Seep Ridge is the site of the company's field pilot that was constructed and operated in 2008 - 2009. The pilot successfully exhibited their technology's proprietary heating methods and oil extraction capabilities.

Red Leaf, together with joint venture partner, Total E&P USA, chose the Seep Ridge Block as the first commercial project site to exhibit the EcoShale technology on a commercial scale. The project received conditional approval for its Large Mine Permit in October 2011 from Utah's Department of Oil, Gas, and Mining (DOGM) and is currently in the process of finalizing remaining permits in order to commence mining operations.

Upon successful completion of the Early Production System (EPS) phase, Red Leaf and Total will enter into a Final Investment Decision to expand the Seep Ridge operations into an estimated 10,000 barrel/day commercial production facility. The joint venture will also add additional oil shale resources to the Seep Ridge Block so that daily production can be increased and the life of the project can be extended.

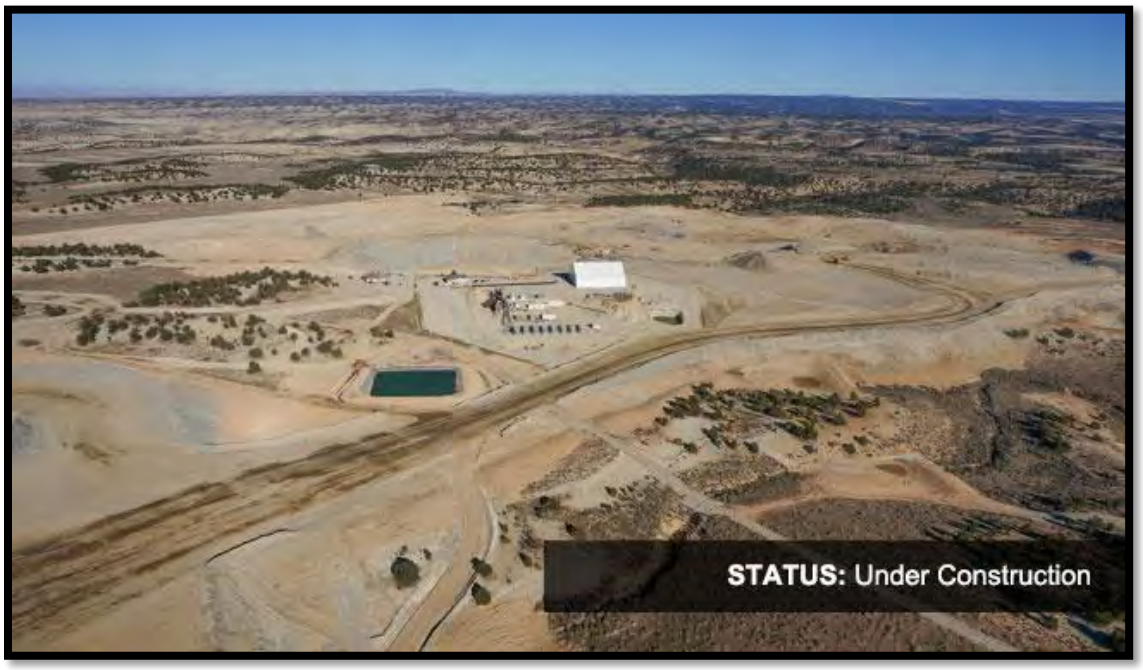

Figure 1 – Redleaf Site - Under Construction

3. Exclusionary Criteria

Site values for the following criteria cannot be met or exceeded.

Category	Value
Seismic	• Peak Ground Acceleration > 0.3 g at a probability of exceedance (PE) of 2 percent in 50 years • Located with five miles (8 Km) of a capable fault
Flooding	• Located within the 100-year flood plain
Hazards	• Accidents at nearby industrial or military facilities posing undue risk to the nuclear plant due to shock waves and missiles from explosions (depends on plant design and distance to plant) • Directly in line with runways on high-operations commercial or military airports. • Low lying areas downstream of major dams
Transmission Lines	• Less than 230 kilo-Volt (kV) capacity and less than two independent sources of off-site power within 30 mi (48.3 km)
Federal and State Lands	Located on one of the following: • National/state parks • National/state historical sites • National/state seashores and lakeshores • National/state rivers and scenic riverways • National/state wildlife refuges • Wilderness areas • National maritime sanctuary areas

	• Cultural resources (American Indian lands, national landmarks)

A summary and evaluation of these exclusionary criteria, as they relate to the site, are described below.

3.1. Seismic

No information provided.

3.2. Flood Zone

The site is located adjacent to Indian Ridge Canyon. Indian Ridge Canyon is dry throughout most of the year and does not contain any baseflow.

Floodplains are land areas adjacent to streams or rivers susceptible to being inundated by stream-derived waters. The Federal Emergency Management Agency (FEMA) Flood Insurance Rate Map was obtained for the site (Panels 49047C1925D and 49047C1950D) and indicates the location of the 100-year floodplain. The Flood Zone map shows that the site is not located in a flood zone (See Attachment 1 and 2 - FEMA Flood Map). The flood map lists Indian Ridge Canyon as Zone A 'No Base Flood Determination'.

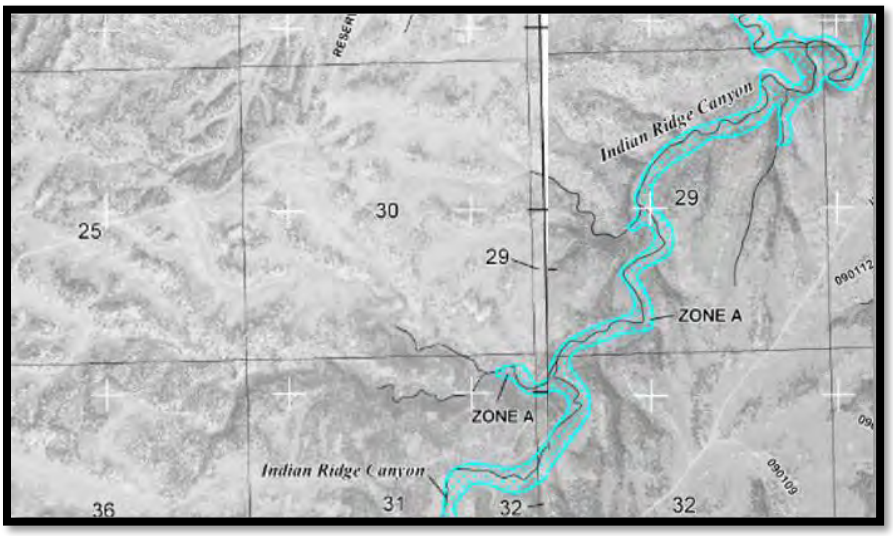

Figure 2 – FEMA Flood Maps

3.3. Hazards

No significant hazards were documented within close proximity to the plant. The following facilities were noted in the area:

- Airports - There are no airports located within 2 miles of the site.
    - The closest airport is the Grand Junction Regional Airport, located 82 miles southeast of the site. (Wikipedia 2017)
- Military Bases – there are no known military installations within 2 miles of the site.
- Industrial/Chemical Sites – there are no known industrial/chemical complexes within 2 miles of the site.
- Pipelines - There are no pipelines located within 2 miles of the site. The nearest pipelines are:
    - Natural Gas pipeline located 19 miles northeast of the site. It is operated by Enterprise Products Operating LLC
    - Natural gas pipeline located 25 miles north of the site. It is operated by Questar Pipeline, LLC. (NPMS 2017)
- Upstream Dams
    - The site is not located on a water body, and therefore is not located near any dams.

3.4. Transmission Lines

The nearest high-voltage transmission line is located 20 miles north of the site.

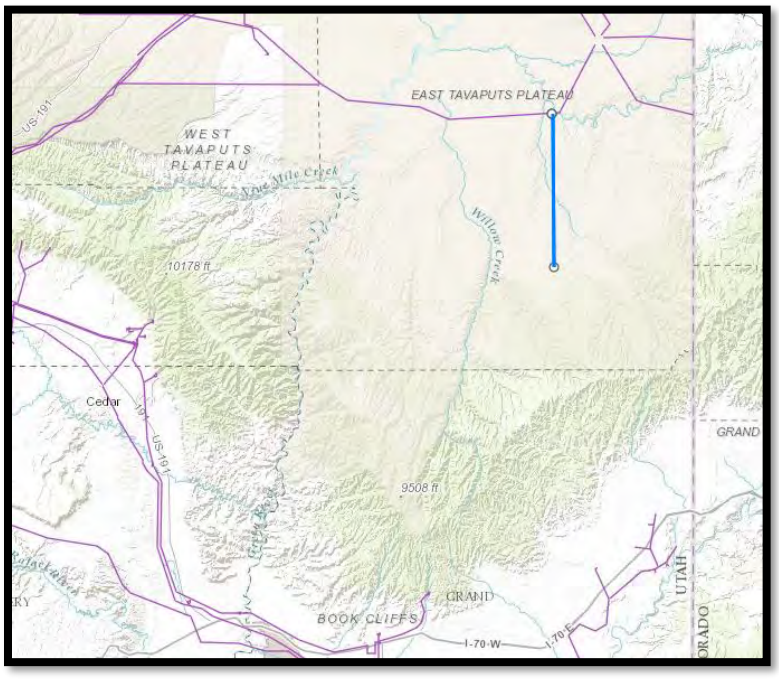

Figure 3– Transmission Lines (ArcGIS 2017)

3.5. Federal and State Lands

The site is located on the Uintah and Ouray Indian Reservation, just outside the boundary of the tribal lands. The reservation is located within a three-county area known as the "Uintah Basin". It is the second largest Indian Reservation in the United States and covers over 4.5 million acres. The Utes have a tribal membership of 2,970 and over half of its membership lives on the Reservation. They operate their own tribal government and oversee approximately 1.3 million acres of trust land. (Ute 2017)

The site is also located just outside of a wilderness under the jurisdiction of the Bureau of Land Management. See Attachment 3 – UT Lands

4. Discretionary Criteria

The following discretionary criteria are not to be used to exclude a site from consideration, but are envisioned to be important to the business case.

Category	Value
Cooling/Dilution Water	• Water amount not sufficient to meet plant design • Water source not located nearby
Need for process heat	• Need for power/ process heat does not exist
Airport, barges, rail lines, and roads	• No preexisting infrastructure with 10 miles (16.1 km)
Population	• Located with four miles (6.4 km) of a population center of 25,000 or more • Located within 10 miles (16.1 km) of a population center of 100,000 or more • Located within 20 miles (32.2 km) of a population center of 500,000 or more • Located within 30 miles (48.3 km) of a population center of 1,000,000 or more
Wetlands	Large amount (> five acres) of wetlands impacted by construction

4.1. Cooling/Dilution Water

There is not a source of surface water nearby this site. For cooling and dilution, other sources would need to be explored. This could include utilizing groundwater and/or grey water. Due to the extensive oil and gas activity in the Uintah Basin, the recycle and reuse of produced water could be a possibility. According to a 2011 report by the Department of Natural Resources, approximately 3 billion gallons of water per year are produced in the Uintah Basin, which would provide adequate cooling water of a 500 MW thermal nuclear reactor. The opportunity exists to create synergy with regional industry in treating and evaporating this produced water rather than utilizing groundwater.

4.2. Need for Power/Process Heat

See Business Case.

4.3. Airports, Barges, Rail lines, Roads

The site does not have easy access to roads, rail and air. Below is a list of the various transportation options at the site.

- Airports – As discussed above, the closest airport is Grand Junction Regional Airport, located 82 miles southeast of the site.
- Rail – The nearest rail line is an abandoned line, Uintah Railway, approximately 20 miles from the site. The closest operational rail line is a main line that runs parallels with I-70, approximately 70 miles south of the site. (OpenRail 2017)
- Roads – Access to the site is via Seep Ridge Road. The closest access to a major highway or interstate is Old US Highway 6 &50/ I-70, approximately 55 miles south of the site. US-191 S/US-40 W is accessible approximately 55 miles to the north of the site. (Google 2017)
- Barge Access – there is no barge access to the site.

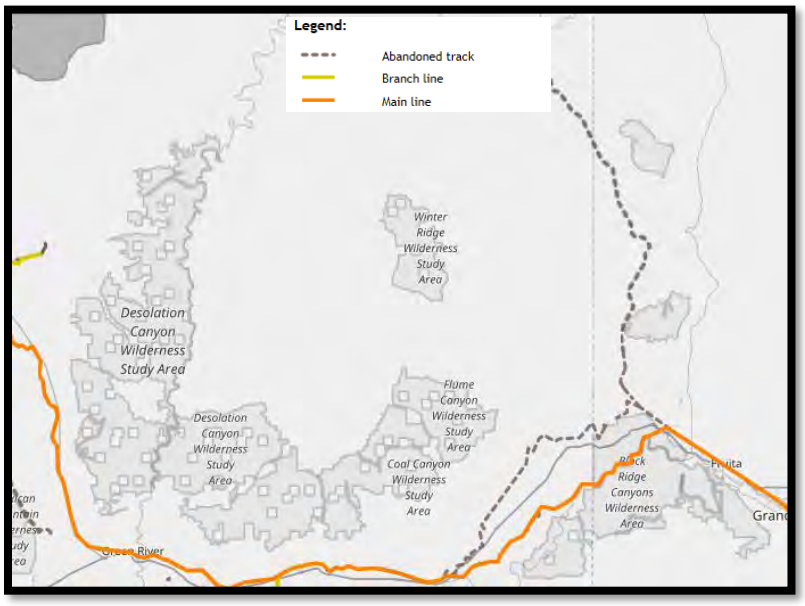

Figure 4 – Area Rail Map

4.4. Population

The site is located on the Uintah and Ouray Indian Reservation which has a population of 19,182.

Population centers noted in the region are as follows:

- Vernal, Utah, population 10,844, located in Uintah County, approximately 56 miles north of the site.
- Grand Junction, Colorado, population 60,210, located in Mesa County, Colorado, 60 miles southeast of the site.
- Moab, Utah, population 5,140, located in Grand County, approximately 74 miles south of the site.
- Price, Utah, population 8,358, located in Carbon County, approximately 76 miles west of the site.
- Provo, Utah, population 114,801, located in Utah County, approximately 125 miles west of the site.

4.5. Wetlands

National Wetland Inventory Maps (Attachment 4) were reviewed and do not indicate any wetlands on the site. (FWS 2017)

Figure 5 – National Wetland Inventory Map

5. Business Case

From others.

References:

(ArcGIS 2017) ArcGIS website, Utah Transmission Lines (Statewide), http://www.arcgis.com/home/webmap/viewer.html?useExisting=1&layers=831bc77130f14125a5b9ebefed72a3f1, accessed May 2017.

(FWS 2017) U.S. Fish and Wildlife Service National Wetland Invetory Mapper website, https://www.fws.gov/wetlands/data/mapper.HTML, accessed March 2017.

(Google 2017) Google Maps website, https://www.google.com/maps, accessed March, 2017.

(NPMS 2017) National Pipeline Mapping System website, https://www.npms.phmsa.dot.gov/, accessed March 2017.

(OpenRail 2017) Open Railway Map website, http://www.openrailwaymap.org, accessed May, 2017.

(Red Leaf 2016) Red Leaf website Seep Ridge Project - Seep Ridge Canyon Utah, USA, http://redleafinc.com/seep-ridge, 2016, accessed May 2017.

(Ute 2017) Ute Indian Tribe website, http://www.utetribe.com/, accessed May 2017.

(Wikipedia 2017) Wikipedia website Grand Junction Regional Airport https://en.wikipedia.org/wiki/Grand_Junction_Regional_Airport, accessed May 2017.

Abbreviations:

DOGM	Utah's Department of Oil, Gas, and Mining
EPS	Early Production System
FEMA	U.S. Federal Emergency Management Agency
Km	kilometer
kV	kilovolt

Attachments:

Attachment 1 – FEMA Floodplain Map

Attachment 2 – FEMA Floodplain Map

Attachment 3 – UT Lands

Attachment 4 – National Wetlands Inventory Map

51-9272172-000

NOTES TO USERS

This map is for use in administering the National Flood Insurance Program. It does not necessarily identify all areas subject to flooding, particularly from local drainage sources of small size. The community map repository should be consulted for possible updated or additional flood hazard information.

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Coastal Base Flood Elevations shown on this map apply only landward of 0.0' North American Vertical Datum of 1988 (NAVD 88). Users of this FIRM should be aware that coastal flood elevations are also provided in the Summary of Stillwater Elevations table in the Flood Insurance Study Report for this jurisdiction. Elevations shown in the Summary of Stillwater Elevations table should be used for construction, and/or floodplain management purposes when they are higher than the elevations shown on this FIRM.

Boundaries of the **floodways** were computed at cross sections and interpolated between cross sections. The floodways were based on hydraulic considerations with regard to requirements of the National Flood Insurance Program. Floodway widths and other pertinent floodway data are provided in the Flood Insurance Study report for this jurisdiction.

Certain areas not in Special Flood Hazard Areas may be protected by **flood control structures**. Refer to Section 2.4 "Flood Protection Measures" of the Flood Insurance Study report for information on flood control structures in this jurisdiction.

The **projection** used in the preparation of this map was Universal Transverse Mercator (UTM) Zone 12. The **horizontal datum** was NAD83, GRS80 spheroid. Differences in datum, spheroid, projection or UTM zones used in the production of FIRMs for adjacent jurisdictions may result in slight positional differences in map features across jurisdiction boundaries. These differences do not affect the accuracy of this FIRM.

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NGS Information Services
NOAA, N/NGS12
National Geodetic Survey, SSMC-3, #9202
1315 East-West Highway
Silver Spring, Maryland 20910-3282
(301) 713-3242

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Base map information shown on this FIRM was derived from multiple sources. This information was compiled from the U.S. Geological Survey, 1989, Utah Automated Geographic Reference Center (AGRC), 1985 and 2003, National Geodetic Survey, 2005, United States Department of Agricultural and Farm Service Agency Aerial Photography Field Office, 2006.

This map reflects more detailed and up-to-date **stream channel configurations** than those shown on the previous FIRM for this jurisdiction. The floodplains and floodways that were transferred from the previous FIRM may have been adjusted to conform to these new stream channel configurations. As a result, the Flood Profiles and Floodway Data tables in the Flood Insurance Study report (which contains authoritative hydraulic data) may reflect stream channel distances that differ from what is shown on this map.

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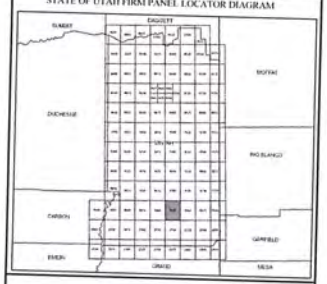
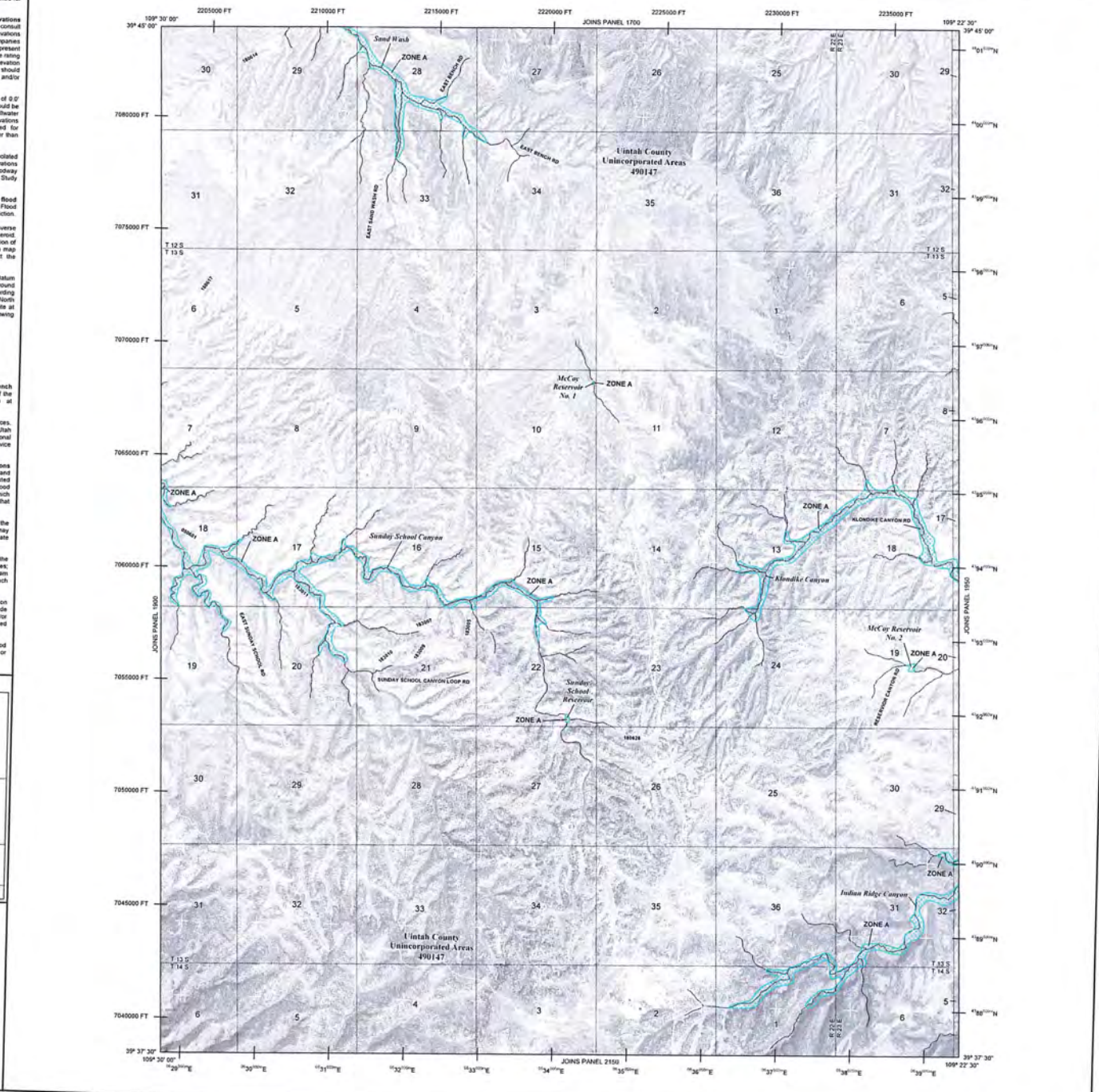
STATE OF UTAH FIRM PANEL LOCATOR DIAGRAM





LEGEND

SPECIAL FLOOD HAZARD AREAS SUBJECT TO INUNDATION BY THE 1% ANNUAL CHANCE FLOOD

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- 513 — Base Flood Elevation line and value; elevation in feet*
- (EL 987) — Base Flood Elevation value where uniform within zone; elevation in feet*

*Referenced to the North American Vertical Datum of 1988

- Cross section line
- Transect line
- 87°07'45", 32°22'30" — Geographic coordinates referenced to the North American Datum of 1983 (NAD 83), Western Hemisphere
- 4276000 FT — 1000-meter Universal Transverse Mercator grid values, zone 12
- 600000 FT — 5000-foot grid ticks: Utah State Plane coordinate system, Central zone (FIPSZONE 4302), Transverse Mercator Projection
- DX5510 — Bench mark (see explanation in Notes to Users section of this FIRM panel)
- M1.5 — River Mile

MAP REPOSITORIES
Refer to Map Repositories list on Map Index.

EFFECTIVE DATE OF COUNTYWIDE FLOOD INSURANCE RATE MAP PANEL
OCTOBER 6, 2010

EFFECTIVE DATE(S) OF REVISION(S) TO THIS PANEL

For communities map revision history prior to countywide mapping, refer to the Community Map History table located in the Flood Insurance Study report for this jurisdiction.

To determine if flood insurance is available in this community, contact your insurance agent or call the National Flood Insurance Program at 1-800-638-1620.

MAP SCALE 1" = 2000'
1000 0 2000 4000
FEET
600 0 600 1200
METERS

NFIP
NATIONAL FLOOD INSURANCE PROGRAM

PANEL 1925D

FIRM
FLOOD INSURANCE RATE MAP

UINTAH COUNTY, UTAH AND INCORPORATED AREAS

PANEL 1925 OF 2450

(SEE MAP INDEX FOR FIRM PANEL LAYOUT)

CONTAINS:

COMMUNITY	NUMBER	PANEL	SUFFIX
UINTAH COUNTY	490147	1925	D

Notice to User: The **Map Number** shown below should be used when placing map orders; the Community Number shown above should be used on insurance applications for the subject community.

MAP NUMBER
49047C1925D

EFFECTIVE DATE
OCTOBER 6, 2010

Federal Emergency Management Agency

NOTES TO USERS

This map is for use in administering the National Flood Insurance Program. It does not necessarily identify all areas subject to flooding, particularly from local drainage sources of small size. The community map repository should be consulted for possible updated or additional flood hazard information.

To obtain more detailed information in areas where **Base Flood Elevations** (BFEs) and/or **floodways** have been determined, users are encouraged to consult the Flood Profiles and Floodway Data and/or Summary of Stillwater Elevations tables contained within the Flood Insurance Study (FIS) report that accompanies this FIRM. Users should be aware that BFEs shown on the FIRM represent rounded whole-foot elevations. These BFEs are intended for flood insurance rating purposes only and should not be used as the sole source of flood elevation information. Accordingly, flood elevation data presented in the FIS report should be utilized in conjunction with the FIRM for purposes of construction and/or floodplain management.

Coastal Base Flood Elevations shown on this map apply only landward of 0.0' North American Vertical Datum of 1988 (NAVD 88). Users of this FIRM should be aware that coastal flood elevations are also provided in the Summary of Stillwater Elevations table in the Flood Insurance Study Report for this jurisdiction. Elevations shown in the Summary of Stillwater Elevations table should be used for construction, and/or floodplain management purposes when they are higher than the elevations shown on this FIRM.

Boundaries of the **floodways** were computed at cross sections and interpolated between cross sections. The floodways were based on hydraulic considerations with regard to requirements of the National Flood Insurance Program. Floodway widths and other pertinent floodway data are provided in the Flood Insurance Study report for this jurisdiction.

Certain areas not in Special Flood Hazard Areas may be protected by **flood control structures**. Refer to Section 2.4 "Flood Protection Measures" of the Flood Insurance Study report for information on flood control structures in this jurisdiction.

The **projection** used in the preparation of this map was Universal Transverse Mercator (UTM) Zone 12. The **horizontal datum** was NAD83, GRS80 spheroid. Differences in datum, spheroid, projection or UTM zones used in the production of FIRMs for adjacent jurisdictions may result in slight positional differences in map features across jurisdiction boundaries. These differences do not affect the accuracy of this FIRM.

Flood elevations on this map are referenced to the North American Vertical Datum of 1988. These flood elevations must be compared to structure and ground elevations referenced to the same vertical datum. For information regarding conversion between the National Geodetic Vertical Datum of 1929 and the North American Vertical Datum of 1988, visit the National Geodetic Survey website at http://www.ngs.noaa.gov or contact the National Geodetic Survey at the following address:

NGS Information Services
NOAA, N/NGS12
National Geodetic Survey, SSMC-3, #9202
1315 East-West Highway
Silver Spring, Maryland 20910-3282
(301) 713-3242

To obtain current elevation, description, and/or location information for **bench marks** shown on this map, please contact the Information Services Branch of the National Geodetic Survey at **(301) 713-3242**, or visit their website at http://www.ngs.noaa.gov/.

Base map information shown on this FIRM was derived from multiple sources. This information was compiled from the U.S. Geological Survey: 1989, Utah Automated Geographic Reference Center (AGRC), 1985 and 2003, National Geodetic Survey, 2005, United States Department of Agricultural and Farm Service Agency Aerial Photography Field Office, 2006.

This map reflects more detailed and up-to-date **stream channel configurations** than those shown on the previous FIRM for this jurisdiction. The floodplains and floodways that were transferred from the previous FIRM may have been adjusted to conform to these new stream channel configurations. As a result, the Flood Profiles and Floodway Data tables in the Flood Insurance Study report (which contains authoritative hydraulic data) may reflect stream channel distances that differ from what is shown on this map.

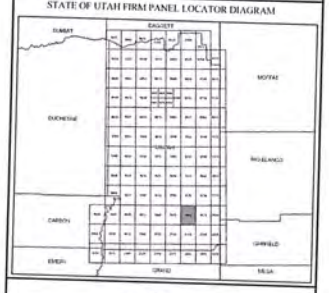
Corporate limits shown on this map are based on the best data available at the time of publication. Because changes due to annexations or de-annexations may have occurred after this map was published, map users should contact appropriate community officials to verify current corporate limit locations.

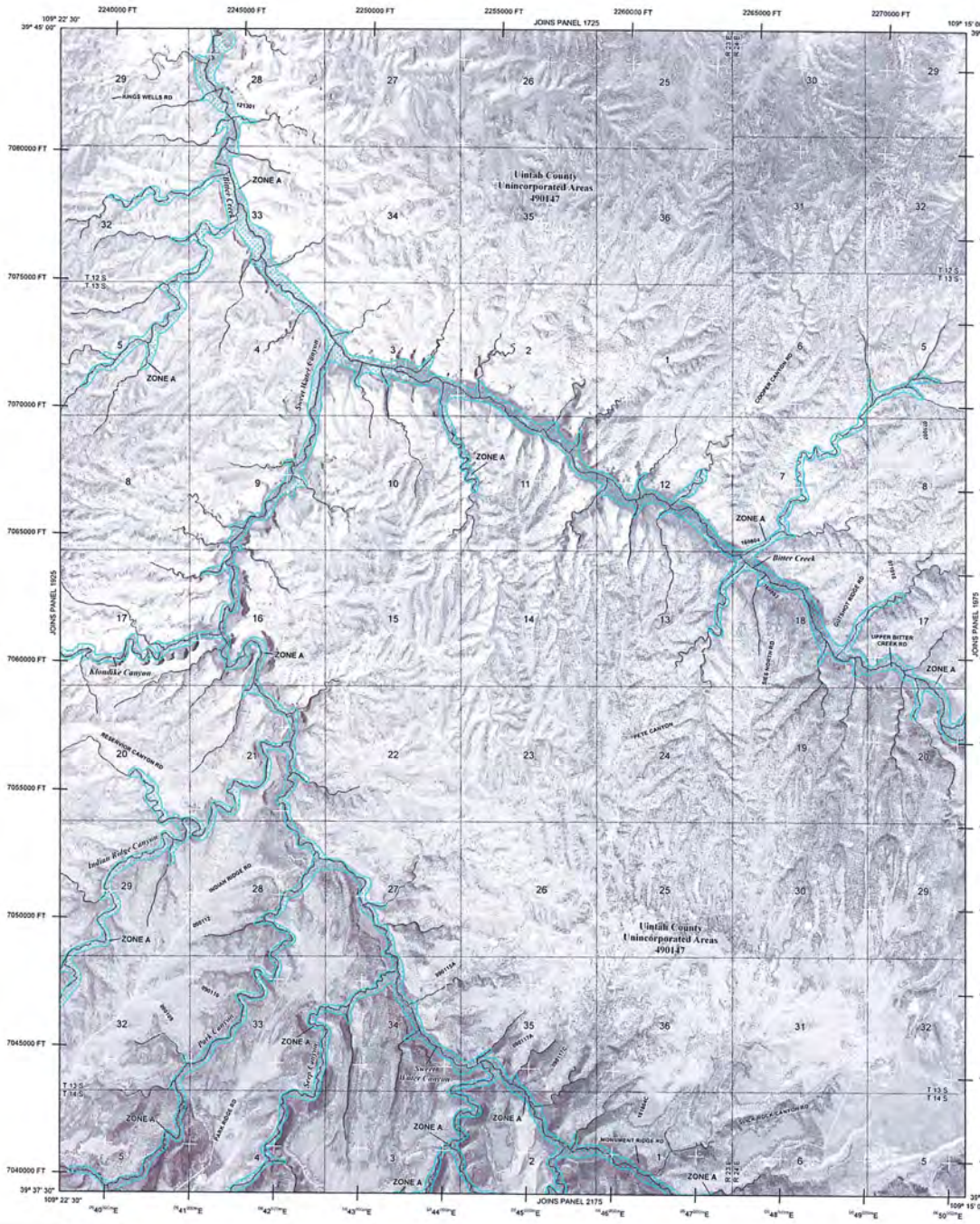
Please refer to the separately printed **Map Index** for an overview map of the county showing the layout of map panels; community map repository addresses; and a Listing of Communities table containing National Flood Insurance Program dates for each community as well as a listing of the panels on which each community is located.

Contact the **FEMA Map Service Center** at 1-800-358-9616 for information on available products associated with this FIRM. Available products may include previously issued Letters of Map Change, a Flood Insurance Study report, and/or digital versions of this map. The FEMA Map Service Center may also be reached by Fax at 1-800-358-9620 and their website at http://www.msc.fema.gov/.

If you have **questions about this map** or questions concerning the National Flood Insurance Program in general, please call **1- 877- FEMA MAP** (1-877-336-2627) or visit the FEMA website at http://www.fema.gov/.

STATE OF UTAH FIRM PANEL LOCATOR DIAGRAM





51-9272172-000

LEGEND

SPECIAL FLOOD HAZARD AREAS SUBJECT TO INUNDATION BY THE 1% ANNUAL CHANCE FLOOD

The 1% annual flood (100-year flood), also known as the base flood, is the flood that has a 1% chance of being equalled or exceeded in any given year. The Special Flood Hazard Area is the area subject to flooding by the 1% annual chance flood. Areas of Special Flood Hazard include Zones A, AE, AH, AO, AR, A99, V, and VE. The Base Flood Elevation is the water-surface elevation of the 1% annual chance flood.

- ZONE A — No Base Flood Elevations determined.
- ZONE AE — Base Flood Elevations determined.
- ZONE AH — Flood depths of 1 to 3 feet (usually areas of ponding); Base Flood Elevations determined.
- ZONE AO — Flood depths of 1 to 3 feet (usually sheet flow on sloping terrain); average depths determined. For areas of alluvial fan flooding, velocities also determined.
- ZONE AR — Special Flood Hazard Area formerly protected from the 1% annual chance flood by a flood control system that was subsequently decertified. Zone AR indicates that the former flood control system is being restored to provide protection from the 1% annual chance or greater flood.
- ZONE A99 — Area to be protected from 1% annual chance flood by a Federal flood protection system under construction; no Base Flood Elevations determined.
- ZONE V — Coastal flood zone with velocity hazard (wave action); no Base Flood Elevations determined.
- ZONE VE — Coastal flood zone with velocity hazard (wave action); Base Flood Elevations determined.

FLOODWAY AREAS IN ZONE AE

The floodway is the channel of a stream plus any adjacent floodplain areas that must be kept free of encroachment so that the 1% annual chance flood can be carried without substantial increases in flood heights.

OTHER FLOOD AREAS

- ZONE X — Areas of 0.2% annual chance flood; areas of 1% annual chance flood with average depths of less than 1 foot or with drainage areas less than 1 square mile; and areas protected by levees from 1% annual chance flood.

OTHER AREAS

- ZONE X — Areas determined to be outside the 0.2% annual chance floodplain.
- ZONE D — Areas in which flood hazards are undetermined, but possible.

COASTAL BARRIER RESOURCES SYSTEM (CBRS) AREAS

OTHERWISE PROTECTED AREAS (OPAs)

CBRS areas and OPAs are normally located within or adjacent to Special Flood Hazard Areas.

- 1% annual chance floodplain boundary
- 0.2% annual chance floodplain boundary
- Floodway boundary
- Zone D boundary
- CBRS and OPA boundary
- Boundary dividing Special Flood Hazard Area Zones and boundary dividing Special Flood Hazard Areas of different Base Flood Elevations, flood depths or flood velocities.
- 513 (EL 987) — Base Flood Elevation line and value; elevation in feet*
- Base Flood Elevation value where uniform within zone; elevation in feet*

*Referenced to the North American Vertical Datum of 1988

- Cross section line
- Transect line
- 87°07'45", 32°22'30" — Geographic coordinates referenced to the North American Datum of 1983 (NAD 83), Western Hemisphere
- 4278000 N — 1000-meter Universal Transverse Mercator grid values, zone 12
- 600000 FT — 5000-foot grid ticks: Utah State Plane coordinate system, Central zone (FIPSZONE 4302), Transverse Mercator Projection
- DX5510 × — Bench mark (see explanation in Notes to Users section of this FIRM panel)
- M1.5 — River Mile

MAP REPOSITORIES
Refer to Map Repositories list on Map Index.

EFFECTIVE DATE OF COUNTYWIDE FLOOD INSURANCE RATE MAP/PANEL
OCTOBER 6, 2010

EFFECTIVE DATE(S) OF REVISION(S) TO THIS PANEL

For community map revision history prior to countywide mapping, refer to the Community Map History table located in the Flood Insurance Study report for this jurisdiction.

To determine if flood insurance is available in this community, contact your insurance agent or call the National Flood Insurance Program at 1-800-638-6620.

MAP SCALE 1" = 2000'
1000 0 2000 4000 FEET
500 0 600 1200 METERS

NFIP
NATIONAL FLOOD INSURANCE PROGRAM

PANEL 1950D

FIRM
FLOOD INSURANCE RATE MAP

UINTAH COUNTY, UTAH
AND INCORPORATED AREAS

PANEL 1950 OF 2450

(SEE MAP INDEX FOR FIRM PANEL LAYOUT)

CONTAINS:

COMMUNITY	NUMBER	PANEL	SUFFIX
VERNAL, CITY OF	490145	1950	D
UINTAH COUNTY	490147	1950	D

Notice to User: The **Map Number** shown below should be used when placing map orders; the Community Number shown above should be used on insurance applications for the subject community.

MAP NUMBER
49047C1950D

EFFECTIVE DATE
OCTOBER 6, 2010

Federal Emergency Management Agency

nationalatlas.gov™
Where We Are

UTAH

FEDERAL LANDS AND INDIAN RESERVATIONS

- Bureau of Indian Affairs
- Bureau of Land Management / Wilderness
- Bureau of Reclamation
- Department of Defense (includes Army Corps of Engineers lakes)
- Fish and Wildlife Service / Wilderness
- Forest Service / Wilderness
- National Park Service / Wilderness

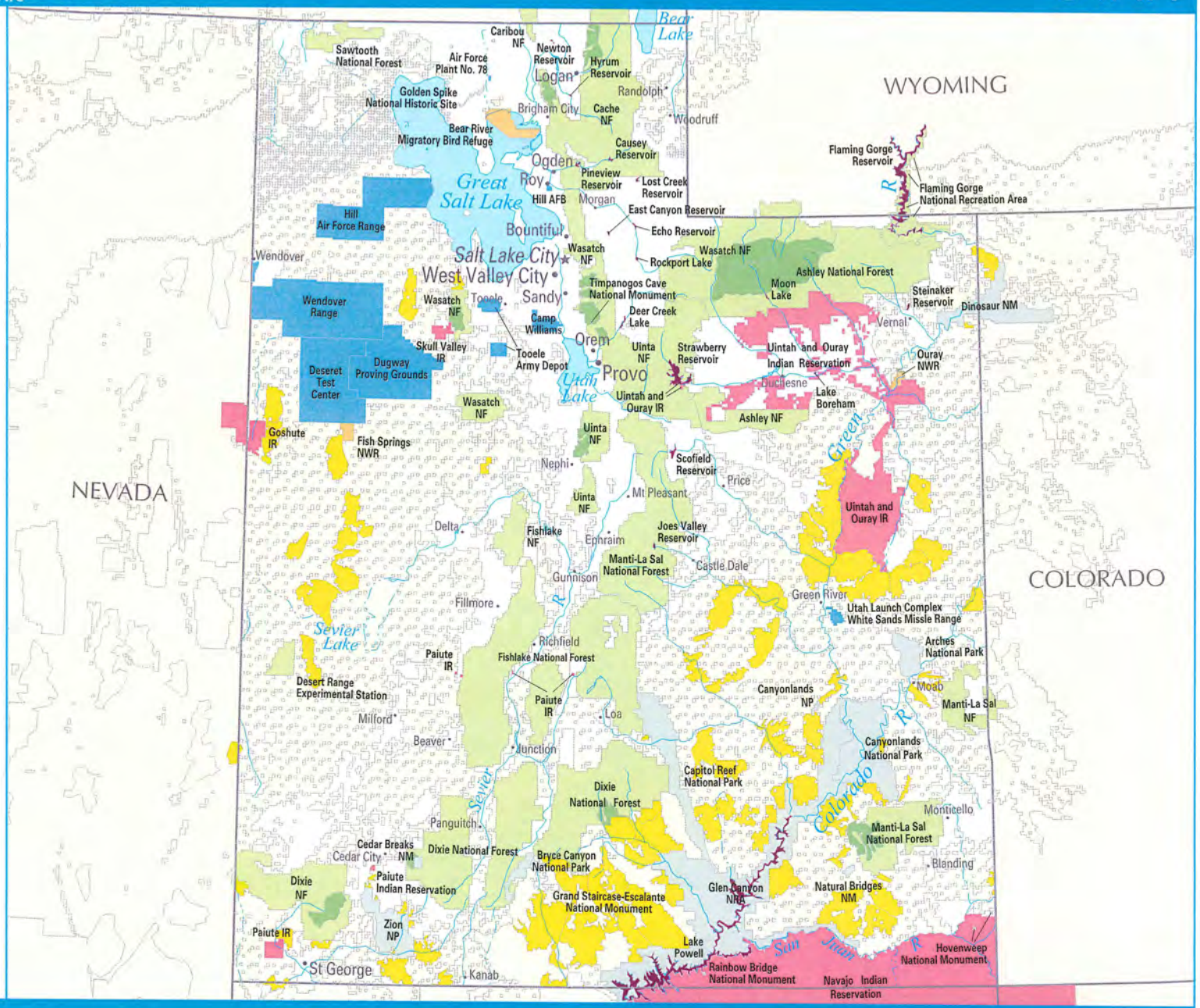
Some small sites are not shown, especially in urban areas.

MILES
0 20 40 60 80

Albers equal area projection

Abbreviations

AFB	Air Force Base
IR	Indian Reservation
NF	National Forest
NM	National Monument
NP	National Park
NRA	National Recreation Area
NWR	National Wildlife Refuge



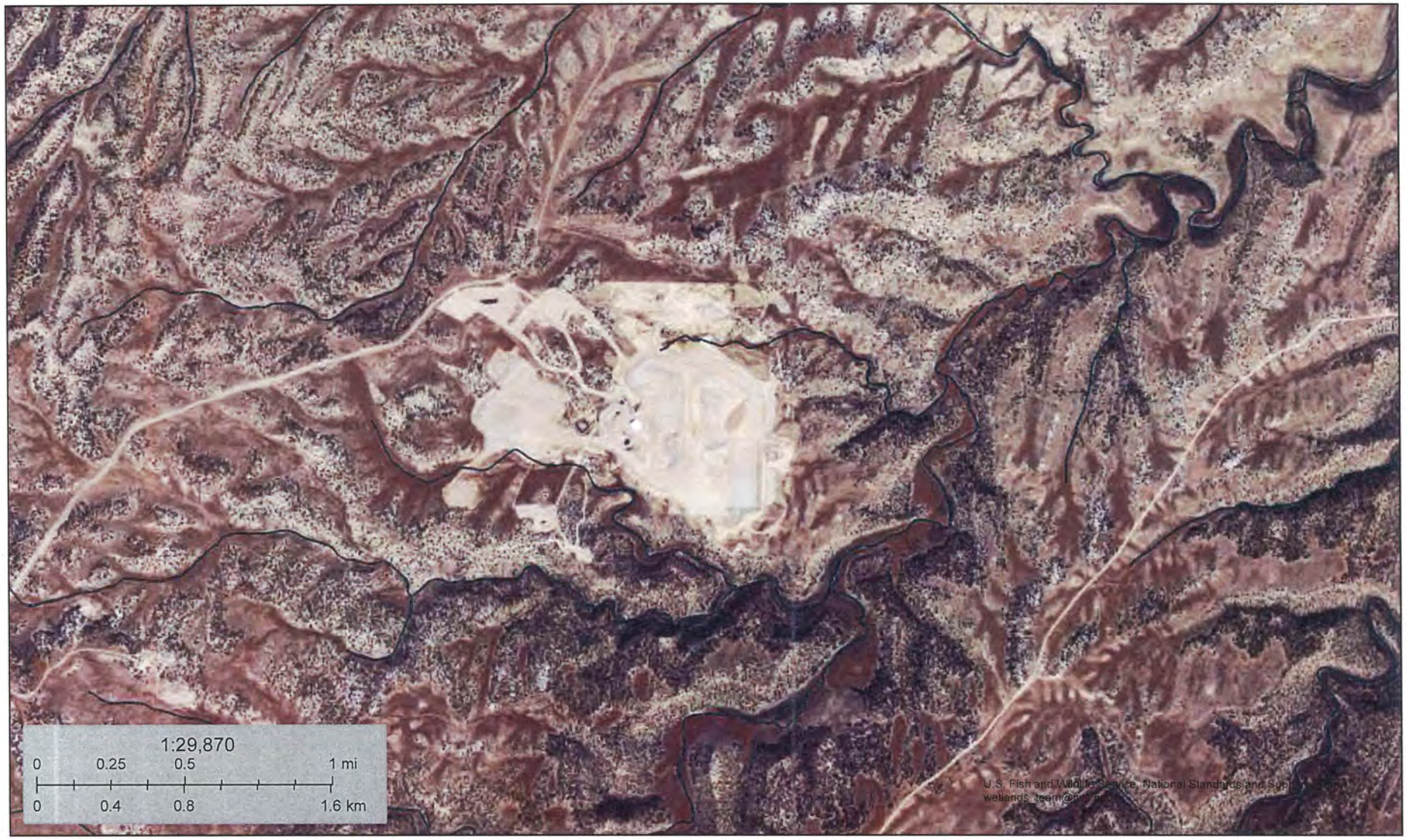
U.S. Department of the Interior
U.S. Geological Survey

The National Atlas of the United States of America®

pagefed_ut5.pdf INTERIOR-GEOLOGICAL SURVEY, RESTON, VIRGINIA-2003

U.S. Fish and Wildlife Service
National Wetlands Inventory

Redleaf Site



June 30, 2017

Wetlands

- Estuarine and Marine Deepwater
- Estuarine and Marine Wetland
- Freshwater Emergent Wetland
- Freshwater Forested/Shrub Wetland
- Freshwater Pond
- Lake
- Other
- Riverine

This map is for general reference only. The US Fish and Wildlife Service is not responsible for the accuracy or currentness of the base data shown on this map. All wetlands related data should be used in accordance with the layer metadata found on the Wetlands Mapper web site.

USNC-NIA-G00012
Revision 0

NGNP Advanced Reactor Site Feasibility Evaluation

Business Case for Evaluation of Advanced Reactor Technologies

Northwest Site
Red Leaf Utah Shale Oil Production

July 2017

LIST OF CONTRIBUTORS

Name	Organization
Matt Richards	USNC
Chris Hamilton	USNC

Approval

Francesco Venneri
Director/CEO Ultra Safe Nuclear Corporation

Date: July 24, 2017

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACRONYMS AND ABBREVIATIONS

DOE	U.S. Department of Energy
FEMA	Federal Emergency Management Agency
LNG	Liquefied Natural Gas
LWR	Light Water Reactor
MCFR	Molten Chloride Fast Reactor
MHR	Modular Helium Reactor
MHTGR	Modular High Temperature Gas Cooled Reactor
NGNP	Next Generation Nuclear Plant
NIA	NGNP Industry Alliance
NOAK	N^{th}-of-a-Kind
NRC	U.S. Nuclear Regulatory Commission
ORNL	Oak Ridge National Laboratory
R&D	Research and Development
RCCS	Reactor Cavity Cooling System
ROK	Republic of Korea
SC-HTGR	Steam Cycle HTGR
SFR	Sodium Fast Reactor
TRL	Technology Readiness Level
USNC	Ultra Safe Nuclear Corporation

1. Executive Summary

Depending on the public/private financial arrangements and commitments, projects could be initiated in the U.S. at one or more sites in the near future for hosting an advanced nuclear reactor demonstration module/plant. Considerations for deployment include strong potential for commercialization and return on investment, supporting U.S. energy and environmental policy goals, and alignment with international energy interests with potential for international collaboration. The overall scope of this study includes evaluation of four possible sites across the U.S.

This report provides an initial business-case evaluation for a potential site in Utah for the application of using process heat from an advanced reactor for recovering oil from shale deposits. The process being investigated for this site was developed by Red Leaf Resources Company and is called the EcoShale® In-Capsule Process. This site is referred to as the Red Leaf Site.

The reactor technologies considered for this study are the Modular Helium Reactor (MHR[1]), the Sodium Fast Reactor (SFR), and the Molten Chloride Fast Reactor (MCFR). These three advanced reactor types are all considered technically feasible and potentially deployable concepts, and are not excluded for any arbitrary site. However, some reactor types may lack the capabilities for deployment at some of the specific sites considered in this study. Examples may include sites with end-user requirements for higher temperature process heat and sites that require high thermal efficiency because of limited availability of cooling water. The MCFR has a significantly lower Technology Readiness Level (TRL) relative to the MHR and SFR.

Because a high temperature, emissions-free technology is a requirement for the Red Leaf application to enable expansion of shale oil recovery, the MHR is well suited for the Red Leaf Site. Because of its lower temperature capability and possibly more stringent siting restrictions, the SFR is judged to be less applicable for a realistic business case at the Red Leaf Site. Because of its relatively low TRL, further evaluation of the MCFR is needed to assess if there is a realistic business case at the Red Leaf Site.

There is strong public/government support for nuclear energy in the State of Utah to support their goals of reducing overall emissions and improving air quality. However, a business case for nuclear deployment at the Red Leaf Site requires a more extensive business plan that likely includes a large-scale refinery to utilize the hydrogen, methane, and other hydrocarbon byproduct gasses from shale oil recovery.

The Red Leaf Site is a very remote site with significant infrastructure/construction requirements, which significantly increases costs for a demonstration module/plant and reduces the likelihood

[1] Also referred to as the Modular High Temperature Gas Cooled Reactor (MHTGR).

that this site would be selected for that purpose. However, if future economic evaluations support large-scale shale oil recovery operations in this region, then this site and surrounding areas represent a potentially very large market for MHR deployment to provide the required process heat and electricity without adverse impact on air quality.

Recommendations include:

- Performing some additional scoping assessments to support more detailed business case and marketing evaluations for the Red Leaf Site.
- Maintaining contact with the State of Utah, Red Leaf, and other companies in support of MHR process heat applications.

2. Background

Depending on the public/private financial arrangements and commitments, projects could be initiated in the U.S. at one or more sites in the near future for hosting an advanced nuclear reactor demonstration module/plant. Considerations for deployment include strong potential for commercialization and return on investment, supporting U.S. energy and environmental policy goals, and alignment with international energy interests with potential for international collaboration. The overall scope of this study includes evaluation of four possible sites across the U.S.

This report provides an evaluation of a potential site in Utah for the application of using process heat from an advanced reactor for extracting oil from shale deposits. The process being investigated for this site was developed by Red Leaf Resources Company and is called the EcoShale® In-Capsule Process. In this report, this site is referred to as the Red Leaf Site. Figure 2-1 shows a simplified schematic of the EcoShale® In-Capsule Process and its features.

The Seep Ridge Block, a subset of Red Leaf's Utah oil shale portfolio, is comprised of approximately 1,600 acres of rich, near surface oil shale. It is located in Seep Ridge Canyon, Utah. Supported by recent drilling and engineering resource reports, the Seep Ridge Block is estimated to hold approximately 120 million barrels of oil that can be recovered using Red Leaf's EcoShale® technology. Seep Ridge is the site of the company's field pilot facility that was constructed and operated during the 2008 – 2009 time frame. The pilot facility successfully exhibited their technology's proprietary heating methods and oil extraction capabilities. As shown in Fig. 2-2, the Seep Ridge Block is part of the Green River Formation, which is the world's largest oil shale deposit. The pilot facility is shown in Fig. 2-3.

Red Leaf is currently seeking investment partners to proceed with a 10,000 barrel/day commercial-scale production facility. The project received conditional approval for its Large Mine Permit in October 2011 from Utah's Department of Oil, Gas, and Mining.

As discussed in [USNC 2017], three advanced reactor types were evaluated for this project. Based on recent assessments [DOE 2016], the Modular Helium Reactor (MHR) and the Sodium Fast Reactor (SFR) are the advanced reactor concepts most ready for near term deployment and are included as part of this study. Both of these concepts have a relatively high Technology Readiness Level (TRL) and are based on previous and currently operational prototypes. Both of these concepts also have received strong support from DOE and private vendors and have strong international support. No technical obstacles are known that would prevent MHR or SFR deployment by 2030.

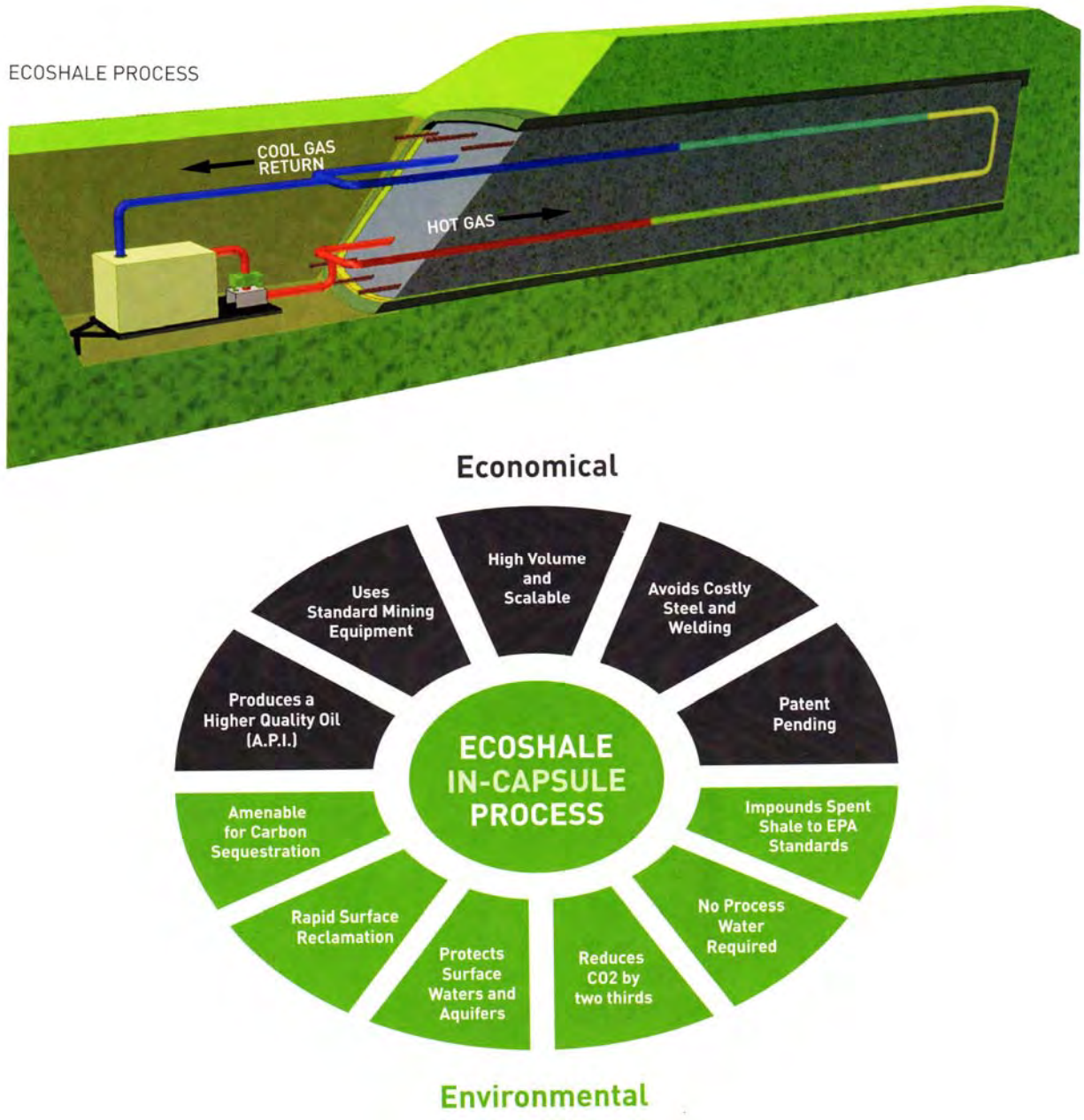


Figure 2-1. EcoShale® In-Capsule Process Schematic and Features

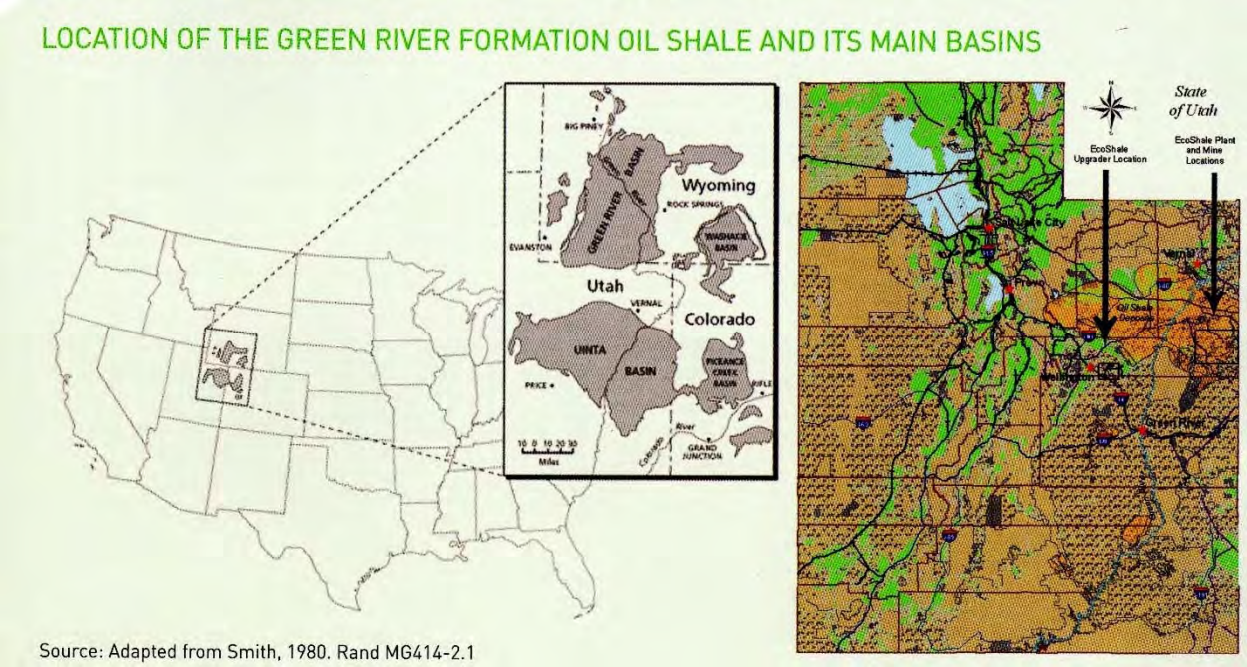


Figure 2-2. Green River Formation

Figure 2-3. EcoShale® Pilot Facility

This study also includes a higher-level evaluation of a more advanced reactor concept, a molten salt based concept called the Molten Chloride Fast Reactor (MCFR). The DOE recently funded an award to Southern Company Services, partnering with TerraPower, Electric Power Research Institute, Vanderbilt University, and Oak Ridge National Laboratory (ORNL) to perform R&D in support of this concept. If sufficient interest develops for more advanced concepts like the MCFR, deployment by 2040 to 2050 may be possible, assuming successful completion of required technology development programs in a timely manner.

3. Exclusionary Criteria

Exclusionary criteria were developed under Task 3 of this project [AREVA 2017] and are given in Table 3-1. A summary and evaluation of these exclusionary criteria, as they relate to the Red Leaf Site, are described below.

Table 3-1. Exclusionary Criteria

Category	Value
Seismic	Peak Ground Acceleration > 0.3 g at a probability of exceedance (PE) of 2 percent in 50 years. Located with five miles (8 Km) of a capable fault.
Flooding	Located within the 100-year flood plain.
Hazards	Accidents at nearby industrial or military facilities posing undue risk to the nuclear plant due to shock waves and missiles from explosions (depends on plant design and distance to plant). Directly in line with runways on high-operations commercial or military airports. Low lying areas downstream of major dams.
Transmission Lines	Less than 230 kilo-Volt (kV) capacity and less than two independent sources of off-site power within 30 mi (48.3 km).
Federal and State Lands	Located on one of the following: National/state parks. National/state historical sites. National/state seashores and lakeshores. National/state rivers and scenic riverways. National/state wildlife refuges. Wilderness areas. National maritime sanctuary areas. Cultural resources (American Indian lands, national landmarks).

3.1. Seismic

Because of the remote location of the Red Leaf Site, it has not been previously considered for commercial nuclear deployment. Further evaluation is needed to determine if any seismic considerations would exclude this site.

3.2. Flooding

The Red Leaf Site is located adjacent to Indian Ridge Canyon. Indian Ridge Canyon is dry throughout most of the year and does not contain any baseflow.

Floodplains are land areas adjacent to streams or rivers susceptible to being inundated by stream-derived waters. The Federal Emergency Management Agency (FEMA) Flood Insurance Rate Map was obtained for this site (Panels 49047C1925D and 49047C1950D) and indicates the location of the 100-year floodplain (see Fig. 3-1). The Flood Zone map shows that the site is not located in a flood zone (See Attachment 1 - FEMA Flood Map). The flood map lists Indian Ridge Canyon as Zone A ‘No Base Flood Determination’.

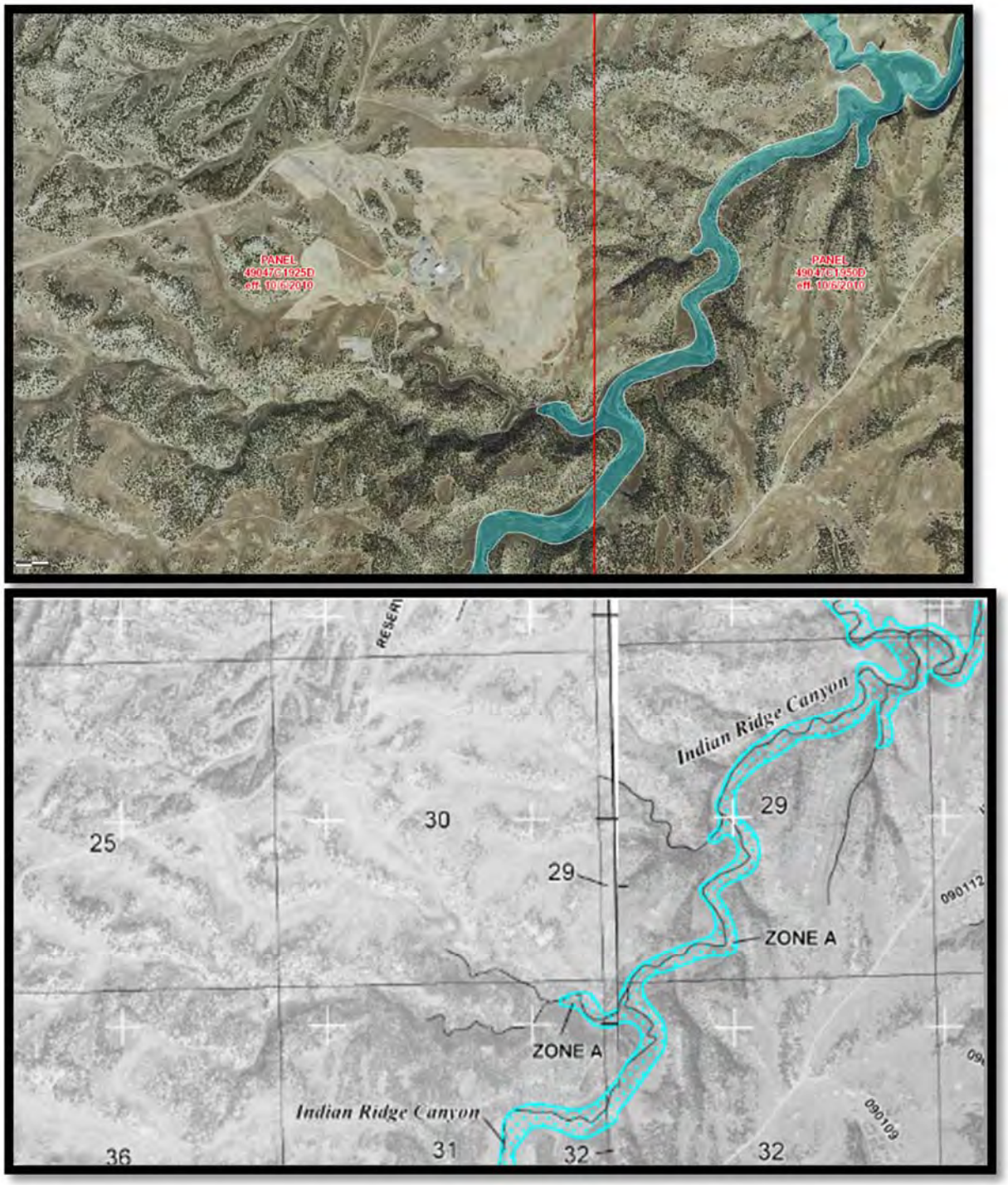


Figure 3-1. FEMA Flood Maps – Red Leaf Site

3.3. Hazards

No significant hazards were documented within close proximity to the site. The following facilities were noted in the area:

- Airports – There are no airports located within 2 miles of the site. The closest airport is the Grand Junction Regional Airport, located 82 miles southeast of the site.
- Military Bases – There are no known military installations within 2 miles of the site.
- Industrial/Chemical Sites – There are no known industrial/chemical complexes within 2 miles of the site.
- Pipelines – There are no pipelines located within 2 miles of the site. The nearest pipelines are:
  - A natural gas pipeline located 19 miles northeast of the site. It is operated by Enterprise Products Operating LLC.
  - A natural gas pipeline located 25 miles north of the site. It is operated by Questar Pipeline, LLC [NPMS 2017].
- Upstream Dams – The site is not located on a water body, and therefore is not located near any dams.

3.4. Transmission Lines

As shown in Fig. 3-2, the nearest high-voltage transmission line is located approximately 20 miles north of the site.

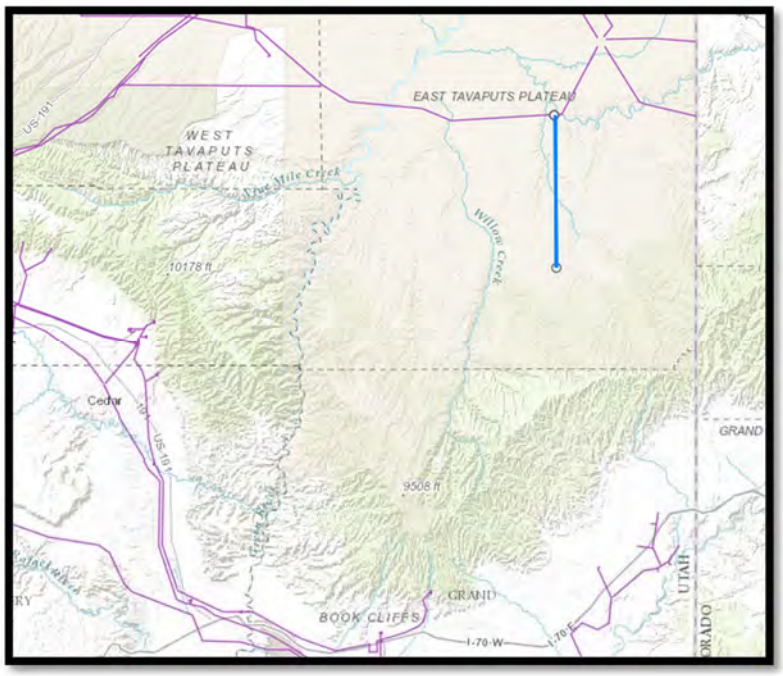


Figure 3-2. High-Voltage Transmission Lines Near the Red Leaf Site [ArcGIS 2017]

3.5. Federal and State Lands

The Red Leaf Site is located on the Uintah and Ouray Indian Reservation, just outside the boundary of the tribal lands. The reservation is located within a three-county area known as the "Uintah Basin". It is the second largest Indian Reservation in the United States and covers over 4.5 million acres. The Utes have a tribal membership of 2,970 and over half of its membership live on the Reservation. They operate their own tribal government and oversee approximately 1.3 million acres of trust land. [Ute 2017]

The site is also located just outside of a wilderness area under the jurisdiction of the Bureau of Land Management (See Attachment 2 – UT Lands).

4. Discretionary Criteria

The discretionary criteria given in Table 4-1 are not to be used to exclude a site from consideration, but are envisioned to be important to the business case.

Table 4-1. Discretionary Criteria

Category	Value
Cooling/Dilution Water	Water amount not sufficient to meet plant design. Water source not located nearby.
Need for process heat	Need for power/ process heat does not exist.
Airport, barges, rail lines, and roads	No preexisting infrastructure with 10 miles (16.1 km).
Population	Located with four miles (6.4 km) of a population center of 25,000 or more. Located within 10 miles (16.1 km) of a population center of 100,000 or more. Located within 20 miles (32.2 km) of a population center of 500,000 or more. Located within 30 miles (48.3 km) of a population center of 1,000,000 or more.
Wetlands	Large amount (> five acres) of wetlands impacted by construction.

4.1. Cooling/Dilution Water

There is not a source of water nearby the Red Leaf Site. However, direct utilization of process heat will reduce cooling water requirements.

4.2. Need for Process Heat

The EcoShale® process involves pyrolysis of shale to produce oil. The process requires heat at about 400°C and significant quantities of electricity. Byproducts of the process include hydrogen, methane, and other hydrocarbon gases. In principle, these gases could be burned to provide the required heat and electricity. However, because of the mountainous topography in the surrounding areas, the emissions from burning large quantities of fossil fuels can have a significant adverse impact on air quality. Hence, if large-scale shale oil recovery operations were performed in this region, nuclear energy could be used to produce the required heat and electricity without significant impacts on air quality. If it is assumed refining operations are also constructed and located near the oil recovery operations, the byproduct gases could be used for upgrading the oil.

4.3. Airports, Barges, Rail Lines, and Roads

The site does not have easy access to roads, rail and air. Below is a list of the various transportation options at the site.

- Airports – As discussed above, the closest airport is Grand Junction Regional Airport, located 82 miles southeast of the site.
- Rail – The nearest rail line is an abandoned line, Uintah Railway, approximately 20 miles from the site. The closest operational rail line is a main line that runs parallels with I-70, approximately 70 miles south of the site [OpenRail 2017]. Figure 4-1 shows the area rail map.
- Roads – Access to the site is via Seep Ridge Road. The closest access to a major highway or interstate is Old US Highway 6 &50/ I-70, approximately 55 miles south of the site. US-191 S/US-40 W is accessible approximately 55 miles to the north of the site.
- Barge Access – there is no barge access to the site.

Figure 4-1. Area Rail Map – Red Leaf Site

4.4. Population

The site is located on the Uintah and Ouray Indian Reservation which has a population of 19,182. Population centers noted in the region are as follows:

- Vernal, Utah, population 10,844, located in Uintah County, approximately 56 miles north of the site.
- Grand Junction, Colorado, population 60,210, located in Mesa County, Colorado, 60 miles southeast of the site.
- Moab, Utah, population 5,140, located in Grand County, approximately 74 miles south of the site.
- Price, Utah, population 8,358, located in Carbon County, approximately 76 miles west of the site.
- Provo, Utah, population 114,801, located in Utah County, approximately 125 miles west of the site.

4.5. Wetlands

National Wetland Inventory Maps (see Attachment 3) were reviewed and do not indicate any wetlands on the site [FWS 2017].

5. Business Case

As discussed in [USNC 2017], screening criteria for deploying advanced reactor concepts at candidate sites can be organized into four major categories:

1. Reactor Technology Considerations
2. Economics and Commercialization Potential
3. Licensing Considerations
4. Siting Considerations

These major categories are divided into several subcategories, as described in [USNC 2017].

5.1. Reactor Technology Considerations

As discussed in Section 2 and [USNC 2017], the reactor technologies considered for this study are the MHR, the SFR, and MCFR. These three advanced reactor types are all considered technically feasible and potentially deployable concepts, and are not excluded for any arbitrary site. However, some reactor types may lack the capabilities for deployment at some of the specific sites considered in this study. Examples may include sites with end-user requirements for higher temperature process heat and sites that require high thermal efficiency because of limited availability of cooling water.

For this higher-level screening study, it is assumed Category 1 (Reactor Technology Considerations) is independent of the site under consideration, with the exception of the overall technology considerations evaluated under Sub-category 4.1 (see Section 5.4 of [USNC 2017]).

5.2. Economics and Commercialization Potential

5.2.1. Market Potential

5.2.1.1. U.S. Market Potential

MHR technology by itself has good future U.S. market potential if natural gas prices rise to the $6-$8/MMbtu level over the next 20-30 years, as indicated by some DOE forecasts [NIA 2015], [USNC 2017]. The Red Leaf Site by itself could be a significant market for MHR technology, but this would require significant industrial development outside of the reactor technology for large-scale shale oil recovery.

The SFR is judged to have lower U.S. market potential than the MHR because of limited applications outside of electricity and possibly more restrictions on potential sites for deployment.

U.S. market potential is difficult to assess for the MCFR because of its low TRL compared to the MHR and SFR.

5.2.1.2. International Market Potential

International market potential is presently judged to be better than that in the U.S. because of the current high Liquified Natural Gas (LNG) prices in international markets like Japan and Korea, which are the world's No. 1 and No. 2 importers of LNG. However, political and related energy policy considerations will impact the international market potential.

SFR technology developed in the U.S. is judged to not have very strong international market potential. The technology is largely limited to nuclear states with significant export control difficulties. Other nuclear states have SFR design/technology programs that are more advanced than the U.S. program.

International market potential is difficult to assess for the MCFR because of its low TRL compared to the MHR and SFR.

5.2.2. Demonstration Module/Plant Costs

Design, technology development, construction, licensing, and start-up of an advanced reactor demonstration module/plant will likely require a large share of government funding regardless of the particular technology [DOE 2016]. For the Red Leaf Site, this category rating is judged to be fairly low relative to the other sites because the surrounding infrastructure is the least developed.

5.2.3. NOAK Commercial Plant Costs

The capital and energy production costs for a Nth-of-a-Kind (NOAK) commercial plant are an important consideration before deciding to proceed with a demonstration plant/module. At a minimum, these costs must be competitive with existing LWRs (for electricity) and fossil fuels (for electricity and process heat) and uncertainties in these costs should be minimized.

Expansion of nuclear energy in the U.S. is significantly inhibited because of the currently low price of fossil fuels and the absence of a national carbon-emission pricing policy. For deployment of new LWRs, [DOE 2016] recommends a production subsidy/payment of approximately $0.027/kWe-hr for generation of carbon-free electricity for a time period to be determined. This subsidy/payment may also be required for advanced reactors if fossil fuel prices remain low out to the time frame of their deployment.

For this study, it is recommended the MHR, SFR, and MCFR be treated equally for evaluation with respect to NOAK commercial plant costs.

5.2.4. Potential for International Collaboration

There has been a high level of international collaboration for both the MHR and SFR, including Generation IV activities and more direct collaborations on design and technology development. Recent examples for the MHR include participation by both Japan and the ROK in the Next Generation Nuclear Plant (NGNP) project [USNC 2015]. The U.S. has collaborated significantly with Japan, France, and other countries on the SFR.

The MHR may be rated somewhat higher than the SFR in this category, in part because of its potential for non-electric applications. The MCFR should be rated lower than the MHR and SFR, primarily because of its low level of technical maturity.

The potential for international collaboration is judged to be more dependent on the reactor technology than its deployment at a particular U.S. site or specific applications of the technology at a given site. However, the Red Leaf Site may generate less interest in participation from international partners because of its remote location, lack of supporting infrastructure, and unique application.

5.2.5. Impacts on Local Economy

Design, technology development, construction, licensing, and start-up of an advanced reactor demonstration module/plant at any site will obviously have a large positive impact on the local economy.

The Red Leaf Site was rated lower than the other sites in this category, primarily because it was judged to be less likely to be selected as a site for an advanced reactor demonstration plan/module, because of its extensive requirements for infrastructure development and because further evaluations are needed to fully assess the exclusionary criteria.

5.3. Licensing Considerations

In August 2012, the NRC provided to Congress a requested report [NRC 2012] addressing advanced reactor licensing. This report addresses the NRC's overall strategy for, and approach to, preparing for the licensing of advanced reactors including advanced non-LWR reactors. The report addresses licensing applications anticipated over the next two decades, as well as potential licensing activity beyond that time. It focuses on the licensing of nuclear reactor facilities for commercial use and illustrates regulatory challenges that may occur if various advanced reactors and advanced non-LWR reactor initiatives evolve into licensing applications.[2]

Also, in 2015, the NRC and the DOE began co-hosting a series of Advanced Non-LWR Workshops.

[2] This paragraph and the following two paragraphs are taken largely verbatim from the NRC website: https://www.nrc.gov/reactors/advanced.html.

As the NRC prepares to review and regulate a new generation of advanced non-light water reactors, a coherent vision and strategy is needed to assure NRC readiness to efficiently and effectively conduct its mission for these technologies. Most recently, the NRC issued its report [NRC 2016] "Vision and Strategy for Safely Achieving Effective and Efficient Non-Light Water Reactor Mission Readiness." The vision and strategy described in this report, once executed, will achieve the goal of assuring NRC readiness to effectively and efficiently review and regulate advanced non-LWRs.

These recent efforts by the NRC provide increased confidence that potential obstacles to licensing of advanced reactors will be addressed by the time licensing applications are submitted for these reactors.

Because of previous experience with NRC licensing efforts, the MHR and SFR should be rated equally for licensing considerations. The MCFR with its molten fuel presents some unique challenges and should be rated lower than the MHR and SFR, even considering the recent NRC initiatives to address licensing of advanced reactors.

Because the State of Utah has no previous experience with licensing a commercial nuclear reactor, the Red Leaf Site is rated lower than other sites in this category.

5.4. Siting Considerations

5.4.1. Technology Considerations

Because high temperature, emissions-free technology is needed for the Red Leaf application to enable expansion of the shale oil recovery, the MHR is well suited for the Red Leaf Site. Because of its lower temperature capability and possibly more stringent siting restrictions, the SFR is judged to be less applicable for a realistic business case at the Red Leaf Site. Because of its relatively low TRL, further evaluation of the MCFR is needed to assess if there is a realistic business case at the Red Leaf Site.

5.4.2. Site-Specific Considerations

There is strong public/government support for nuclear energy in the State of Utah to reduce overall emissions and improve air quality. However, a business case for nuclear deployment at the Red Leaf Site likely requires a much larger business plan that involves a large-scale refinery to utilize the hydrogen, methane, and other hydrocarbon byproduct gasses from shale oil recovery. Also, the Red Leaf Site is a very remote site with significant infrastructure requirements, which significantly increases costs for a demonstration module/plant and reduces the likelihood that this site would be selected for that purpose.

However, if future economic evaluations support large-scale shale oil recovery operations in this region,[3] then this site and surrounding areas represent a potentially very large market for MHR deployment.

[3] These economic evaluations will depend on a number of factors, including the market price for oil. Initial evaluations indicate shale oil recovery in this region becomes economical when oil prices are approximately $70/barrel.

6. Conclusions and Recommendations

There is strong public/government support for nuclear energy in the State of Utah to reduce overall emissions and improve air quality. However, a business case for nuclear deployment at the Red Leaf Site likely requires a much larger business plan that likely involves a large-scale refinery to utilize the hydrogen, methane, and other hydrocarbon byproduct gasses from shale oil recovery.

The Red Leaf Site is a very remote site with significant infrastructure requirements, which significantly increases costs for a demonstration module/plant and reduces the likelihood that this site would be selected for that purpose. However, if future economic evaluations support large-scale shale oil recovery operations in this region, then this site and surrounding areas represent a potentially very large market for MHR deployment to provide the required process heat and electricity without adverse impact on air quality.

Recommendations include:

- Performing some additional scoping assessments to support more detailed business case and marketing evaluations for the Red Leaf Site.
- Maintaining contact with the State of Utah, Red Leaf, and other companies in support of MHR process heat applications.

7. References

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[USNC 2017] "NGNP Advanced Reactor Site Feasibility Evaluation, Business Case Template for Evaluation of Advanced Reactor Technologies at Candidate Sites, USNC-NIA-G00008, Ultra Safe Nuclear Corporation, Los Alamos, NM, February 2017.

[Ute 2017] Ute Indian Tribe website, http://www.utetribe.com/, accessed May 2017.

Appendix A – Business Case Screening Evaluation

As discussed in [USNC 2017], screening criteria for deploying advanced reactor concepts at candidate sites can be organized into four major categories:

1. Reactor Technology Considerations
2. Economics and Commercialization Potential
3. Licensing Considerations
4. Siting Considerations

These major categories are divided into several subcategories, as described in [USNC 2017]. For this higher-level screening study, it is assumed Category 1 (Reactor Technology Considerations) is independent of the site under consideration, with the exception of the overall technology considerations evaluated under Sub-category 4.1 (see Section 5.4 of [USNC 2017]).

The screening methodology assigns percentage values to each of the four main screening categories and splits these percentages among subcategories (where applicable). A candidate site is then selected. The MHR is rated on a scale of 1 (lowest rating) to 10 (highest rating) for each category or subcategory. The product of the percentage and rating is the score for that category or subcategory. The total score is the sum of the category/subcategory scores. Qualitative remarks are provided for the other reactor technologies (SFR and MCFR).

Site Location/Description: NW Site (Red Leaf Utah Shale Oil Production)						
		Advanced Reactor Technologies				
		MHR			SFR	MCFR
Category/Subcategory	(%)	Rating	Score	Basis	Qualitative Remarks	Qualitative Remarks
1. Reactor Technology Considerations (25)						
1.1 Technology Readiness	4	6	24	Overall TRL rating. See Section 5.1.1 of [USNC 2017].	Approximately same TRL as MHR.	Much lower TRL than MHR and SFR. Much later deployment time frame.
1.2 Fuel Qualification	4	6	24	AGR program. See Section 5.1.2 of [USNC 2017].	Approximately same or slightly lower rating than MHR.	Molten fuel may have significant challenges.
1.3 Safety Considerations	7	9	63	Complete loss of coolant does not impact safety case. See Section 5.1.3 of [USNC 2017].	Loss of sodium coolant can lead to severe consequences.	Loss of molten fuel can lead to severe consequences.
1.4 Process Heat Capability	6	8	48	Can replace fossil fuels and transition to higher temperatures. See Sections 2 and 5.1.4 of [USNC 2017].	Current design is for electricity only. Lower coolant outlet temperature (~500°C) is less suitable for process heat applications.	Current design is for electricity only. With its 800°C outlet temperature, design could be adapted for process heat applications.
1.5 Energy Efficiency	4	8	32	High coolant outlet temperatures increase thermal efficiency. Direct utilization of process heat also increases efficiency. See Section 5.1.5 of [USNC 2017].	Lower thermal efficiency than MHR for electricity generation.	Somewhat higher thermal efficiency for electricity generation than MHR.
1.6 Fuel Cycle Considerations	0	N/A	N/A	Dependent on national fuel cycle policy. Per Section 7.2 of [USNC 2017], good fuel cycle synergy with fast reactors.	Fast neutron spectrum allows for breeding fissile fuel. Operation in burner mode allows destruction of transuranics.	Insufficient information to assess fuel cycle considerations.
2. Economics and Commercialization Potential (35)						
2.1a Market Potential – U.S.	7	3	21	MHR technology by itself has good future U.S. market potential if natural gas prices rise to the $6-$8/MMbtu level over the next 20-30 years, as indicated by some DOE forecasts. Category rating is	Co-location with other industries may prove challenging. Lower coolant outlet temperature (~500°C) is less suitable for process heat applications. Additional geologic opportunities to recover oil from shale may be limited.	May share some of the same potential as MHR. Difficult to assess because of the low Technology Readiness Level compared to the MHR and SFR.

Site Location/Description: NW Site (Red Leaf Utah Shale Oil Production)						
		Advanced Reactor Technologies				
		MHR			SFR	MCFR
Category/Subcategory	(%)	Rating	Score	Basis	Qualitative Remarks	Qualitative Remarks
				judged to be low for this particular site relative to the other sites because actual U.S. market is limited to this site, which requires significant industrial development outside of the reactor technology.		
2.1b Market Potential - International	7	4	28	Judged to be higher than the U.S. market because of the current high LNG prices in international markets like Japan and Korea that are No. 1 and No. 2 in imported LNG. Political and related energy policy considerations will impact the international market potential.	Lower coolant outlet temperature (~500°C) is less suitable for process heat applications Additional geologic opportunities to recover oil from shale may be limited. The technology is largely limited to nuclear states with significant export control restrictions. Other nuclear states have SFR design/technology programs that are more advanced than the U.S. program. The travelling wave sodium reactor under development is attempting to address the export control challenges.	May share some of the same potential as MHR. Difficult to assess because of the low Technology Readiness Level compared to the MHR and SFR.
2.2 Demonstration Module/Plant Costs	3	3	9	Requires large gov't funding regardless of technology. Category rating is judged to be low for this particular site relative to the other sites because surrounding infrastructure is the least developed.	About the same as the MHR.	Much more uncertain than the MHR.
2.3 NOAK Commercial Plant Costs	5	N/A	N/A	Relative to other energy technologies. Not evaluated at this screening stage. More detailed	Not evaluated at this screening stage.	Not evaluated at this screening stage.

Site Location/Description: NW Site (Red Leaf Utah Shale Oil Production)						
		Advanced Reactor Technologies				
		MHR			SFR	MCFR
Category/Subcategory	(%)	Rating	Score	Basis	Qualitative Remarks	Qualitative Remarks
				business model needed to evaluate this category.		
2.4 Potential for International Collaboration	5	7	35	Several existing international programs.	Possibly good. But Russia, France and Japan already have strong national programs.	Unknown, but the U.S. seems to be the country primarily interested in MSR at this stage
2.5 Impacts on Local Economy	8	6	48	Any project should have strong impacts on local economy.	Greenfield project should have strong impacts on local economy.	Greenfield project should have strong impacts on local economy.
3. Licensing Considerations (15)	15	5	75	No previous commercial nuclear projects in Utah.	SFR should not have any significant licensing issues relative to the MHR; however, licensing/safety evaluation is likely more complex.	Less mature technology requires further evaluation to assess realistic licensing case at Red Leaf.
4. Siting Considerations (25)						
4.1 Technology Considerations	10	8	80	High temperature, emissions-free technology is needed for the Red-Leaf application to enable expansion of the shale oil recovery.	Technology less applicable for realistic business case at Red Leaf.	Less mature technology requires further evaluation to assess realistic business case at Red Leaf.
4.2 Site-Specific Considerations	15	4	60	Strong public/government support for nuclear energy in Utah to reduce overall emissions and improve air quality. However, a business case for HTGR nuclear deployment at Red Leaf likely requires a much larger business plan that involves a large-scale refinery to utilize the H2, CH4, and other hydrocarbon off gasses from shale oil recovery. Also, a very remote site with	Remote site and ancillary services are extremely limited. Technology less applicable for realistic business case at Red Leaf.	Remote site and ancillary services are extremely limited. Less mature technology requires further evaluation to assess realistic business case at Red Leaf.

Site Location/Description: NW Site (Red Leaf Utah Shale Oil Production)						
		Advanced Reactor Technologies				
		MHR			SFR	MCFR
Category/Subcategory	(%)	Rating	Score	Basis	Qualitative Remarks	Qualitative Remarks
				significant infrastructure requirements.		
Total	100	**Total**	547			

NOTES TO USERS

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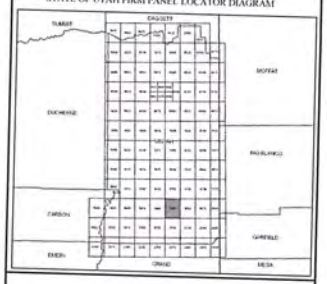
STATE OF UTAH FIRM PANEL LOCATOR DIAGRAM



LEGEND

SPECIAL FLOOD HAZARD AREAS SUBJECT TO INUNDATION BY THE 1% ANNUAL CHANCE FLOOD

The 1% annual flood (100-year flood), also known as the base flood, is the flood that has a 1% chance of being equaled or exceeded in any given year. The Special Flood Hazard Area is the area subject to flooding by the 1% annual chance flood. Areas of Special Flood Hazard include Zones A, AE, AH, AO, AR, A99, V, and VE. The Base Flood Elevation is the water-surface elevation of the 1% annual chance flood.

- ZONE A — No Base Flood Elevations determined.
- ZONE AE — Base Flood Elevations determined.
- ZONE AH — Flood depths of 1 to 3 feet (usually areas of ponding); Base Flood Elevations determined.
- ZONE AO — Flood depths of 1 to 3 feet (usually sheet flow on sloping terrain); average depths determined. For areas of alluvial fan flooding, velocities also determined.
- ZONE AR — Special Flood Hazard Area formerly protected from the 1% annual chance flood by a flood control system that was subsequently decertified. Zone AR indicates that the former flood control system is being restored to provide protection from the 1% annual chance or greater flood.
- ZONE A99 — Area to be protected from 1% annual chance flood by a Federal flood protection system under construction; no Base Flood Elevations determined.
- ZONE V — Coastal flood zone with velocity hazard (wave action); no Base Flood Elevations determined.
- ZONE VE — Coastal flood zone with velocity hazard (wave action); Base Flood Elevations determined.

FLOODWAY AREAS IN ZONE AE

The floodway is the channel of a stream plus any adjacent floodplain areas that must be kept free of encroachment so that the 1% annual chance flood can be carried without substantial increases in flood heights.

OTHER FLOOD AREAS

- ZONE X — Areas of 0.2% annual chance flood; areas of 1% annual chance flood with average depths of less than 1 foot or with drainage areas less than 1 square mile; and areas protected by levees from 1% annual chance flood.

OTHER AREAS

- ZONE X — Areas determined to be outside the 0.2% annual chance floodplain.
- ZONE D — Areas in which flood hazards are undetermined, but possible.

COASTAL BARRIER RESOURCES SYSTEM (CBRS) AREAS

OTHERWISE PROTECTED AREAS (OPAs)

CBRS areas and OPAs are normally located within or adjacent to Special Flood Hazard Areas.

- 1% annual chance floodplain boundary
- 0.2% annual chance floodplain boundary
- Floodway boundary
- Zone D boundary
- CBRS and OPA boundary
- Boundary dividing Special Flood Hazard Area Zones and boundary dividing Special Flood Hazard Areas of different Base Flood Elevations, flood depths or flood velocities.
- 513 (EL. 987) — Base Flood Elevation line and value; elevation in feet*
- Base Flood Elevation value where uniform within zone; elevation in feet*

*Referenced to the North American Vertical Datum of 1988

- (A) (A) — Cross section line
- Transect line
- 87°07'45", 32°22'30" — Geographic coordinates referenced to the North American Datum of 1983 (NAD 83), Western hemisphere
- 4276000 FT — 1000-meter Universal Transverse Mercator grid values, zone 12
- 600000 FT — 5000-foot grid ticks: Utah State Plane coordinate system, Central zone (FIPSZONE 4302), Transverse Mercator Projection
- DX5510 X — Bench mark (see explanation in Notes to Users section of this FIRM panel)
- M1.5 — River Mile

MAP REPOSITORIES
Refer to Map Repositories list on Map Index.

EFFECTIVE DATE OF COUNTYWIDE FLOOD INSURANCE RATE MAP PANEL
OCTOBER 6, 2010

EFFECTIVE DATE(S) OF REVISION(S) TO THIS PANEL

For community map revision history prior to countywide mapping, refer to the Community Map History table located in the Flood Insurance Study report for this jurisdiction.

To determine if flood insurance is available in this community, contact your insurance agent or call the National Flood Insurance Program at 1-800-638-6620.

MAP SCALE 1" = 2000'
1000 0 2000 4000 FEET
500 0 600 1200 METERS

NFIP
NATIONAL FLOOD INSURANCE PROGRAM

PANEL 1925D

FIRM
FLOOD INSURANCE RATE MAP

UINTAH COUNTY, UTAH
AND INCORPORATED AREAS

PANEL 1925 OF 2450

(SEE MAP INDEX FOR FIRM PANEL LAYOUT)

CONTAINS:

COMMUNITY	NUMBER	PANEL	SUFFIX
UINTAH COUNTY	490147	1925	D

Notice to User: The **Map Number** shown below should be used when placing map orders; the Community Number shown above should be used on insurance applications for the listed community.

MAP NUMBER
49047C1925D

EFFECTIVE DATE
OCTOBER 6, 2010

Federal Emergency Management Agency

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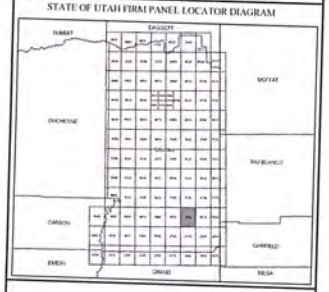
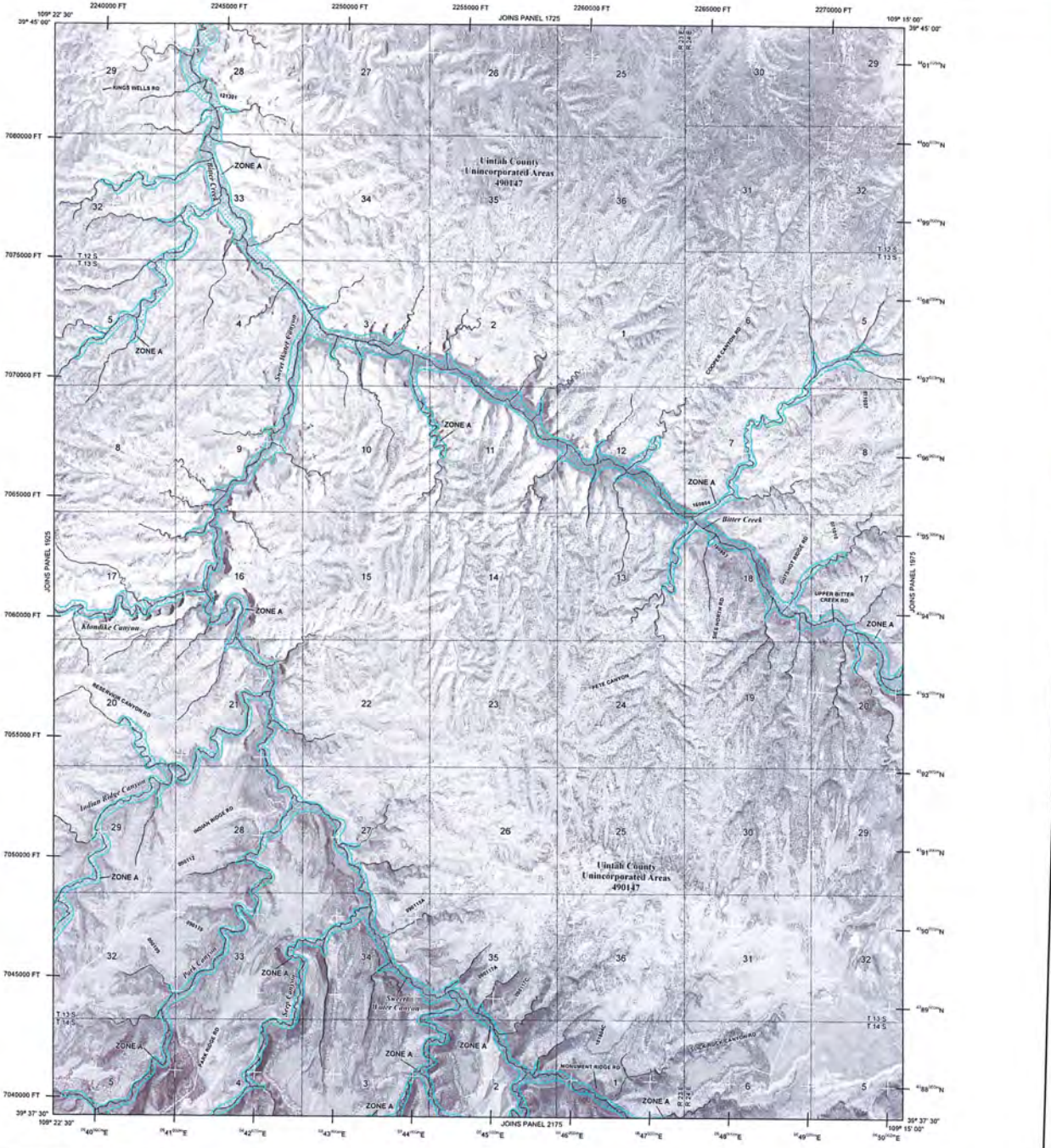
If you have **questions about this map** or questions concerning the National Flood Insurance Program in general, please call **1- 877- FEMA MAP** (1-877-336-2627) or visit the FEMA website at http://www.fema.gov/.

STATE OF UTAH FIRM PANEL LOCATOR DIAGRAM





51-4072172-000

LEGEND

SPECIAL FLOOD HAZARD AREAS SUBJECT TO INUNDATION BY THE 1% ANNUAL CHANCE FLOOD

The 1% annual flood (100-year flood), also known as the base flood, is the flood that has a 1% chance of being equaled or exceeded in any given year. The Special Flood Hazard Area is the area subject to flooding by the 1% annual chance flood. Areas of Special Flood Hazard include Zones A, AE, AH, AO, AR, A99, V, and VE. The Base Flood Elevation is the water-surface elevation of the 1% annual chance flood.

- **ZONE A** — No Base Flood Elevations determined.
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FLOODWAY AREAS IN ZONE AE

The floodway is the channel of a stream plus any adjacent floodplain areas that must be kept free of encroachment so that the 1% annual chance flood can be carried without substantial increases in flood heights.

OTHER FLOOD AREAS

- **ZONE X** — Areas of 0.2% annual chance flood; areas of 1% annual chance flood with average depths of less than 1 foot or with drainage areas less than 1 square mile; and areas protected by levees from 1% annual chance flood.

OTHER AREAS

- **ZONE X** — Areas determined to be outside the 0.2% annual chance floodplain.
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COASTAL BARRIER RESOURCES SYSTEM (CBRS) AREAS

OTHERWISE PROTECTED AREAS (OPAs)

CBRS areas and OPAs are normally located within or adjacent to Special Flood Hazard Areas.

- 1% annual chance floodplain boundary
- 0.2% annual chance floodplain boundary
- Floodway boundary
- Zone D boundary
- CBRS and OPA boundary
- Boundary dividing Special Flood Hazard Area Zones and boundary dividing Special Flood Hazard Areas of different Base Flood Elevations, flood depths or flood velocities.
- 513 — Base Flood Elevation line and value; elevation in feet*
- (EL. 987) — Base Flood Elevation value where uniform within zone; elevation in feet*

*Referenced to the North American Vertical Datum of 1988

- Cross section line
- Transect line
- 87°07'45", 32°22'30" — Geographic coordinates referenced to the North American Datum of 1983 (NAD 83), Western Hemisphere
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- 600000 FT — 5000-foot grid ticks: Utah State Plane coordinate system, Central zone (FIPSZONE 4302), Transverse Mercator Projection
- DX5510 × — Bench mark (see explanation in Notes to Users section of this FIRM panel)
- M1.5 — River Mile

MAP REPOSITORIES
Refer to Map Repositories list on Map Index

EFFECTIVE DATE OF COUNTYWIDE FLOOD INSURANCE RATE MAP PANEL
OCTOBER 6, 2010

EFFECTIVE DATE(S) OF REVISION(S) TO THIS PANEL

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To determine if flood insurance is available in this community, contact your insurance agent or call the National Flood Insurance Program at 1-800-638-6620.

MAP SCALE 1" = 2000'
1000 0 2000 4000 FEET
500 0 500 1000 METERS

NATIONAL FLOOD INSURANCE PROGRAM

PANEL 1950D

FIRM
FLOOD INSURANCE RATE MAP

UINTAH COUNTY, UTAH
AND INCORPORATED AREAS

PANEL 1950 OF 2450

(SEE MAP INDEX FOR FIRM PANEL LAYOUT)

CONTAINING:

COMMUNITY	NUMBER	PANEL	SUFFIX
UINTAH COUNTY	490147	1950	D

Notice to User: The Map Number shown below should be used when placing map orders; the Community Number shown above should be used on insurance applications for the subject community.

MAP NUMBER
49047C1950D

EFFECTIVE DATE
OCTOBER 6, 2010

Federal Emergency Management Agency

nationalatlas.gov™
Where We Are

UTAH

FEDERAL LANDS AND INDIAN RESERVATIONS

- Bureau of Indian Affairs
- Bureau of Land Management / Wilderness
- Bureau of Reclamation
- Department of Defense (includes Army Corps of Engineers lakes)
- Fish and Wildlife Service / Wilderness
- Forest Service / Wilderness
- National Park Service / Wilderness

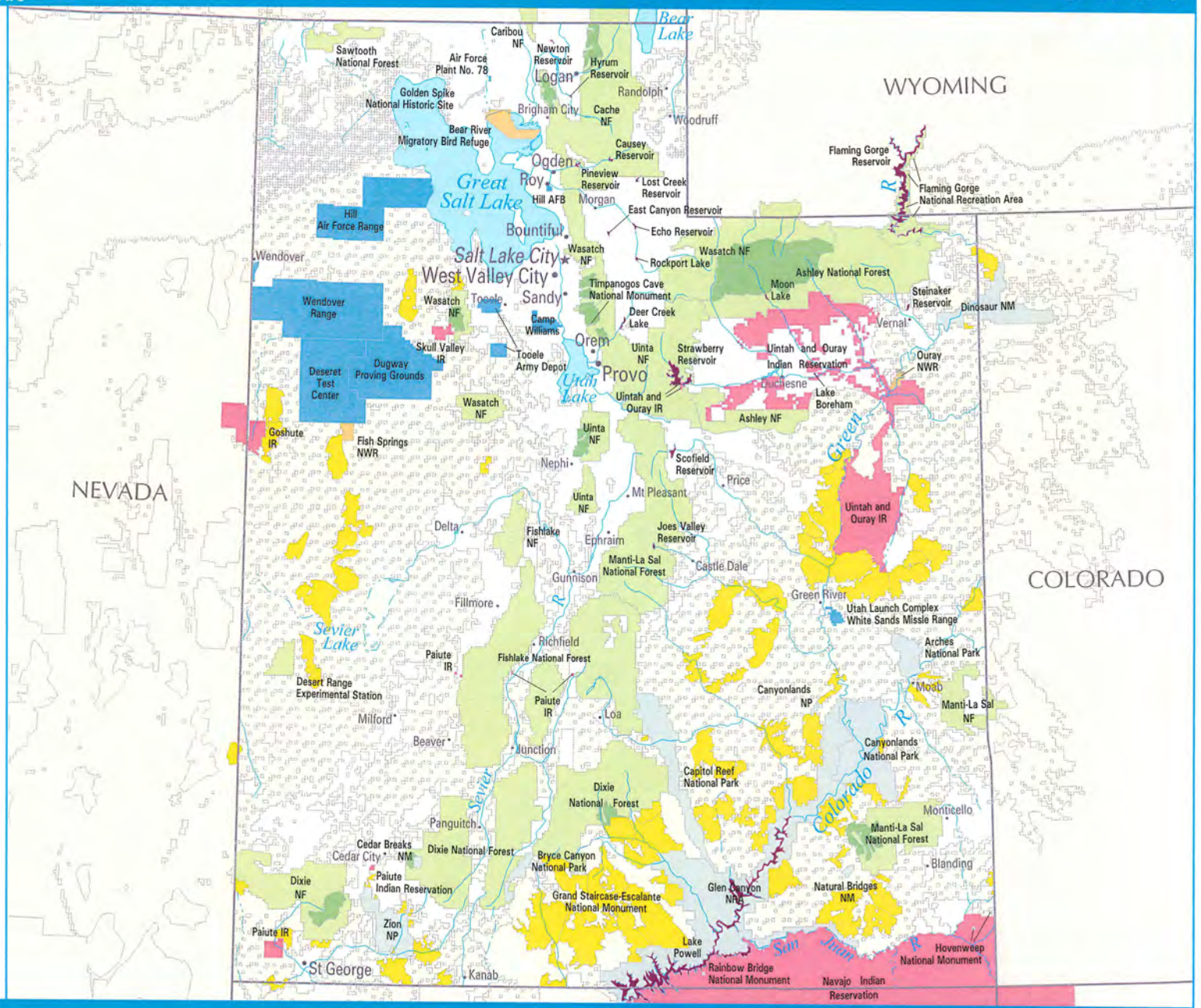
Some small sites are not shown, especially in urban areas.

MILES
0 20 40 60 80

Albers equal area projection

Abbreviations

AFB	Air Force Base
IR	Indian Reservation
NF	National Forest
NM	National Monument
NP	National Park
NRA	National Recreation Area
NWR	National Wildlife Refuge



U.S. Department of the Interior
U.S. Geological Survey

The National Atlas of the United States of America®

U.S. Fish and Wildlife Service

National Wetlands Inventory

Redleaf Site

June 30, 2017

Wetlands

- Estuarine and Marine Deepwater
- Estuarine and Marine Wetland
- Freshwater Emergent Wetland
- Freshwater Forested/Shrub Wetland
- Freshwater Pond
- Lake
- Other
- Riverine

This map is for general reference only. The US Fish and Wildlife Service is not responsible for the accuracy or currentness of the base data shown on this map. All wetlands related data should be used in accordance with the layer metadata found on the Wetlands Mapper web site.

National Wetlands Inventory (NWI)
This page was produced by the NWI mapper

APPENDIX D: SW PROXY SITE

Date: 06/30/2017
ND-17-1173
R-Type SND.BD.L06

Signature Block 1: Matthew T Montz

Signature Block 2:

Version Summary

Version	Description
0	Issued as final

Southwestern Demonstration Plant Site

1. Executive Summary

TBD – Common for all sites

2. Background

University of Texas Permian Basin (UTPB) site description…

The site is located in Ector County, just south of Interstate 20, approximately 15 miles southwest of Odessa, Texas.

Figure 1 – Plant Site

3. Exclusionary Criteria

Site values for the following criteria cannot be met or exceeded. None of these values are met or exceeded by this site.

Category	Value
Seismic	• Peak Ground Acceleration > 0.3 g at a probability of exceedance (PE) of 2 percent in 50 years • Located with five miles (8 kilometers (Km)) of a capable fault
Flooding	• Located within the 100-year flood plain

Hazards	• Accidents at nearby industrial or military facilities posing undue risk to the nuclear plant due to shock waves and missiles from explosions (depends on plant design and distance to plant) • Directly in line with runways on high-operations commercial or military airports. • Low lying areas downstream of major dams
Transmission Lines	• Less than 230 kilo-Volt (kV) capacity and less than two independent sources of off-site power within 30 mi (48.3 km)
Federal and State Lands	Located on one of the following: • National/state parks • National/state historical sites • National/state seashores and lakeshores • National/state rivers and scenic riverways • National/state wildlife refuges • Wilderness areas • National maritime sanctuary areas • Cultural resources (American Indian lands, national landmarks)

A summary and evaluation of these exclusionary criteria as they relate to the site are described below.

3.1. Seismic

Information not provided.

3.2. Flood Zone

Floodplains are land areas adjacent to streams or rivers susceptible to being inundated by stream-derived waters. The Federal Emergency Management Agency (FEMA) Flood Insurance Rate Map was obtained for the site (Map Number 48135C0450E) and indicates the location of the 100-year floodplain.

The Flood Zone map shows that the site is not located in a flood zone (See Attachment 1 - FEMA Flood Map), and lists the site as Zone X, “Other Flood Areas”. Zone X is describes as “Areas of 0.2% annual chance of flood, areas of 1% annual change of flood with average depths of less than 1 food or drainage areas less than 1 square mile; and areas protected by levees from 1% annual flood.” (FEMA 2017)

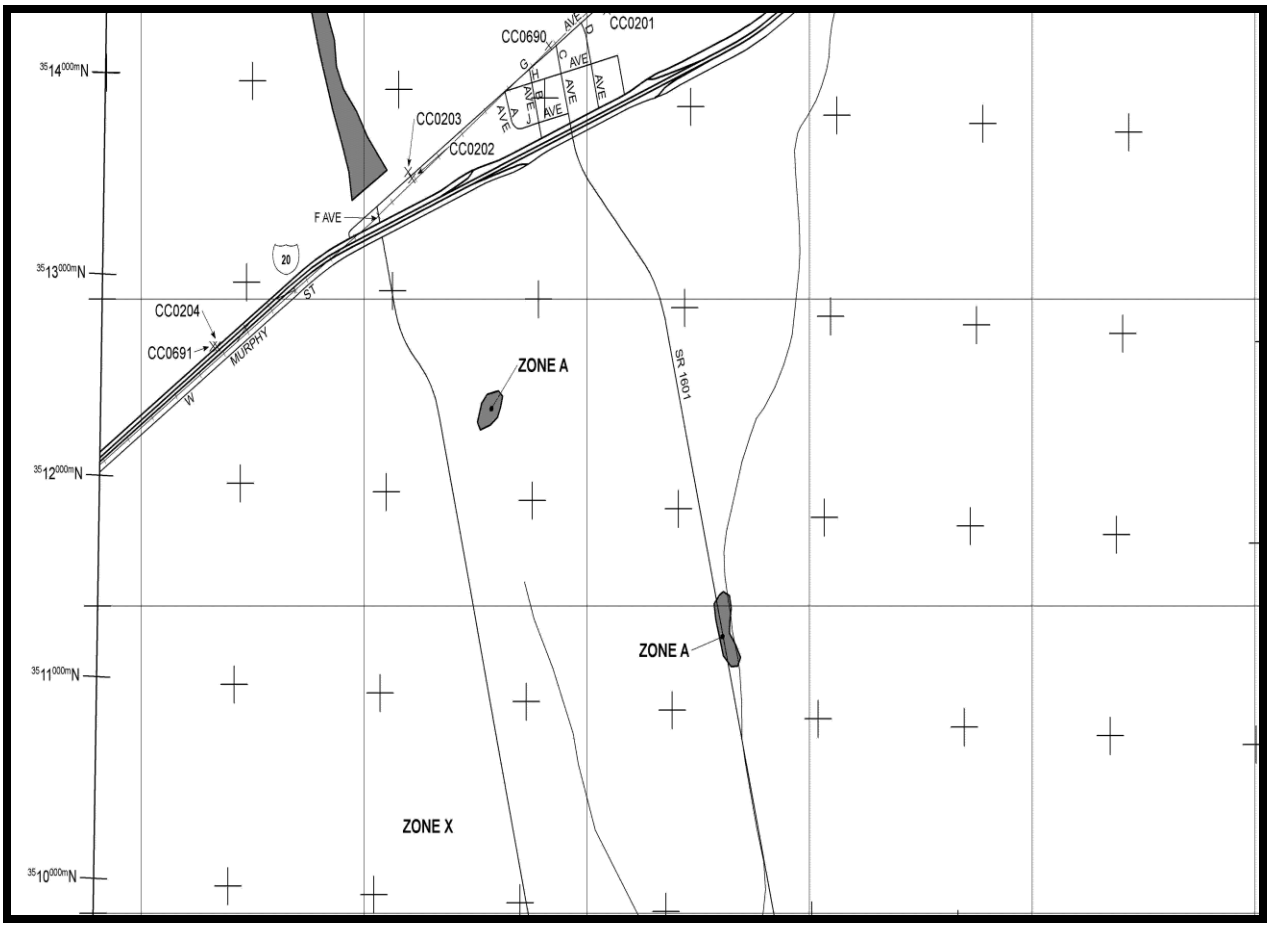


Figure 2 – FEMA Flood Map

3.3. Hazards

Several potential hazards are within close proximity to the plant and will require evaluation prior to proceeding with a licensing action. The following facilities were noted in the area:

- Airports – there are no airports within 2 miles of the site. The airport nearest to the site is Odessa-Schlemeyer Field located approximately 17 miles northeast.
    - Other airports/airfields in the area include:
        - Wood Farm Airfield – located approximately 25 miles northeast.
        - Midland International Air and Space Port – located approximately 26 miles northeast.
        - Sky West – located approximately 31 miles east. (Google 2017)
- Military Bases – there are no known military installations within 2 miles of the site.
- Industrial/Chemical Sites

  - There numerous oil/gas wells located both on the site and within 2 miles of the site. Additional evaluations are needed to determine the significance of these potential hazards.
  - No other large industrial/chemical facilities were noted within 2 miles of the site.
  - A cement plant, owned by Cemex USA, is located approximately 2.7 miles east of the site.
- Pipelines - Per the National Pipeline Mapping System website (NPMS 2017) several pipelines were noted within 2 miles of the site. Additional evaluations are needed to determine the significance of these potential hazards. The nearest pipelines are:
  - Crude oil pipeline operated by Centurion Pipeline, L.P., located approximately 3,000 ft. east of the site.
  - Crude oil pipeline operated by Plain Pipeline, L.P., located approximately 4,000 ft. south of the site.
  - Natural gas pipeline operated by OneOK West Texas Transmission, located approximately 1.5 miles east of the site.
  - Carbon dioxide pipeline, operated by Kinder Morgan, located approximately 1.5 miles east of the site.
  - Natural gas liquids pipeline, operated by Energy Transfer Company, located approximately 2 miles south of the site.
  - Natural gas pipeline, operated by OneOK West Texas Transmission, located approximately 2 miles south of the site.
- Upstream Dams – there are no dams/impoundments located within 2 miles of the site.
- Subsurface Mining – One surface mine (sand/gravel) associated with the Cemex USA cement plant is located approximately 2 miles east of the site. No other surface mines were noted within 2 miles of the site.

3.4. Transmission Lines

The nearest high voltage transmission line to the site is a 69-kv line approximately 1 mile south of the site. Additional lines are located in the area, the next closest being a 138-kV line approximately 6.8 miles northeast of the site. (EIA 2017)

Though the exact location is not known, the Electric Reliability Council of Texas (ERCOT) has proposed the construction of a new 345-kV transmission line north of the site. (ERCOT 2016)

3.5. Federal and State Lands

The site is not on or located adjacent to any state of federal lands. There are no know state or federal lands within 2 miles of the site.

The nearest state park is Monahans Sandhills State Park located approximately 15 miles southwest of the site.

4. Discretionary Criteria

The following discretionary criteria are not to be used to exclude a site from consideration, but are envisioned to be important to the business case.

Category	Value

Cooling/Dilution Water	• Water amount not sufficient to meet plant design • Water source not located nearby
Need for process heat	• Need for power/ process heat does not exist
Airport, barges, rail lines, and roads	• No preexisting infrastructure with 10 miles (16.1 km)
Population	• Located with four miles (6.4 km) of a population center of 25,000 or more • Located within 10 miles (16.1 km) of a population center of 100,000 or more • Located within 20 miles (32.2 km) of a population center of 500,000 or more • Located within 30 miles (48.3 km) of a population center of 1,000,000 or more
Wetlands	Large amount (> five acres) of wetlands impacted by construction

4.1. Cooling/Dilution Water

Not known at this time.

4.2. Need for Power/Process heat

See Business Case

4.3. Airports, Barges, Rail lines, Roads

The site has access to roads, rail and air. Below is a list of the various transportation options at the site.

- Airports – As discussed above, the airport nearest to the site is Odessa-Schlemeyer Field located approximately 17 miles northeast. The Midland International Air and Space Port is located approximately 26 miles northeast of the site.
- Rail – The site is approximately 3300 ft. south of the Toyah Subdivision, a mainline railroad operated by Kiewit Infrastructure West. (OpenRail 2017)
- Roads – Access is via I-20, located immediately north of the site. (Google 2017)
- Barge Access – there is no barge access to the site.

4.4. Population

Population centers near the site are as follows:

- West Odessa, Texas, population 22,707, located in Ector County, approximately 8 miles northeast of the site.
- Odessa, Texas, population 118,918, located in Ector County, approximately 15 miles northeast of the site.
- Monahans, Texas, population 6,953, located in Ward County, approximately 20 miles southwest of the site.
- Gardendale, Texas, population 1,574, located in Ector County, approximately 24 miles northeast of the site.
- Midland, Texas, population 111,147, located in Midland County, approximately 35 miles northeast of the site.

- Kermit, Texas population 5,708, located in Winkler County, approximately 30 miles northwest of the site.

4.5. Wetlands

Current wetland delineations have not been performed at the site. However, a review of the National Wetland Inventory (NWI) Maps (Attachment 2) did not indicate any wetlands on the site.

Two small freshwater forested/shrub wetlands located just to the south of the site were noted on the NWI maps. (FWS 2017) Site specific wetland delineations are needed to confirm their existence.

Figure 4 – National Wetland Inventory Map

5. Business Case

From others.

References:

(EIA 2017) U.S. Energy Information Administration, U.S. Energy Mapping System, https://www.eia.gov/state/maps.php, accessed May, 2017.

(ERCOT 2016) Electric Reliability Council of Texas, “2016 Long-Term System Assessment for the ERCOT Region”, December, 2016.

(FEMA 2017) U.S. Federal Emergency Management Agency, Flood Map Service Center, http://msc.fema.gov/portal/search, accessed May, 2017.

(FWS 2017) U.S. Fish and Wildlife Service National Wetland Inventory Mapper website, https://www.fws.gov/wetlands/data/mapper.HTML, accessed May 2017.

(Google 2017) Google Maps website, https://www.google.com/maps, accessed May, 2017.

(NPMS 2017) National Pipeline Mapping System website, https://www.npms.phmsa.dot.gov/, accessed May 2017.

(OpenRail 2017) Open Railway Map website, http://www.openrailwaymap.org, accessed May, 2017.

Abbreviations:

ERCOT	Electric Reliability Council of Texas
FEMA	U.S. Federal Emergency Management Agency
Km	kilometer
kV	kilovolt
NWI	National Wetland Inventory
PE	probability of exceedance
UTPB	University of Texas Permian Basin

Attachments

Attachment 1 – FEMA Floodplain Map

Attachment 2 – National Wetland Inventory Map

NOTES TO USERS

This map is for use in administering the National Flood Insurance Program. It does not necessarily identify all areas subject to flooding, particularly from local drainage sources of small size. The community map repository should be consulted for possible updated or additional flood hazard information.

To obtain more detailed information in areas where **Base Flood Elevations (BFEs)** and/or floodways have been determined, users are encouraged to consult the Flood Profiles and Floodway Data and/or Summary of Stillwater Elevations tables contained within the Flood Insurance Study (FIS) report that accompanies this FIRM. Users should be aware that BFEs shown on the FIRM represent rounded whole-foot elevations. These BFEs are intended for flood insurance rating purposes only and should not be used as the sole source of flood elevation information. Accordingly, flood elevation data presented in the FIS report should be utilized in conjunction with the FIRM for purposes of construction and/or floodplain management.

Coastal Base Flood Elevations (BFEs) shown on this map apply only landward of 0.0 North American Vertical Datum of 1988 (NAVD 88). Users of this FIRM should be aware that coastal flood elevations are also provided in the Summary of Stillwater Elevations table in the Flood Insurance Study report for this jurisdiction. Elevations shown in the Summary of Stillwater Elevations table should be used for construction and/or floodplain management purposes when they are higher than the elevations shown on this FIRM.

Boundaries of the **floodways** were computed at cross sections and interpolated between cross sections. The floodways were based on hydraulic considerations with regard to requirements of the National Flood Insurance Program. Floodway widths and other pertinent floodway data are provided in the Flood Insurance Study report for this jurisdiction.

Certain areas not in Special Flood Hazard Areas may be protected by **flood control structures**. Refer to Section 2.4 "Flood Protection Measures" of the Flood Insurance Study report for information on flood control structures for this jurisdiction.

The **projection** used in the preparation of this map was Texas Central State Plane Coordinate System (FIPS 4203). The **horizontal datum** was NAD83, GRS1980 spheroid. Differences in datum, spheroid, projection or State Plane Coordinate Systems used in the production of FIRMs for adjacent jurisdictions may result in slight positional differences in map features across jurisdiction boundaries. These differences do not affect the accuracy of this FIRM.

Flood elevations on this map are referenced to the North American Vertical Datum of 1988. These flood elevations must be compared to structure and ground elevations referenced to the same vertical datum. For information regarding conversion between the National Geodetic Vertical Datum of 1929 and the North American Vertical Datum of 1988, visit the National Geodetic Survey website at http://www.ngs.noaa.gov/ or contact the National Geodetic Survey at the following address:

NGS Information Services
NOAA, NINES12
National Geodetic Survey
SSMC-3, #9202
1315 East-West Highway
Silver Spring, Maryland 20910-3282
(301) 713-3242

To obtain current elevation, description, and/or location information for bench marks shown on this map, please contact the Information Services Branch of the National Geodetic Survey at (301) 713-3242 or visit its website at http://www.ngs.noaa.gov/.

Base map information shown on this FIRM was provided in digital format by the City of Odessa GIS Department and the Texas Statewide Strategic Mapping Program.

This map reflects more detailed and up-to-date stream channel configurations than those shown on the previous FIRM for this jurisdiction. The floodplains and floodways that were transferred from the previous FIRM may have been adjusted to conform to these new stream channel configurations. As a result, the Flood Profiles and Floodway Data tables in the *Flood Insurance Study report* (which contains authoritative hydraulic data) may reflect stream channel distances that differ from what is shown on this map.

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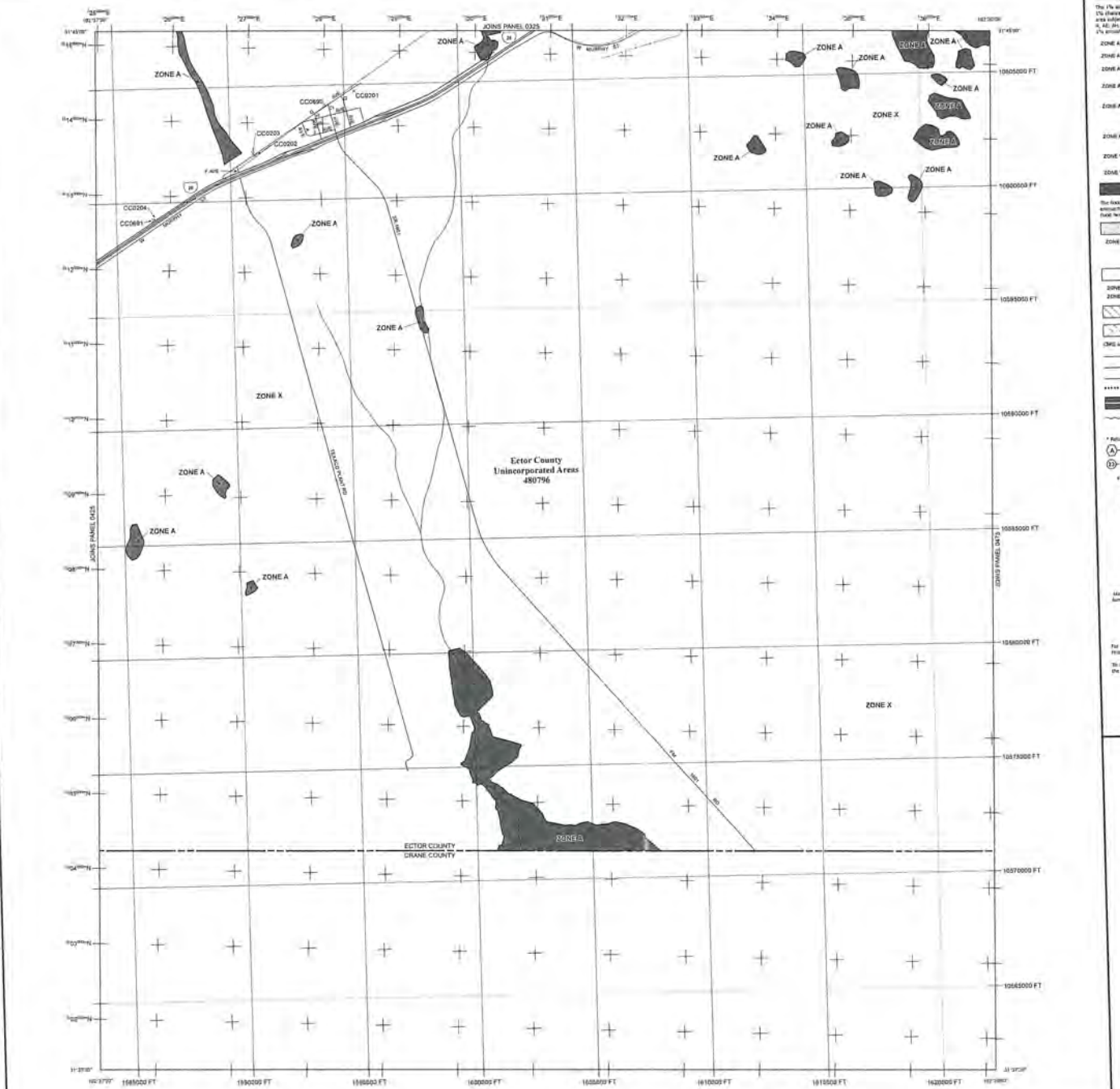
The "**profile base lines**" depicted on this map represent the hydraulic modeling baselines that match the flood profiles in the FIS report. As a result of improved topographic data, the "profile base line", in some cases, may deviate significantly from the channel centerline or appear outside the SFHA.



LEGEND

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* Referenced to the North American Vertical Datum of 1988

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MAP REPOSITORIES
Refer to Map Repositories List on Map Index

EFFECTIVE DATE OF COUNTYWIDE FLOOD INSURANCE RATE MAP
March 4, 1991

EFFECTIVE DATE(S) OF REVISION(S) TO THIS PANEL
October 25, 1996

March 15, 2012 - to update corporate limits, to change Special Flood Hazard Areas, to update map format, to add roads and road names, or to incorporate previously issued Letters of Map Revision, and to reflect updated topographic information.

For community map revision history prior to countywide mapping, refer to the Community Map History table located in the Flood Insurance Study report for this jurisdiction.

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MAP SCALE 1" = 2000'

NATIONAL FLOOD INSURANCE PROGRAM

PANEL 0450E

FIRM

FLOOD INSURANCE RATE MAP

ECTOR COUNTY, TEXAS AND INCORPORATED AREAS

PANEL 450 OF 500

(SEE MAP INDEX FOR FIRM PANEL LAYOUT)

CONTAINS:			
COMMUNITY	NUMBER	PANEL	SUFFIX
ECTOR COUNTY (UNINCORPORATED AREAS)	480796	0450	E

Notice to User: The Map Number shown below should be used when placing map orders; the Community Number shown above should be used on insurance applications for the subject community.

MAP NUMBER
48135C0450E

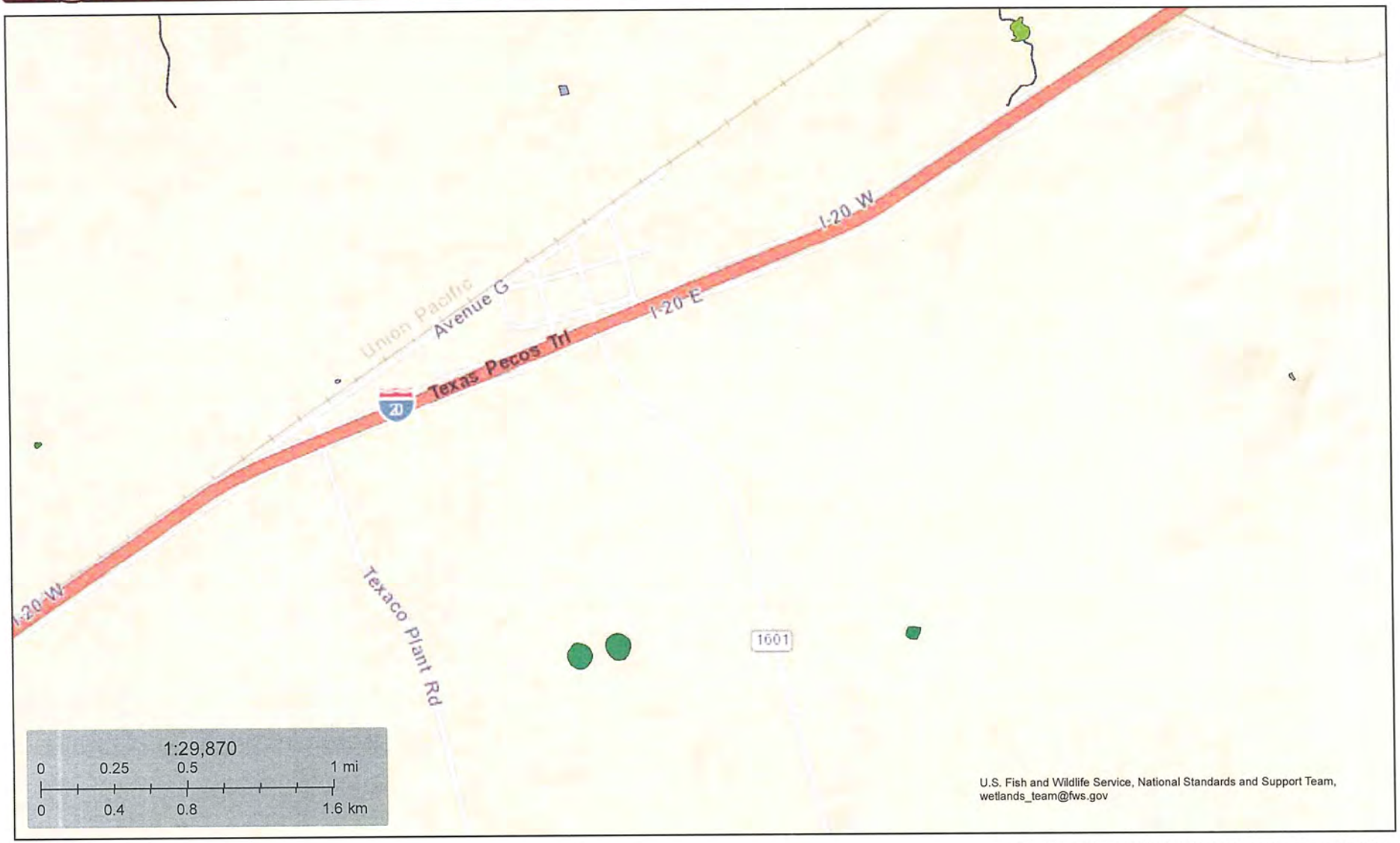
MAP REVISED
MARCH 15, 2012

Federal Emergency Management Agency

U.S. Fish and Wildlife Service

National Wetlands Inventory

UTPB Site



May 17, 2017

Wetlands

- Estuarine and Marine Deepwater
- Estuarine and Marine Wetland
- Freshwater Emergent Wetland
- Freshwater Forested/Shrub Wetland
- Freshwater Pond
- Lake
- Other
- Riverine

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National Wetlands Inventory (NWI)
This page was produced by the NWI mapper

PROPRIETARY

AREVA Inc.

ENGINEERING INFORMATION RECORD

Document No.: 51 - 9273184 - 000

NGNP Advanced Reactor Site Feasibility Evaluation – Task 4 Southwestern Demonstration Plant Site

Safety Related? ☐ YES ☒ NO

Does this document establish design or technical requirements? ☐ YES ☒ NO

Does this document contain assumptions requiring verification? ☐ YES ☒ NO

Does this document contain Customer Required Format? ☐ YES ☒ NO

Signature Block

Name and Title/Discipline	Signature	P/LP, R/LR, M, A-CRF, A	Date	Pages/Sections Prepared/Reviewed/ Approved or Comments
Theodore A. Messier Principal Scientist	*TA MESSIER* *7/26/2017*	LP		All
Barbara Hubbard Advisory Engineer	*BY HUBBARD* *7/26/2017*	LR		All
Justin Byard First Line Leader	*JN BYARD* *7/26/2017*	A		All

Note: P/LP designates Preparer (P), Lead Preparer (LP)
M designates Mentor (M)
R/LR designates Reviewer (R), Lead Reviewer (LR)
A-CRF designates Project Manager Approver of Customer Required Format (A-CRF)
A designates Approver/RTM – Verification of Reviewer Independence

Project Manager Approval of Customer References (N/A if not applicable)

Name (printed or typed)	Title (printed or typed)	Signature	Date
N/A			

Record of Revision

Revision No.	Pages/Sections/ Paragraphs Changed	Brief Description / Change Authorization
000	All	Initial release

Table of Contents

Page

List of Tables

Page

List of Figures

Page

List of Acronyms

ERCOT	Electric Reliability Council of Texas
FEMA	U.S. Federal Emergency Management Agency
FOAK	First of a Kind
Km	kilometer
kV	kilovolt
kW	kilowatt
LNG	liquefied natural gas
LWR	light-water reactors
MHR	Modular High Temperature Gas Reactor
MSR	TerraPower Molten Salt Reactor
MW	megawatt
NIA	NGNP Industry Alliance
NOAK	N^{th}-of-a-Kind
NRC	U.S. Nuclear Regulatory Commission
NWI	National Wetland Inventory
PE	probability of exceedance
PGA	peak ground acceleration
ROK	Republic of Korea
SFR	GE PRISM Sodium Fast Reactor
UTPB	University of Texas Permian Basin

1.0 EXECUTIVE SUMMARY

A preliminary site feasibility evaluation was conducted for the southwestern proxy site that bounds representative United States advanced reactor types (Modular High Temperature Gas Reactor (HTGR) / MHR, GE PRISM Sodium Fast Reactor / SFR, TerraPower Molten Salt Reactor / MSR) (Reference [1]).

Although there is interest and potential business application for a Generation IV reactor, the abundant supply of inexpensive natural gas and absence of a ready market for electricity production, hydrogen generation, or process steam presently precludes development of a positive business case.

Literature searches indicated that there are large quantities of water being used for fracking and substantial cost incurred for disposal of that water. The temperatures from process heat to clean "fracking" water are relatively low compared to what an HTGR could provide; however, the amount of heat available after petroleum refining usage is envisioned to be sufficient to clean the large volumes of fracking water currently used in the area.

The business case was focused on the petroleum refinery industry; however, the local market to the site does not exist at this time. Either the petroleum refinery industry could build a facility close to the proxy site or the reactor could be sited near an existing facility.

A CO_2 line was recently discovered in near proximity to the site that may be the subject of a future business case application (production of methanol).

Nothing was found to preclude the construction of a Generation IV reactor at the site.

There is space available to build a process heat industrial site.

It is recommended that a future study combines multiple applications into one business case to maximize effective use of an HTGR and provide guidance on optimal business conditions for future project development.

2.0 BACKGROUND

The site is located in Ector County, just south of Interstate Route 20, approximately 15 miles southwest of Odessa, Texas (see Figure 2-1).

Figure 2-1: Plant Site

3.0 EXCLUSIONARY CRITERIA

Site values for the criteria presented in Table 3-1 cannot be met or exceeded. None of these values are met or exceeded by the southwestern site.

Table 3-1: Exclusionary Criteria

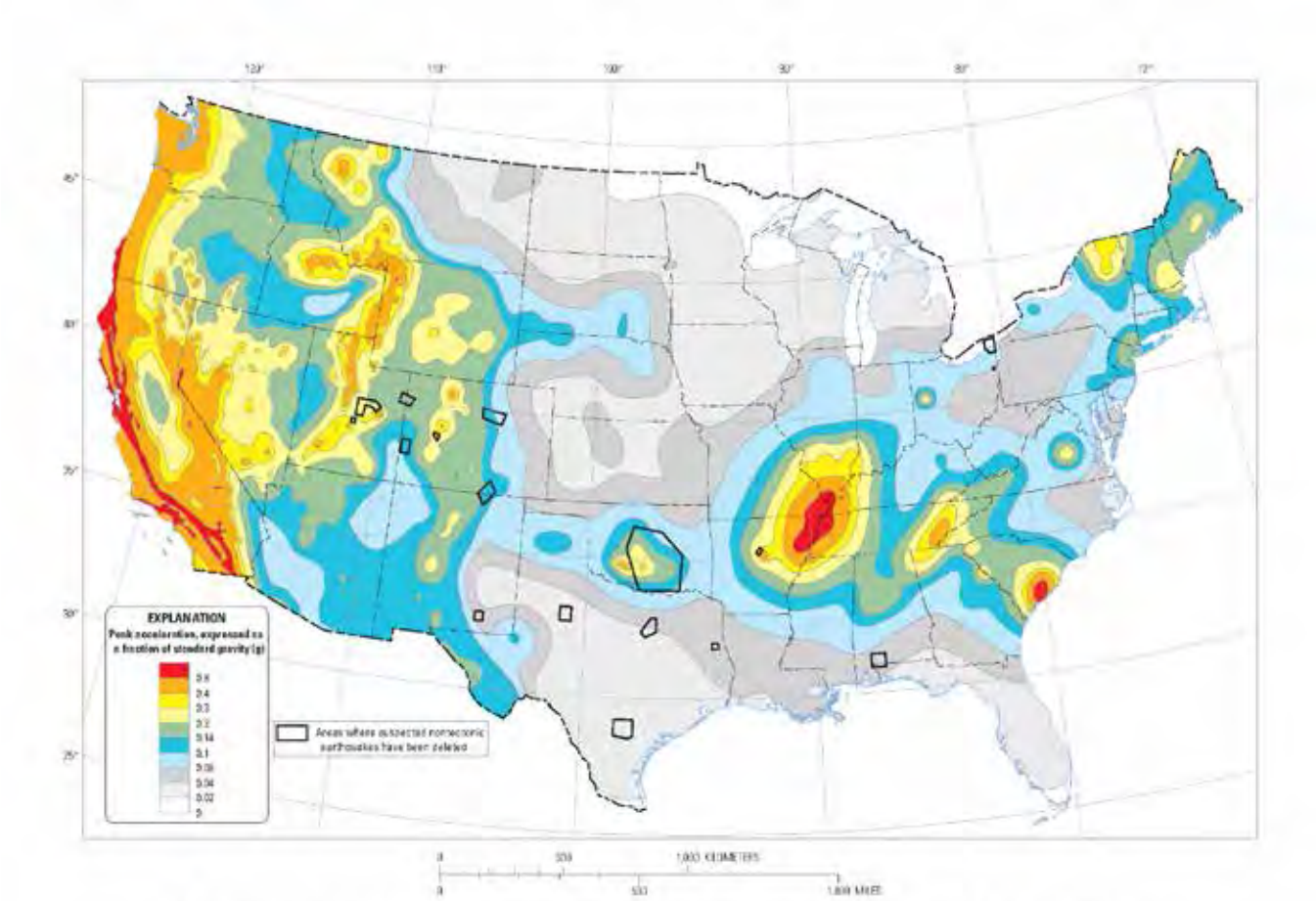
Category	Value
Seismic	· Peak Ground Acceleration > 0.3 g at a probability of exceedance (PE) of 2 percent in 50 years · Located with five miles (8 kilometers (Km)) of a capable fault
Flooding	· Located within the 100-year flood plain
Hazards	· Accidents at nearby industrial or military facilities posing undue risk to the nuclear plant due to shock waves and missiles from explosions (depends on plant design and distance to plant) · Directly in line with runways on high-operations commercial or military airports. · Low lying areas downstream of major dams
Transmission Lines	· Less than 230 kilo-Volt (kV) capacity and less than two independent sources of off-site power within 30 mi (48.3 km)
Federal and State Lands	Located on one of the following: · National / state parks · National / state historical sites · National / state seashores and lakeshores · National / state rivers and scenic riverways · National / state wildlife refuges · Wilderness areas · National maritime sanctuary areas · Cultural resources (American Indian lands, national landmarks)

A summary and evaluation of these exclusionary criteria as they relate to the site are described below.

3.1 Seismic

The site meets the seismic exclusionary criteria in that the peak ground acceleration is not greater than 0.3 g at a probability of exceedance of two percent in 50 years, as portrayed in Figure 3-1 (Reference [2]).

Figure 3-1: Seismic Hazard Map



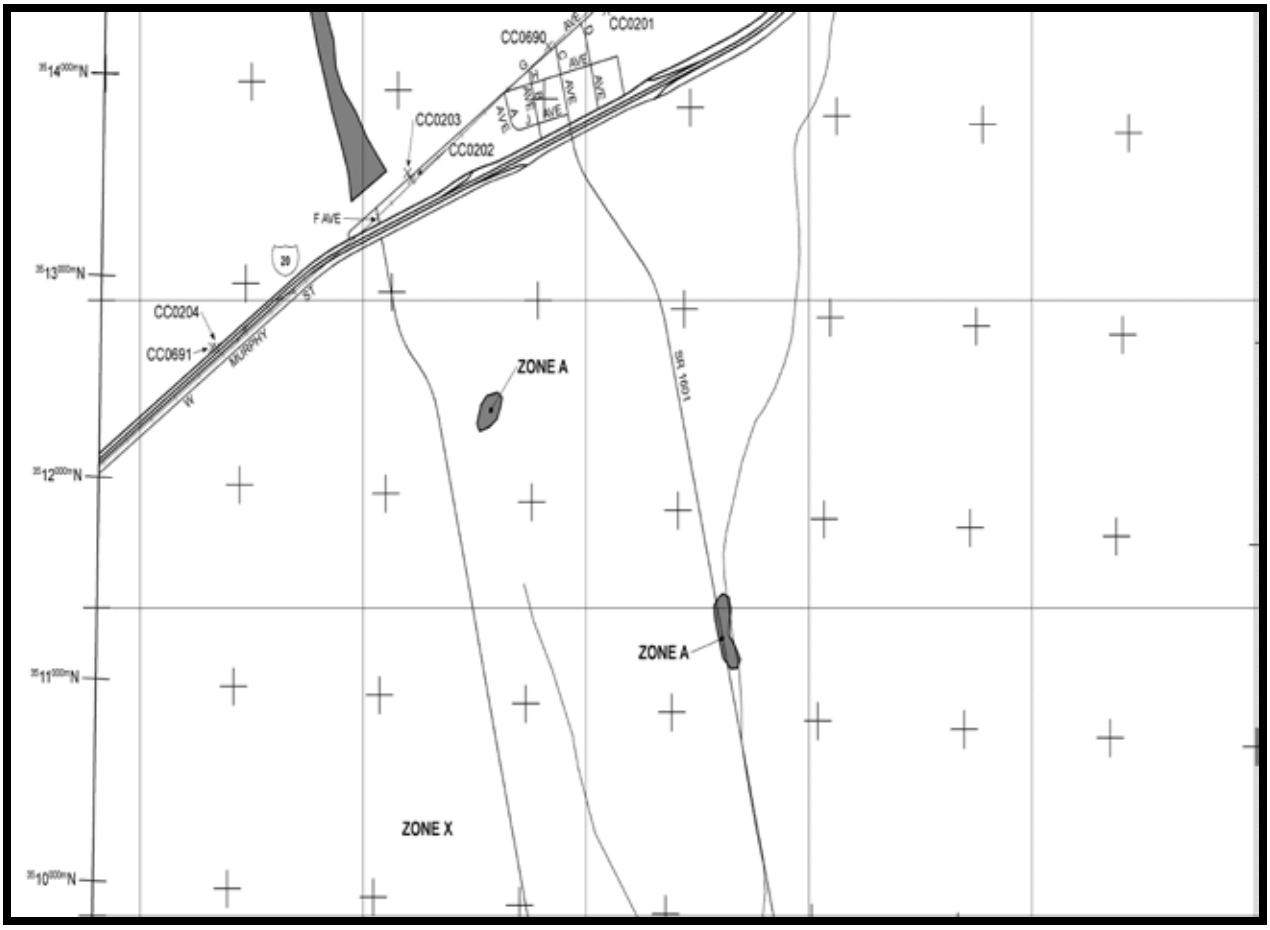
Two-percent probability of exceedance in 50 years map of peak ground acceleration

3.2 Flood Zone

Floodplains are land areas adjacent to streams or rivers susceptible to being inundated by stream-derived waters. The Federal Emergency Management Agency (FEMA) Flood Insurance Rate Map was obtained for the site (Map Number 48135C0450E) and indicates the location of the 100-year floodplain.

The Flood Zone map presented in Figure 3-2 shows that the site is not located in a flood zone, and lists the site as Zone X, "Other Flood Areas". Zone X is described as "Areas of 0.2% annual chance of flood; areas of 1% annual chance flood with average depths of less than 1 foot or drainage areas less than 1 square mile; and areas protected by levees from 1% annual chance flood." (Reference [3])

Figure 3-2: FEMA Flood Zone Map



3.3 Hazards

Several potential hazards are within close proximity to the plant and will require evaluation prior to proceeding with a licensing action. The following facilities were noted in the area:

- Airports – there are no airports within two miles of the site. The airport nearest to the site is Odessa-Schlemeyer Field located approximately 17 miles northeast.
    - Other airports / airfields in the area include:
        - Wood Farm Airfield – located approximately 25 miles northeast.
        - Midland International Air and Space Port – located approximately 26 miles northeast.
        - Sky West – located approximately 31 miles east. (Reference [4])
- Military Bases – there are no known military installations within two miles of the site.
- Industrial / Chemical Sites
    - There are numerous oil / gas wells located both on the site and within two miles of the site. Additional evaluations are needed to determine the significance of these potential hazards.
    - No other large industrial / chemical facilities were noted within two miles of the site.
    - A cement plant, owned by Cemex USA, is located approximately 2.7 miles east of the site.
- Pipelines - Per the National Pipeline Mapping System website (Reference [5]), several pipelines were noted within two miles of the site. Additional evaluations are needed to determine the significance of these potential hazards. The nearest pipelines are:
    - Crude oil pipeline operated by Centurion Pipeline, L.P., located approximately 3,000 ft. east of the site.
    - Crude oil pipeline operated by Plain Pipeline, L.P., located approximately 4,000 ft. south of the site.
    - Natural gas pipeline operated by OneOK West Texas Transmission, located approximately 1.5 miles east of the site.
    - Carbon dioxide pipeline, operated by Kinder Morgan, located approximately 1.5 miles east of the site.
    - Natural gas liquids pipeline, operated by Energy Transfer Company, located approximately two miles south of the site.
    - Natural gas pipeline, operated by OneOK West Texas Transmission, located approximately two miles south of the site.
- Upstream Dams – there are no dams / impoundments located within two miles of the site.
- Subsurface Mining – One surface mine (sand / gravel) associated with the Cemex USA cement plant is located approximately two miles east of the site. No other surface mines were noted within two miles of the site.

3.4 Transmission Lines

The nearest high voltage transmission line to the site is a 69-kv line approximately one mile south of the site. Additional lines are located in the area, the next closest being a 138-kV line approximately 6.8 miles northeast of the site. (Reference [6])

Though the exact location is not known, the Electric Reliability Council of Texas (ERCOT) has proposed the construction of a new 345-kV transmission line north of the site. (Reference [7])

3.5 Federal and State Lands

The site is not on, or located adjacent to, any state or federal lands. There are no known state or federal lands within two miles of the site.

The nearest state land is Monahans Sandhills State Park located approximately 15 miles southwest of the site.

4.0 DISCRETIONARY CRITERIA

The discretionary criteria presented in Table 4-1 are not to be used to exclude a site from consideration, but are envisioned to be important to the business case.

Table 4-1: Discretionary Criteria

Category	Value
Cooling / Dilution Water	· Water amount not sufficient to meet plant design · Water source not located nearby
Need for process heat	· Need for power / process heat does not exist
Airports, barges, rail lines, and roads	· No preexisting infrastructure with 10 miles (16.1 km)
Population	· Located with four miles (6.4 km) of a population center of 25,000 or more · Located within 10 miles (16.1 km) of a population center of 100,000 or more · Located within 20 miles (32.2 km) of a population center of 500,000 or more · Located within 30 miles (48.3 km) of a population center of 1,000,000 or more
Wetlands	· Large amount (> five acres) of wetlands impacted by construction

4.1 Cooling / Dilution Water

It is unknown at this time what will be the source water for the facility. Water is not required for reactor core cooling but may be desirable for steam generation for certain business applications.

4.2 Need for Power / Process Heat

The Texas Permian Basin is a major source of crude oil. Oil production uses large amounts of water which must be cleaned or disposed. Water cleanup could potentially make economic use of a Generation IV nuclear reactor's waste heat. However, the use of a reactor in this application would contain both regulatory, First of a Kind (FOAK), and competing technology risks.

The heat needed for desalinization is much lower than that produced by a high temperature (> 500°C) Generation IV reactor. To increase economic viability, the high temperature steam must be used for producing electricity, manufacturing hydrogen, or supplying process steam.

The use of a small Generation IV reactor for electricity production is not presently economically attractive in the Permian Basin where the wholesale electricity price is approximately six cents per kilowatt hour.

Hydrogen can be utilized for a number of industrial applications including hydrogenation of oils, certain types of chemical manufacture, or iron ore reduction. The high temperature output of Generation IV reactors is a good match for high-temperature steam electrolysis. Current state-of-the-art of this type of electrolysis is modules in the range of 500 kW or less. Stacking such modules to produce hydrogen in large quantities may be possible in the future; however, it is yet to be demonstrated. Precluding this possibility is the absence of a large enough market in the Permian Basin area to use the hydrogen from a large (> 100 MW) plant.

From a competitive standpoint current large-scale hydrogen production is performed by steam methane reforming using natural gas. The cost of such hydrogen production depends on the price of natural gas. Again, with the low price of natural gas now and in the foreseeable future, new technologies such as the high temperature steam electrolysis are judged not to be competitive.

In the Permian Basin area again, as in the case of use of hydrogen, no sizable market currently exists for use of process steam.

4.3 Airports, Barges, Rail Lines, and Roads

The site has access to roads, rail and air. Below is a list of the various transportation options at the site.

- Airports – As discussed above, the airport nearest to the site is Odessa-Schlemeyer Field located approximately 17 miles northeast. The Midland International Air and Space Port is located approximately 26 miles northeast of the site.
- Barge Access – there is no barge access to the site.
- Rail – The site is approximately 3300 ft. south of the Toyah Subdivision, a mainline railroad operated by Kiewit Infrastructure West. (Reference [8])
- Roads – Access is via I-20, located immediately north of the site. (Reference [4])

4.4 Population

Population centers near the site are as follows:

- West Odessa, Texas, population 22,707, located in Ector County, approximately 8 miles northeast of the site.
- Odessa, Texas, population 118,918, located in Ector County, approximately 15 miles northeast of the site.
- Monahans, Texas, population 6,953, located in Ward County, approximately 20 miles southwest of the site.
- Gardendale, Texas, population 1,574, located in Ector County, approximately 24 miles northeast of the site.
- Midland, Texas, population 111,147, located in Midland County, approximately 35 miles northeast of the site.
- Kermit, Texas population 5,708, located in Winkler County, approximately 30 miles northwest of the site.

4.5 Wetlands

Current wetland delineations have not been performed at the site. However, a review of the National Wetland Inventory (NWI) Maps presented in Figure 4-1 did not indicate any wetlands on the site.

Two small freshwater forested / shrub wetlands located just to the south of the site were noted on the NWI maps. (Reference [9]) Site specific wetland delineations are needed to confirm their existence.

Figure 4-1: National Wetland Inventory Map

5.0 BUSINESS CASE

The following sections discuss aspects of the business case. Reactor ratings for the southwestern site are presented in Table 5-2.

5.1 Reactor Technology Considerations

The reactor technologies considered for this study are the Modular High Temperature Gas-Cooled Reactor (MHR), the Sodium Fast Reactor (SFR), and the Molten Salt Reactor (MSR). Reactor technology descriptions and considerations for deployment are discussed in the Task 2 report "Business Case Template for Evaluation of Advanced Reactor Technologies at Candidate Sites," (Reference [10]). Reactor technology considerations include:

1. Technology Readiness
2. Fuel Qualification
3. Safety Considerations
4. Process Heat Capability
5. Energy Efficiency
6. Fuel Cycle Considerations

These considerations and recommended approaches for evaluating these considerations are discussed in (Reference [10]).

The NGNP Industry Alliance (NIA) has the expertise and design information to quantitatively evaluate the MHR for deployment at the four candidate sites. However, because the NIA supports MHR technology, the NIA does not intend to quantitatively evaluate the SFR and MSR with respect to the MHR, since inherent biases may result. Instead, the NIA will make qualitative remarks on these technologies based on the judgments of those performing the screening evaluations and project review of the screening evaluations.

The Task 2 report describes a screening methodology for the four candidate sites under consideration and includes a Business Case Screening Evaluation Template. For these higher-level business case assessments, it is assumed that most reactor technology considerations are independent of the site under consideration, with some allowance for exceptions at sites that may favor a particular reactor technology. The Task 2 template provides the NIA assessment of the MHR site-independent technology considerations with qualitative remarks for the SFR and MSR, and includes site-specific allowances under a separate category.

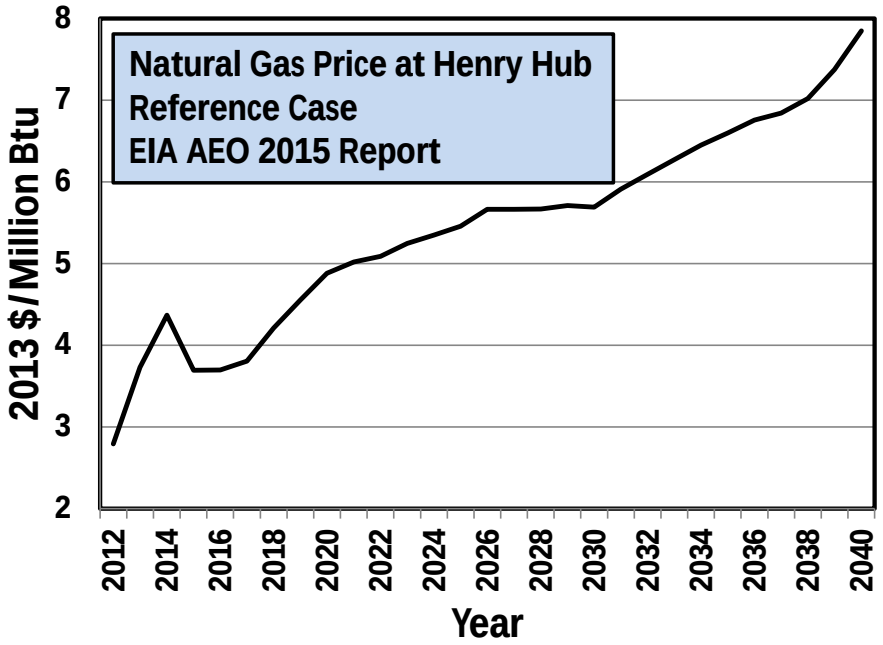
5.2 Economics and Commercialization Potential

5.2.1 Market Potential – U.S. and International

The potential market for advanced reactors depends on a number of factors, including: (1) costs of producing electricity and / or process heat relative to fossil fuels and other alternatives, (2) capability to penetrate non-electric markets, (3) government energy and environmental policy, and (4) public acceptance of advanced reactor technologies.

The U.S. and several other countries have expressed a strong interest in developing the MHR. Marketing assessments have recently been performed for the MHR (Reference [11]), (Reference [12]), (Reference [13]). As discussed in Reference [11], in the absence of carbon taxes, MHRs are competitive with natural gas when the natural gas price is in the range $6 - $8 / million Btu. As indicated in Figure 5-1, natural gas prices in the U.S. are presently well below this range and are not expected to reach this range until the 2030 – 2040 time frame (Reference [14]). Japan and the Republic of Korea (ROK) import natural gas in the form of liquefied natural gas (LNG) and are the world's No. 1 and No. 2 importers of LNG. Liquefaction and transportation required for LNG adds significant costs. The long-term contract price for LNG in Japan and the ROK is expected to remain above the $6 - $8 / million Btu range. The relatively high fossil fuel costs in Europe also make MHRs more economically competitive in the nearer term.

Figure 5-1: U.S. Natural Gas Price at Henry Hub



Nearer-term market analyses for MHR global commercialization should focus on replacement of fossil fuels for both electricity and industrial applications, especially for regions where fossil fuels are presently required, but costs are expected to remain relatively high and access to low-cost fossil fuels has significant challenges. The market analysis described in (Reference [13]) considered both nearer-term applications with MHRs operating with coolant outlet temperatures in the 700°C - 750°C range and longer-term applications with Very High Temperature Reactors (VHTRs) operating with coolant outlet temperatures in the 900°C - 950°C range.

Replacement of just 20% of the LNG imports used for electricity generation only in Japan and the ROK is potentially a large nearer-term market that could account for one hundred or more MHR modules. MHRs providing process steam for industrial applications could further expand the nearer-term market. A large market potential also exists in both countries for using VHTRs to produce hydrogen for industry and possibly for transportation. Between Japan and the ROK, the steel manufacturing industry alone could support approximately two hundred 600-MWt VHTR modules producing both hydrogen for iron-ore reduction and the large quantity of electricity required by the manufacturing process. In both countries, steel manufacturing is the single largest emitter of carbon dioxide (approximately 10% of the total emissions), and conversion to nuclear hydrogen and electricity would essentially eliminate these emissions. Significant opportunities for MHR co-generation applications also exist in Europe.

The U.S. and several other countries have also expressed strong interest in developing the SFR for electricity production and as a potential solution to address fuel cycle sustainability and actinide management.

Because of its enhanced safety characteristics and capability for process heat applications, the MHR should be rated higher than the SFR in this category. Although not explicitly considered as part of this study, the MHR's very high level of proliferation resistance should also provide an advantage in terms of export market potential. The MSR is a potential alternative to the SFR, but should be rated lower than the SFR in this category for the present evaluation.

5.2.2 Demonstration Module / Plant Costs

The costs of the demonstration module / plant are an important consideration for determining whether to proceed with the project at a selected site. Generally, these costs are related to the N^{th}-of-a-Kind (NOAK) commercial plant costs. These costs for a candidate MHR concept are given in Table 5-1.

Table 5-1: MHR Development Venture and Deployment Project Cost Elements

Cost Element	$M (2012)
Development Venture	
Technology Development	245
Complete Preliminary Design	280
Complete Final Design	200
Licensing Activities	165
First Module Modifications for Initial Operations	75
Total – Development Venture	965
Deployment Project	
Site-Specific Design	100
NRC License and Regulatory Permits	65
Equipment Procurement (Including Long-Lead Items)	432
Construction	625
Startup and Testing	55
Initial Operations (3 Years)	348
Revenue (3 Years)	-265
Total – Deployment Project	1,360
Total – Development + Deployment for Demonstration Module	2,325

The demonstration module / plant costs are not expected to be a significant differentiating factor for the advanced reactor concepts considered in this study. In terms of evaluating the SFR and MSR relative to the MHR, engineering / economic judgments can be made in terms of multipliers on the cost elements provided in Table 5-1.

5.2.3 NOAK Commercial Plant Costs

The capital and energy production costs for a NOAK commercial plant are an important consideration before deciding to proceed with a demonstration plant / module. At a minimum, these costs must be competitive with existing light-water reactors (LWRs) (for electricity) and fossil fuels (for electricity and process heat) and uncertainties in these costs should be minimized.

As discussed in Section 5.2.1 and in Reference [15], expansion of nuclear energy in the U.S. is significantly inhibited because of the currently low price of fossil fuels and the absence of a national carbon-emission pricing policy. For deployment of new LWRs, Reference [15] recommends a production subsidy / payment of approximately $0.027 / kWe-hr for generation of carbon-free electricity for a time period to be determined. This subsidy / payment may also be required for advanced reactors if fossil fuel prices remain low out to the time frame of their deployment.

For this study, it is recommended the MHR, SFR, and MSR be treated equally for evaluation with respect to NOAK commercial plant costs.

5.2.4 Potential for International Collaboration on Reactor Technology

There has been a high level of international collaboration for both the MHR and SFR, including Generation IV activities and more direct collaborations on design and technology development. Recent examples for the MHR include participation by both Japan and the ROK in the NGNP project (Reference [13]). The U.S. has collaborated significantly with Japan, France, and other countries on the SFR.

Demonstration plants in the U.S. licensed by the NRC could provide a valuable carbon-free energy option for the future, both for the U.S. and globally, especially if there is a significant level of international collaboration towards a common design to reduce the technology and other investment risks / costs.

At present, the MHR should be rated somewhat higher than the SFR, in part because of its potential for non-electric applications. The MSR should be rated lower than the SFR, primarily because of the lower level of international interest.

5.2.5 Impacts on Local Economy

Construction and operation of any advanced reactor demonstration plant will have a significant positive impact on the local economy, including construction jobs, operations and maintenance jobs, support jobs, and increased tax base.

The MHR, SFR, and MSR should be evaluated equally for sites with electricity-only applications. The MHR and MSR should be evaluated somewhat higher than the SFR for sites that include process heat applications.

5.3 Licensing Considerations

Several potential hazards are within close proximity to the plant and will require evaluation prior to proceeding with a licensing action. The distance from the nearest 240-kV or 345-kV transmission line to the site is unknown. The source of water for the site is unknown; however, water would not be used to cool the reactor.

5.4 Siting Considerations

The capability to meet the exclusionary criteria has been discussed in Section 3. Another important consideration is the ability to hire, train, and maintain a qualified workforce. Training and education is available at the UTPB.

The general situation for new nuclear power in the United States is negative. Little if any increase in electric power needs results in less demand for any new electric power source. Although aging plants, and in particular coal power plants, are being replaced, the replacement is being done with natural gas power plants and subsidized renewable energy. These replacements result in electricity that is currently less expensive than that produced by nuclear power. This situation is likely to remain as long as a supply of cheap (< $6) natural gas exists. In the U.S. this is expected to be the case for 10 - 20 years.

For years the idea of a small Generation IV reactor to be located in the Midland / Odessa TX area for either educational, research, or industrial purposes has been discussed. Most recently the idea of using such a reactor for water cleanup has been put forth. Tentatively, bonds for water cleanup may be available in the amount of $1B+ at an interest rate of approximately 5% versus a normal commercial interest rate of 8-9%. This would provide an enormous potential boost to commercial viability.

Table 5-2: Reactor Ratings for Southwestern Site

Site Location / Description: Southwestern						
Category / Subcategory		**Advanced Reactor Technologies**				
		MHR			**SFR**	**MSR**
		Petroleum refinery			***Petroleum refinery***	***Petroleum refinery***
	(%)	**Rating**	**Score**	**Basis**	**Qualitative Remarks**	**Qualitative Remarks**
1. Reactor Technology Considerations (25)						
1.1 Technology Readiness	4	6	24	Overall TRL rating. See Section 5.1.1 of Reference 13.	Approximately same TRL as MHR.	Much lower TRL than MHR and SFR. Much later deployment time frame.
1.2 Fuel Qualification	4	6	24	AGR program. See Section 5.1.2 of Reference 13.	Approximately same or slightly lower rating than MHR.	Molten fuel may have significant challenges.
1.3 Safety Considerations	7	9	63	Complete loss of coolant does not impact safety case. See Section 5.1.3 of Reference 13.	Loss of sodium coolant can lead to severe consequences.	Loss of molten fuel can lead to severe consequences.
1.4 Process Heat Capability	6	8	48	Can replace fossil fuels and transition to higher temperatures. See Sections 2 and 5.1.4 of Reference 13.	Current design is for electricity only. Lower coolant outlet temperature (~500°C) is less suitable for process heat applications.	Current design is for electricity only. With its 800°C outlet temperature, design could be adapted for process heat applications.
1.5 Energy Efficiency	4	8	32	High coolant outlet temperatures increase thermal efficiency. Direct utilization of process heat also	Lower thermal efficiency than MHR for electricity generation.	Somewhat higher thermal efficiency for electricity generation than MHR.

Site Location / Description: Southwestern						
Category / Subcategory		**Advanced Reactor Technologies**				
		MHR			**SFR**	**MSR**
		Petroleum refinery			***Petroleum refinery***	***Petroleum refinery***
	(%)	**Rating**	**Score**	**Basis**	**Qualitative Remarks**	**Qualitative Remarks**
				increases efficiency. See Section 5.1.5 of Reference 13.		
1.6 Fuel Cycle Considerations	0	N/A	N/A	Dependent on national fuel cycle policy. Per Section 7.2 of Reference 13, good fuel cycle synergy with fast reactors.	Fast neutron spectrum allows for breeding fissile fuel. Operation in burner mode allows destruction of transuranics.	Insufficient information to assess fuel cycle considerations.
2. Economics and Commercialization Potential (35)						
2.1a Market Potential – U.S.	7	3	21	Low U.S. nuclear energy market potential because of low natural gas prices.	Even lower U.S. market potential. Co-location with other industries may prove challenging. Lower coolant outlet temperature (~500°C) is less suitable for process heat applications.	May share some of the same potential as MHR. Difficult to assess because of the low Technology Readiness Level compared to the MHR and SFR.
2.1b Market Potential - International	7	4	28	High LNG prices.	Low potential. Lower coolant outlet	Low potential. May share some of the same

Site Location / Description: Southwestern						
Category / Subcategory		**Advanced Reactor Technologies**				
		MHR			**SFR**	**MSR**
		Petroleum refinery			***Petroleum refinery***	***Petroleum refinery***
	(%)	**Rating**	**Score**	**Basis**	**Qualitative Remarks**	**Qualitative Remarks**
					temperature (~500°C) is less suitable for process heat applications. The technology is largely limited to nuclear states with significant export control restrictions. Other nuclear states have SFR design/technology programs that are more advanced than the U.S. program. The travelling wave sodium reactor under development is attempting to address the export control challenges.	potential as MHR. Difficult to assess because of the low Technology Readiness Level compared to the MHR and SFR.
2.2 Demonstration Module/Plant Costs	3	4	12	Requires large government funding regardless of technology.	About the same as MHR.	Much more uncertain than MHR.
2.3 NOAK Commercial Plant Costs	5	0	0	Not evaluated at this time. More work is needed to determine. Relative to other energy technologies.	Less favorable compared to MHR.	Less favorable compared to MHR.

Site Location / Description: Southwestern						
Category / Subcategory		**Advanced Reactor Technologies**				
		MHR			**SFR**	**MSR**
		Petroleum refinery			***Petroleum refinery***	***Petroleum refinery***
	(%)	**Rating**	**Score**	**Basis**	**Qualitative Remarks**	**Qualitative Remarks**
2.4 Potential for International Collaboration on Reactor Technology	5	8	40	Several existing international programs.	Possibly good. But Russia, France and Japan already have strong national programs.	Unknown, but the U.S. seems to be the country primarily interested in MSR at this stage.
2.5 Impacts on Local Economy	8	5	40	Any project should have strong impacts on local economy.	Greenfield project should have strong impacts on local economy.	Greenfield project should have strong impacts on local economy.
3. Licensing Considerations (15)	15	6	90	Potential hazards that would require evaluation before licensing.	SFR should not have any significant licensing issues relative to the MHR; however, licensing/safety evaluation is likely more complex.	Less mature technology requires further evaluation to assess realistic licensing case at Odessa.
4. Siting Considerations (25)						
4.1 Technology Considerations	10	7	70	Process steam, hydrogen production, and electricity generation.	Technology not applicable for realistic business case at southwestern site.	Less mature technology requires further evaluation to assess realistic licensing case at Odessa.
4.2 Site-Specific	15	5	75	It is unknown at this time what water source is available. At	Technology not currently applicable for realistic	Technology not currently applicable for realistic

Site Location / Description: Southwestern						
Category / Subcategory		**Advanced Reactor Technologies**				
		MHR			**SFR**	**MSR**
		Petroleum refinery			***Petroleum refinery***	***Petroleum refinery***
	(%)	**Rating**	**Score**	**Basis**	**Qualitative Remarks**	**Qualitative Remarks**
Considerations				this time it is unknown what the distance would be from the site to either a 230-kV or a 345-kV transmission line.	business case at Odessa site; however, additional locations should be considered in the southwest.	business case at Odessa site; however, additional locations should be considered in the southwest.
Total	100	**Total**	567			

6.0 CONCLUSIONS / RECOMMENDATIONS

Although there is interest and potential business application for a Generation IV reactor, the abundant supply of inexpensive natural gas and absence of a ready market for electricity production, hydrogen generation, or process steam presently precludes development of a positive business case.

In the event of an increase in the price of natural gas, HTGR's would be able to produce process heat at a competitive price. There is a significant demand for refining petroleum, domestically and internationally. The MHR is well suited to this application because it can provide process heat and is most suited to be collocated on industrial sites. The amount of heat available after petroleum refining usage is envisioned to be sufficient to clean the large volumes of fracking water currently used in the area.

It is recommended that a future study combines multiple applications into one business case to maximize effective use of an HTGR and provide guidance on optimal business conditions for future project development.

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