National Advanced Drilling

and

Excavation Technologies Program

Summary of Third Meeting
of
Interested Federal Agencies

Geothermal Division
U.S. Department of Energy

DISCLAIMER

National Advanced Drilling and Excavation Technologies Program

Summary of Third Meeting

of

Interested Federal Agencies

The third meeting of Federal agency representatives interested in the National Advanced Drilling and Excavation Technologies (NADET) Program took place on December 7, 1993. The Geothermal Division of the U.S. Department of Energy (DOE) hosted the meeting at the Washington, D.C., offices of DOE. Representatives from the National Science Foundation, U.S. Geological Survey, National Aeronautics and Space Administration, Nuclear Regulatory Commission, Federal Transit Administration, U.S. Army and various offices within the Department of Energy attended. For a complete list of attendees see Attachment A.

The purpose of the meeting was: 1) to discuss a proposal by the Massachusetts Institute of Technology (MIT) outlining a National Advanced Drilling and Excavation Technologies Program, 2) to brief participants on events since the last meeting, and 3) to hear about drilling research activities funded by the Department of Energy. The meeting agenda is included as Attachment B.

In his opening statement, **Dr. John (Ted) Mock**, Director of the Geothermal Division, welcomed participants and briefed them on the ongoing efforts funded by his division to strengthen drilling and excavation technologies. He informed participants of a letter sent by the president of MIT to Mr. Jack Gibbons, Science Advisor to the President of the United States, which introduces the MIT proposal. The letter requested support from the Executive Branch.

Dr. Allan Jelacic, of the Geothermal Division, acquainted attendees with the registration packets they had received. He summarized recent events concerning NADET, including responses by industry to the Division's campaign for expressions of interest. Dr. Jelacic made special mention of a draft outline of an interagency cooperative agreement for NADET that had been distributed to the attendees. He also presented six logos designed for the NADET program. Participants voted on two favorite logo designs.

Professor Jefferson Tester, of MIT, outlined the proposed National Advanced Drilling and Excavation Technologies Program. Professor Tester indicated that industry cannot afford to fund such a program on its own. For such a program to work, it is vital to establish a National Institute for Advanced Drilling to bring all the parts together. He recommended a budget for the proposed institute of $5 million for the first few years growing to $25 to $35 million per year at its peak. Professor Tester emphasized the importance of getting Congressional backing and said that the program could start up quickly once a mandate is in place. Professor Tester further indicated that the U.S. has a global lead in drilling and excavation technologies and that the current technology is industry directed rather than research driven. He told participants that

future R&D should concentrate on lowering costs and making drilling and excavation technologies environmentally sustainable.

Dr. Thomas Usselman, of the National Academy of Sciences, informed participants of the status of a study by the National Research Council on advanced drilling technologies. He indicated that the final report is expected to be out for Academy review in a week. Dr. Usselman pointed out that addressing the concerns of stakeholders (constituencies) of the advanced drilling and excavation technologies program needs to be as important as proving the technical feasibility. He further noted the importance of a systems approach to provide answers to such questions as "how do improvements in one area affect the whole drilling system?" Dr. Usselman indicated that the prime interest in NADET by both the drilling and mining industries is on new bit development for rock cutting/breaking. He said that completion and guidance technologies are of major interest for the drillers and miners, respectively. Dr. Usselman stated that there will be a growing need to improve environmental drilling, which would become a major technology application in the near future. He estimated that $7 billion has been invested to date for environmental restoration. For transportation applications, he indicated the current technical problem is supporting underground structures rather than penetrating or breaking rock.

Mr. Lew Pratsch, Program Manager for Drilling and Geothermal Heat Pump Technology at the Geothermal Division, outlined the status of the ongoing R&D efforts funded by the division. He pointed out that drilling was important to the Climate Change Action Plan since two of the cleanest fuels, geothermal and natural gas, either of which could supply up to 25 percent of the U.S. electric supply, heavily depend on reliable, economic drilling. Mr. Pratsch outlined some recent technology advancements by the division -- a new rotary head seal and a new borehole televiewer -- now commercially available. Overheads used during his talk are included as Attachment C.

Mr. David Biancosino, Program Manager at the Office of Environmental Restoration and Waste Management of the Department of Energy, informed participants that a total of 3,700 sites covering 26,000 acres have contamination problems. He summarized drilling activities performed by his office at the Nevada Test Site. He made mention of current drilling applications under investigation and the allocated research funding of $1 million for resonant sonic drilling, $1.53 million for a cone penetrometer, and $475 thousand for directional drilling. Mr. Biancosino indicated the objectives of the R&D including: 1) increasing the depth capability of the penetrometer, 2) increasing the reliability of sonic drilling, 3) improving borehole stabilization, and 4) better containment of cuttings. Mr. Biancosino referred to three recent reports: 1) "Results of Testing the Sonic Drilling System at the Hanford Site," 2) "ResonantSonic Drilling: History, Progress and Advances in Environmental Restoration Programs," and 3) "Demonstration of a Heavyweight Cone Penetrometer at the Hanford Site." He also informed participants of an upcoming meeting on directional drilling for drilling manufacturers and contractors. The meeting will be held in Richland, Washington. Overheads used during his talk and the title pages of the above-mentioned reports are included as Attachment D.

Mr. Terry R. Crump, of Roy F. Weston, Inc. (a contractor for the Department of Energy), spoke on behalf of Dr. Stephan J. Brocoum, of the Department of Energy's Office of Civilian Radioactive Waste Management. Mr. Crump briefed participants on the Yucca Mountain Site Characterization Project in Nevada and indicated that two of the project activities would be of special interest to the meeting. The first activity is Surface-Based, Large-Diameter, Unsaturated Zone Drilling, the purpose of which is to collect continuous samples, at selected locations, through the entire proposed repository block with minimal disturbance to the block. The project utilizes a custom designed, dry drilling system (LM 300) to collect core and over-ream the hole for emplacement of various instrument packages. The second activity involves Exploratory Studies and Facility Excavation, the purpose of which is to develop an underground testing facility using mechanized excavation techniques and a tunnel boring machine (TBM) to minimize disturbance to the proposed repository horizon. Overheads used during his talk are included as Attachment E.

Mr. Carl Magnell representing the Civil Engineering Research Foundation (CERF), an arm of the American Society of Civil Engineers, briefed participants about CERF and its activities. Mr. Magnell introduced the concept of geomedia and defined it as the interaction between the geologic medium or environment and man-made structures or systems. He discussed plans for a workshop on high-performance geomedia materials and systems. The workshop is to take place in the Washington, D.C., area during May 19 to 21, 1994. The purpose of the workshop is to establish a national agenda that will focus attention on critical aspects of civil engineering.

During the open discussion that followed, several participants expressed continued interest in the proposed NADET program and agreed to work towards its success.

Dr. Allan Jelacic indicated that the budget cycle, to some degree, is the driving force. He further stressed that fiscal year 1996 would be the earliest that major funding could be allocated to NADET and that the interested Federal agencies should begin working to that end. He urged the participants to review the outline of an interagency cooperative agreement, provided in the registration packet, as the basis for future interaction among the interested agencies.

Dr. David Russ, of the U.S. Geological Survey, spoke of the importance of an integrated program rather than focussed individual projects.

Dr. Ted Mock stressed that, at this point, the two driving forces for the success of NADET are the study by the National Academy of Sciences and industry support/lobbying.

Dr. Matt Tumay from the National Science Foundation emphasized that the way the program sells will determine the amount of seed money for civil infrastructure, automation, etc. He stressed that the different agencies should do their best to promote and sell the idea of this proposed national program.

Finally, **Dr. Jelacic** expressed hope that sometime next year, after publication of the Academy's study and further analysis, there will be a better defined program that people can embrace.

Attachment A

National Advanced Drilling and Excavation Technologies Program

Third Meeting of Interested Federal Agencies
December 7, 1993

Participants:

Civil Engineering Research Facility
Carl Magnell

Department of Energy - Geothermal Division
John "Ted" Mock
Allan Jelacic
Lew Pratsch

Department of Energy - Other Offices
David Biancosino, Environmental Restoration and Waste Management
Bill Gwilliam, Morgantown Energy Technology Center

Federal Transit Administration
Jeffrey Mora

Massachusetts Institute of Technology
Jefferson Tester, Energy Laboratory
Carl Peterson, Department of Mechanical Engineering

National Academy of Science
Tom Usselman

National Aeronautic and Space Administration
John D. Rummel

National Science Foundation
Mahmet "Matt" Tumay, Geomechanical, Geotechnical, and Geo-Environmental Systems
Basil Dendrou, MEi/Zi Inc.

Nuclear Regulatory Commission
Jacob Philip

Roy F. Weston, Inc
Dan Zerga
Terry Crump

U.S. Army Research Laboratory
Albert Horst

U.S. Geological Survey
David Russ

Waste Policy Institute
Michael Winokur

Attachment B

National Advanced Drilling and Excavation Technologies Program

Third Meeting of Interested Federal Agencies
December 7, 1993

Hosted by
Geothermal Division
U.S. Department of Energy

1:00 pm	Registration - Room 8E-089	
1:30 pm	Welcome	John Mock Department of Energy
1:35 pm	Update of activities concerning the NADET Program	Allan Jelacic Department of Energy
1:45 pm	Planning Study by the Organizing Committee for NADET	Jefferson Tester Massachusetts Institute of Technology
2:00 pm	Status of National Research Council Study of Advanced Drilling Technologies	Peter Smeallie National Research Council
2:10 pm	FY 1994 Studies in Drilling and Excavation Technologies at Department of Energy	
	- Geothermal Energy	Lew Pratsch Department of Energy
	- Environmental Restoration and Waste Management	David Biancosino Department of Energy
	- Civilian Radioactive Waste Management	Terry R. Crump Roy F. Weston, Inc.
3:10 pm	Plans for Workshop on High-Performance Geomedia Materials and Systems	Carl Magnell Civil Engineering Research Foundation
3:20 pm	Open discussion	All
3:50 pm	Closing Remarks	John Mock

Attachment C

Overhead Transparencies Presented by Mr. Lew Pratsch

GEOTHERMAL DRILLING R&D

by

Lew W. Pratsch
Geothermal Division
Department of Energy
(202) 586-1512

December 7, 1993

LET US DREAM A LITTLE!

If we really believe in CLIMATE CHANGE, drilling deeper is more important to the World than going to the moon--and we achieved that in less than a decade!

LET ME EXPLAIN

GEOTHERMAL & NATURAL GAS--CLEANEST FUELS

BOTH ARE ABUNDANT IN THE UNITED STATES
EITHER COULD SUPPLY 25% PLUS OF U.S. MWs

BOTH REQUIRE LOWER COST DRILLING

GEOTHERMAL ONLY BASE LOAD RENEWABLE
GAS--ALTERNATIVE TRANSPORTATION FUEL

INDUSTRY INPUT/TECHNOLOGY TRANSFER

1. INDUSTRIAL REVIEW PANEL

2. GEOTHERMAL RESOURCE COUNCIL

3. GEOTHERMAL DRILLING ORGANIZATION
   A. ROTARY HEAD SEAL
   B. BOREHOLE TELEVIEWER

4. EMPHASIS--PROJECTS THAT JOINTLY BENEFIT GEOTHERMAL, PLUS OIL AND GAS
   A. GREATLY IMPROVES COMMERCIALIZATION
   B. INCREASES ACCESS TO R&D FUNDS
   C. FOR EXAMPLE--ROLLING FLOAT METER
      --ROTARY HEAD SEAL
      --SYNTHETIC-DIAMOND DRILL BITS

SYSTEMS ANALYSIS

PRIMARY CONCERN

- LOST CIRCULATION & CEMENTING
- HIGH-TEMP. TOOLS & INSTRUMENTATION
- EXPLORATION & RESOURCE DEFINITION

MULTIPLE MENTION

- FISHING & FISHING RELATED PROBLEMS
- INFORMATION ACCESS AND TRANSFER
- CORROSION & SCALE BUILD-UP
- DATA REDUCTION & INTERPRETATION

PROGRAM ACTIVITIES

LOST CIRCULATION CONTROL

HARD ROCK BITS

SLIM HOLE DRILLING

BOREHOLE INSTRUMENTATION

ACOUSTIC TELEMETRY

GEOTHERMAL HEAT PUMPS

GEOTHERMAL DRILLING ORGANIZATION

ACOUSTIC DATA TELEMETRY

MEASUREMENT-WHILE-DRILLING (MUD PULSE)

$700 MILLION ANNUAL MARKET
$10,000 PER DAY
1-4 BITS PER SECOND

ACOUSTIC DATA TELEMETRY

20-100 BITS PER SECOND
$1,000 PER DAY
TWO-WAY COMMUNICATION

PARTNERSHIP WITH BAKER HUGHES-INTEQ

ACOUSTIC DATA TELEMETRY

1992-3 VERIFIED IN LAB AND FIELD EXPERIMENTS

1994-5 WITH INDUSTRY EVALUATE IN VARIOUS WELL CONFIGURATIONS

1996 CONSTRUCT PROTOTYPE WITH BAKER HUGHES-INTEQ

1996 FIELD TESTS WITH INDUSTRY

BOREHOLE INSTRUMENTATION

ESTABLISH A SUITE OF MEMORY TOOLS

- ELIMINATE LOGGING TRUCK/COST
- AIRLINE LUGGAGE SIZE
- AFFORDABLE FOR DRILLERS, $10-20K
- EASY TO USE IN FIELD

TOOLS UNDER DEVELOPMENT

- PRESSURE/TEMPERATURE
- SPECTRAL GAMMA-RAY TOOL
- FLUID/GAS SAMPLER (DOE/BASIC ENERGY)

SLIMHOLE DRILLING

IDENTIFICATION OF COMMERCIAL GRADE RESERVOIRS KEY TO GEOTHERMAL GROWTH

HALVE THE COST OF EXPLORATION DRILLING

COMPARE COREHOLE & PRODUCTION WELL

DEMONSTRATE SLIMHOLE DATA ADEQUATE

IMPROVE SLIMHOLE DRILLING TECHNOLOGY

HARD-ROCK DRILL BITS

SANDIA DEVELOPED SYNTHETIC-DIAMOND BITS FOR SOFT & MEDIUM FORMATIONS (1980'S)

GOAL--DEVELOP ADVANCED SYNTHETIC-DIAMOND BITS FOR HARD-ROCK FORMATIONS

- IMPREGNATED DIAMOND BITS
- POLYCRYSTALLINE DIAMOND COMPACT (PDC)
- THERMALLY STABLE POLYCRYSTALLINE (TSP)

DOUBLE PENETRATION RATE & BIT LIFE CUTS COSTS OF GEOTHERMAL WELL 15%

SANDIA HAS NINE INDUSTRY PARTNERS

LOST CIRCULATION CONTROL

MOST EXPENSIVE GEOTHERMAL DRILLING PROBLEM

GOAL--REDUCE LOST CIRCULATION COSTS 30-50%

DIAGNOSTIC TECHNIQUES
- DETERMINE SIZE AND LOCATION OF LOSS ZONE
- DETERMINE APPROPRIATE REMEDY
- DEPLOY L.C. MATERIAL @ CORRECT LOCATION

DOWNHOLE TOOLS FOR L.C. CONTROL
- DRILLABLE STRADDLE PACKER
- POROUS PACKER
- DOWNHOLE MATERIAL INJECTOR

"IF YOU CAN DESCRIBE IT, WE CAN CEMENT IT"

R&D CHALLENGES

ABILITY TO IDENTIFY HIGH PAYOFF DRILLING R&D FOR THE GEOTHERMAL INDUSTRY WITHIN OUR BUDGET

"EVERY COMPANY IS TRYING TO IMPROVE ITS HIT RATE AND ONE OF THE HARDEST THINGS IS FIGURING OUT WHAT RESEARCH TO STOP." JAN H. SUWINSKI, CORNING INC. WALL STREET JOURNAL, JUNE 25, 1991

PETER DRUCKER, 1992 NATIONAL TQM TELECONFERENCE

A. HAS THE R&D MADE A DIFFERENCE?
B. WOULD YOU START THE R&D TODAY?
C. TEACH, LET INDUSTRY KNOW ABOUT YOUR R&D SUCCESSES

Attachment D

Overhead Transparencies Presented by Mr. David Biancosino

and

Title Pages of Reports Referenced in Presentation

WHC-SD-EN-TRP-002
Revision 0

Results of Testing the Sonic Drilling System at the Hanford Site

(September 1991 to May 1992)

Prepared for the U.S. Department of Energy
Office of Environmental Restoration and
Waste Management

Westinghouse
Hanford Company Richland, Washington

Hanford Operations and Enginnering Contractor for the
U.S. Department of Energy under Contract DE-AC06-87RL10930

Approved For Public Release

Copies are available on request

WHC-SA-1949-FP

ResonantSonic Drilling: History, Progress and Advances in Environmental Restoration Programs

Prepared for the U.S. Department of Energy
Office of Environmental Restoration and
Waste Management

Westinghouse
Hanford Company Richland, Washington

Hanford Operations and Enginnering Contractor for the
U.S. Department of Energy under Contract DE-AC06-87RL10930

Approved For Public Release

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WHC-SD-EN-TRP-003
Revision 0

Demonstration of a Heavyweight Cone Penetrometer at the Hanford Site

Prepared for the U.S. Department of Energy
Office of Environmental Restoration and
Waste Management

Westinghouse
Hanford Company Richland, Washington

Hanford Operations and Enginnering Contractor for the
U.S. Department of Energy under Contract DE-AC06-87RL10930

Approved For Public Release

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Environmental Restoration Drilling Activities
U.S. Department of Energy
Office of Technology Development

Presented by:
David Biancosino
Program Manager-VOC Arid Integrated Demonstration
December 7, 1993

PROBLEM

There are 3,700 contaminated sites with approximately 26,000 acres of hazardous and radioactive contaminated soil or groundwater together with pockets of heavy metals

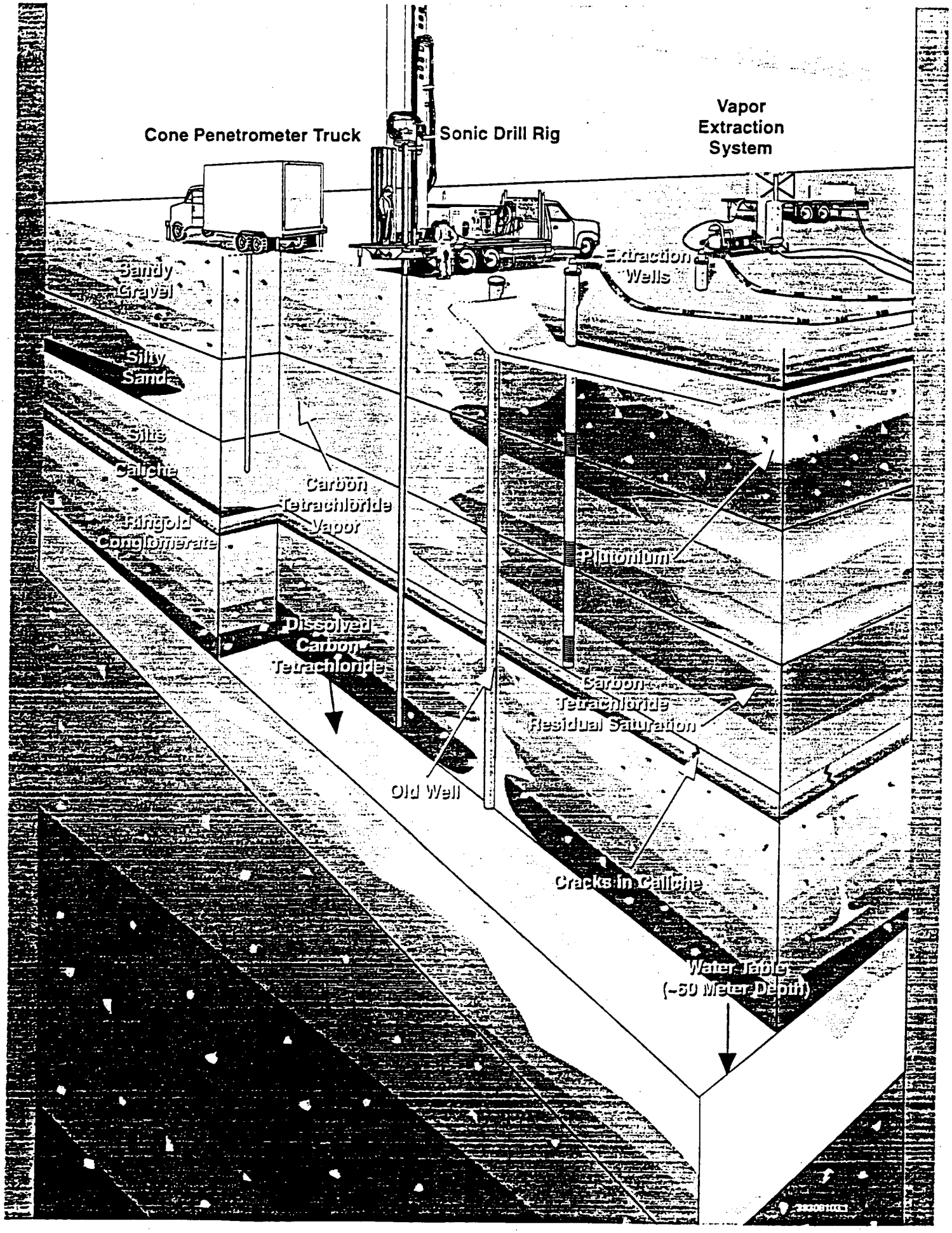
Examples: 740 acres of volatile organic compounds (VOC)-contaminated groundwater plume at Savannah River.

4,000 acres of VOC-contaminated plume at Hanford.

3,200 acres of plutonium-contaminated soils at the Nevada Test Site.

1.5 million cubic meters of uranium-contaminated soils at Fernald

360,000 cubic meters of uranium-contaminated disposed sludge in waste pits at Fernald.


Cone Penetrometer Truck
Sonic Drill Rig
Vapor Extraction System
Extraction Wells
Sandy Gravel
Silty Sand
Silts
Caliche
Carbon Tetrachloride Vapor
Ringold Conglomerate
Plutonium
Dissolved Carbon Tetrachloride
Carbon Tetrachloride Residual Saturation
Old Well
Cracks in Caliche
Water Table (~50 Meter Depth)

Current Methods Under Investigation

- ReasonantSonic™ Drilling - $1,000 K
- Cone Penetrometer - $1,530 K
- Directional Drilling - $475 K

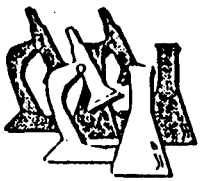
Drilling Applications

- Placement of characterization and monitoring devices
- Removal of contaminants from soil and groundwater
- Injection of flushing agents (air, steam) and nutrients
- Placement of physical and chemical barriers, and containment curtains

Drilling Needs

- Reduction/elimination of drilling fluids or muds
- Increase directional drilling penetration rates and depths
- Increase cone penetrometer depths in rocky terrain
- Improve reliability of ReasonantSonic™ drilling rigs
- Borehole stabilization techniques
- Containment of drill cuttings during operation

PROBLEM



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Attachment E

Overhead Transparencies Presented by Mr. Terry R. Crump

DEPARTMENT OF ENERGY

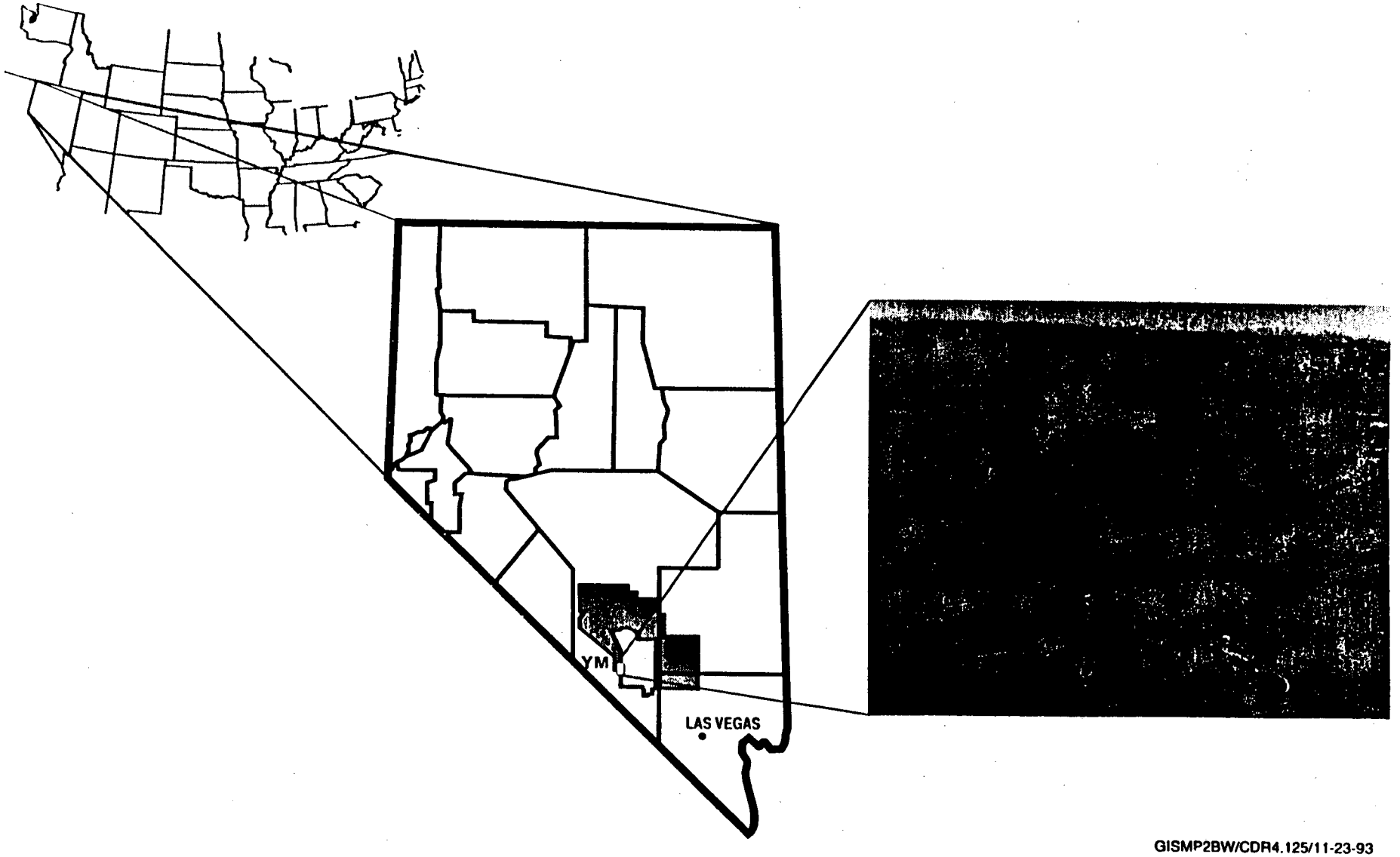
NATIONAL ADVANCED DRILLING AND EXCAVATION TECHNOLOGY CONFERENCE

DRY DRILLING AND MECHANICAL TUNNELING AT YUCCA MOUNTAIN, NEVADA

DECEMBER 7,1993

Presented by
Dr. Stephan J. Brocoum
Office Of Geologic Disposal
Office of Civilian Radioactive Waste Management

IN 1987, CONGRESS TOLD DOE TO STUDY ONLY YUCCA MOUNTAIN



GISMP2BW/CDR4.125/11-23-93

SITE CHARACTERIZATION IS REQUIRED BY NWPA AND 10 CFR 60

- DOE MUST CONDUCT A PROGRAM OF SITE CHARACTERIZATION, INCLUDING IN SITU EXPLORATION AND TESTING AT DEPTH

- DOE MUST PREPARE A GENERAL PLAN FOR THE ACTIVITIES TO BE CONDUCTED

- BEFORE CONSTRUCTION OF THE UNDERGROUND EXPLORATORY FACILITY DOE MUST:

  - SUBMIT ITS PLANS TO NRC AND STATE OF NEVADA FOR REVIEW AND COMMENT

  - HOLD PUBLIC HEARINGS TO RECEIVE COMMENTS

FOCUS OF SITE CHARACTERIZATION

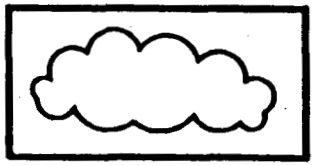
- UNDISTURBED PERFORMANCE OF NATURAL SYSTEM - UNDERSTAND PAST AND PRESENT CONDITIONS AND EVOLUTION OVER TIME
  - GEOLOGIC-HYDROLOGIC SETTING AS IT AFFECTS TRANSPORT AND RELEASE OF RADIONUCLIDES
- POTENTIAL FOR DISRUPTION AND CHANGE THAT MAY AFFECT THE EXPECTED PERFORMANCE OF THE NATURAL SYSTEM
  - VOLCANISM
  - TECTONICS (FAULTING, SEISMICITY)
  - CLIMATE CHANGE
  - HUMAN INTERFERENCE

THE SITE CHARACTERIZATION TESTING PROGRAM INCLUDES ACTIVITIES TO ESTABLISH THE GEOLOGIC CONDITIONS AND HISTORY OF THE SITE

- **Surface-Based tests**
  - Extend the results of ESF tests to the entire site area
  - Laboratory studies
    * Geochemistry; fracture flow; waste package
- **Exploratory Studies Facility (ESF) tests**
  - Waste isolation performance
  - Effects of ESF construction
  - Establish underground conditions

Drilling Objectives

- Obtain core containing the in situ conditions of the mountain
- Provide boreholes without disturbing the in situ conditions of the mountain



Drilling Technique

- Top-head drive, push-pull and rotate capability
- Dual wall, reverse circulation
- Conditioned air as a drilling medium
- Core through the reaming bit with the drill string in the borehole
- Wireline core retrieval
- Polycrystalline diamond composite (PDC) core bits
- Alternate cone-reaming bits

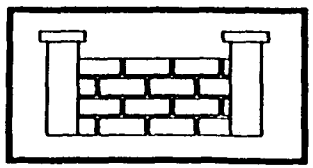
LM-300 Rig Specifications

Rig Dimensions:

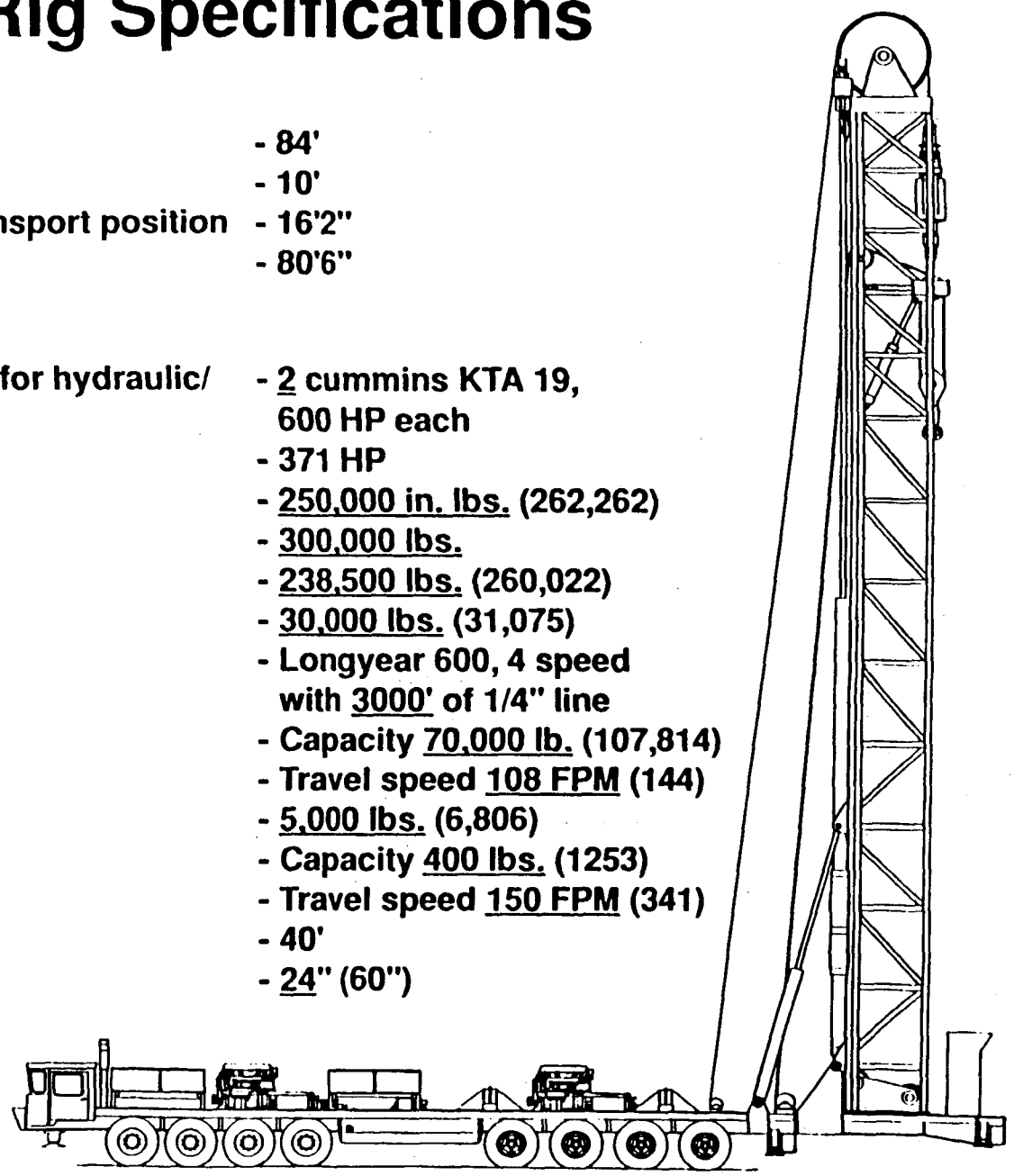
- Overall height with mast erect - 84'
- Overall width - 10'
- Overall height with mast in transport position - 16'2"
- Length of mast - 80'6"

Drilling Capabilities:

- Primary and secondary power for hydraulic/ drive systems - 2 cummins KTA 19, 600 HP each
- Power to tophead drive - 371 HP
- Torque - 250,000 in. lbs. (262,262)
- Max. mast load - 300,000 lbs.
- Pullback capability - 238,500 lbs. (260,022)
- Pulldown capability - 30,000 lbs. (31,075)
- Main hoist - Longyear 600, 4 speed with 3000' of 1/4" line
  - Capacity 70,000 lb. (107,814)
  - Travel speed 108 FPM (144)
- Pipe handling winch rating - 5,000 lbs. (6,806)
- Wireline winch - Capacity 400 lbs. (1253)
  - Travel speed 150 FPM (341)
- Max. tubular length - 40'
- Max. tubular diameter - 24" (60")



Parentheses = Actuals



Overall length with tag axles 99'9-1/2"

DRYDRILL.125.NWTRB/4 7/8-92

Research is Worthwhile

- Develop prototype tool. PDC bits get 150 to 200 feet.

- Drill string vibration.

  . Centralizers

  . Dampers

- Hole deviation.

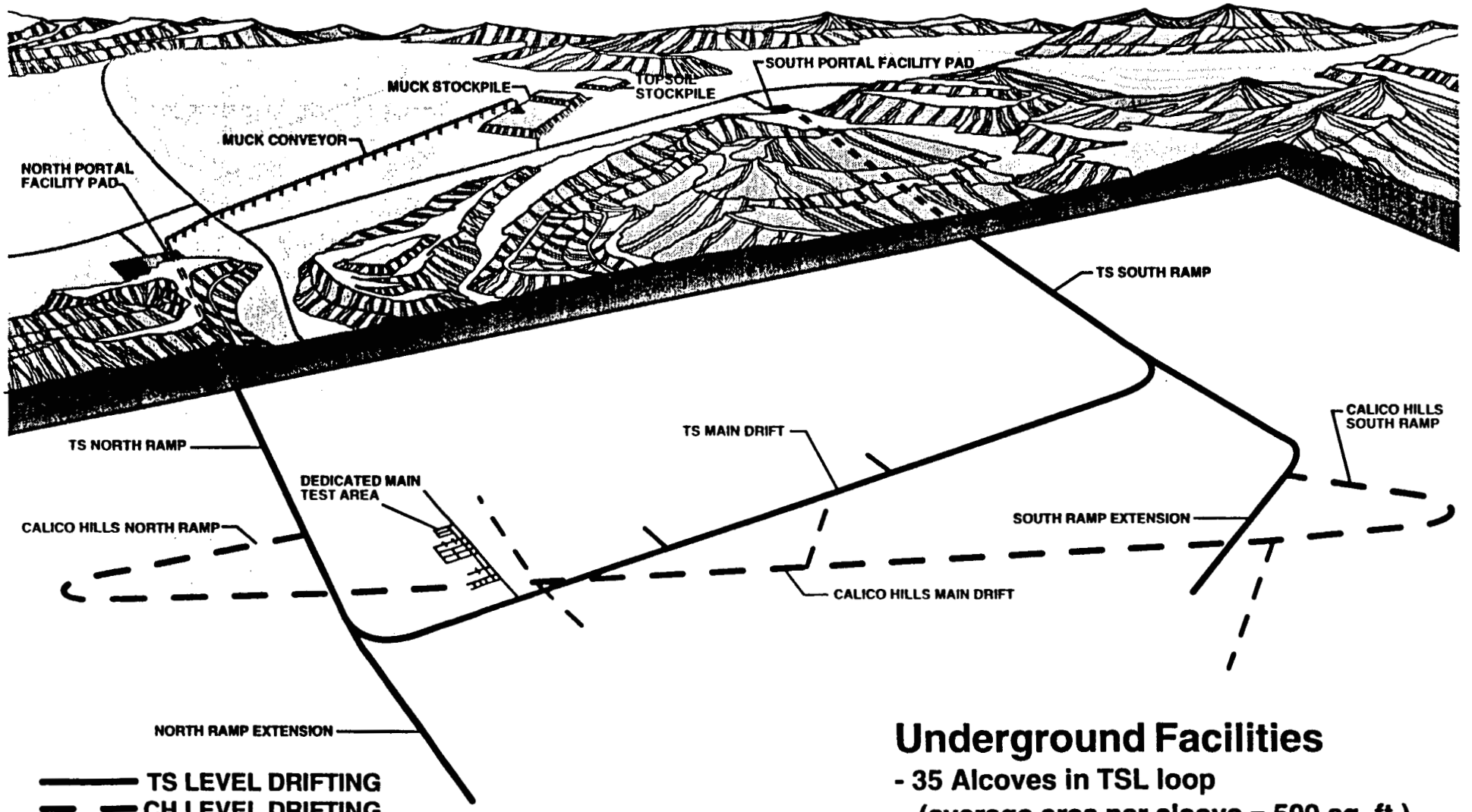
  > 35 RPM

  < 1,000 PSI bit pressure

ESF MISSION IS TO PROVIDE ACCESS TO GEOLOGIC HORIZONS TO EVALUATE SUITABILITY OF GEOLOGIC BARRIERS TO ISOLATE WASTE

- Enable testing in "underground laboratory"
- Determine the suitability/unsuitability of Yucca Mountain as a potential repository site
  - Provide access to the potential repository horizon (Topopah Spring) for inspection and testing
  - Provide access to the Calico Hills level for inspection and testing
    -- Primary barrier for radionuclide transport
- Develop data for potential repository design and construction

PROPOSED ESF DESIGN



TS LEVEL DRIFTING

CH LEVEL DRIFTING

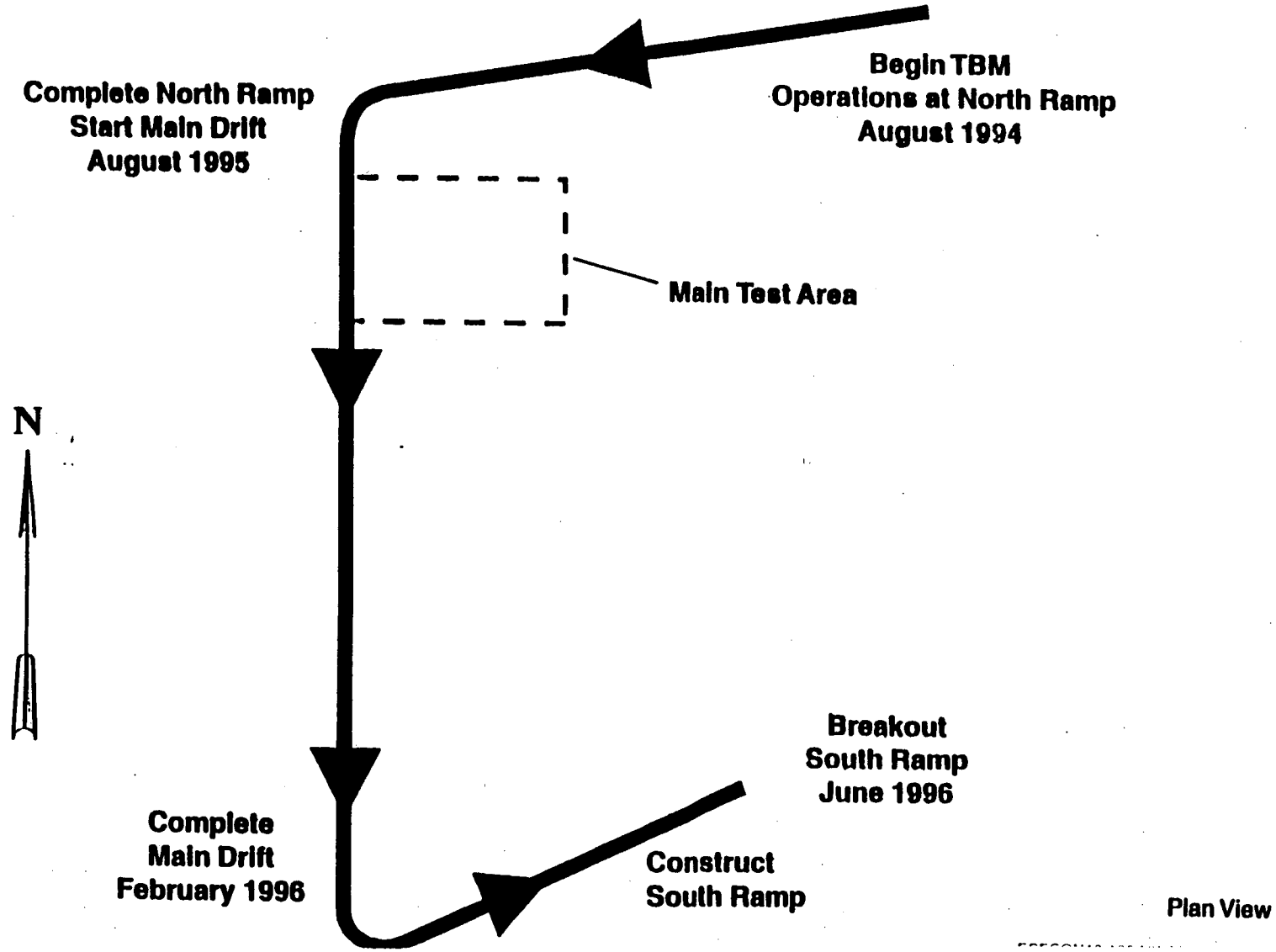
(CH IS APPROX. 170 METERS BELOW TS)

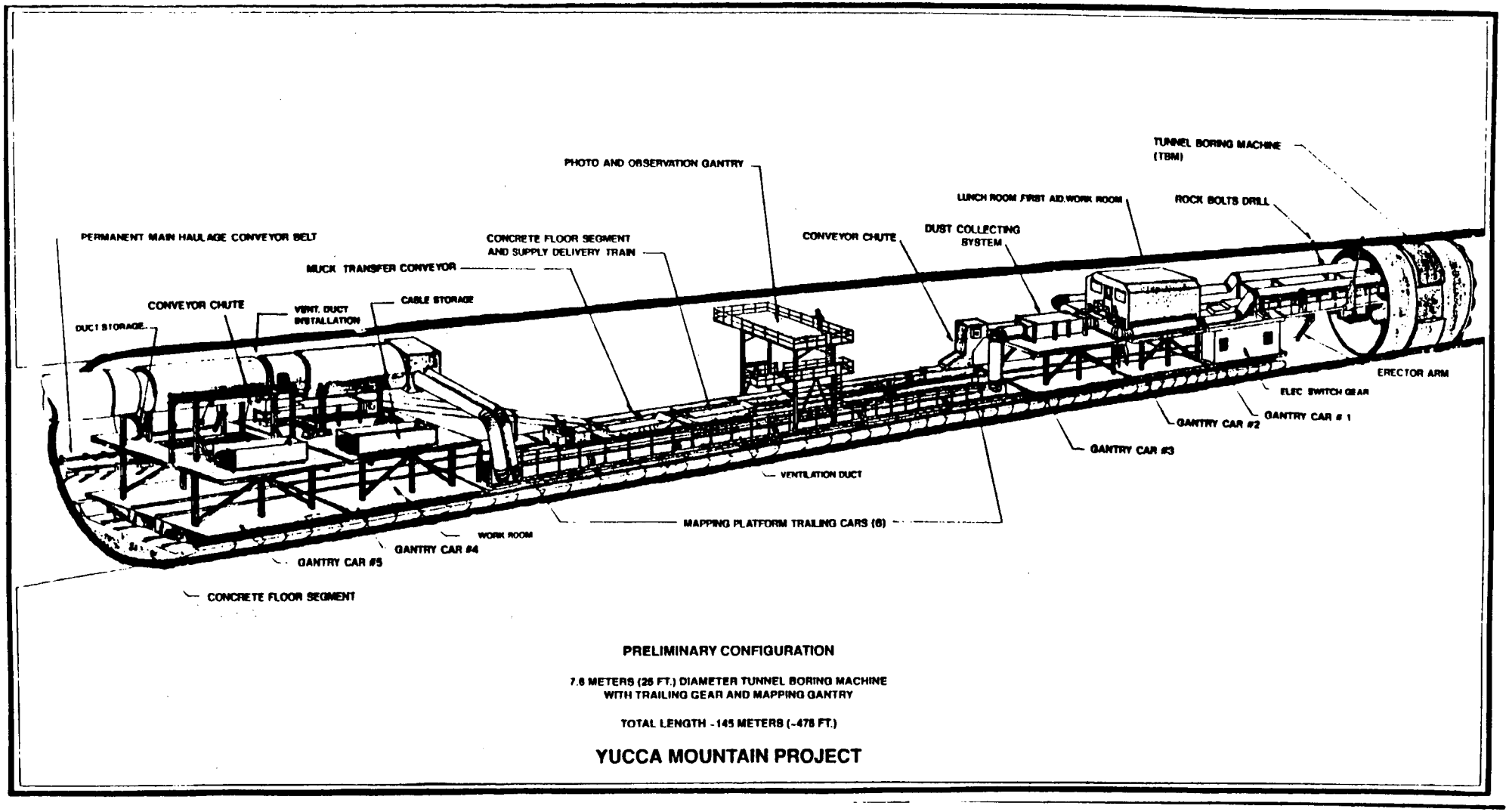
Underground Facilities

- 35 Alcoves in TSL loop
  (average area per alcove = 500 sq. ft.)
- Main Test Area is approx. 18.5 acres

ESFPRPD1/CDR4.XSECTNS/10-22-93

INITIAL 5-MILE RAMP/DRIFT LOOP WILL PROVIDE EARLY SITE SUITABILITY INFORMATION





PRELIMINARY CONFIGURATION

7.6 METERS (25 FT.) DIAMETER TUNNEL BORING MACHINE
WITH TRAILING GEAR AND MAPPING GANTRY

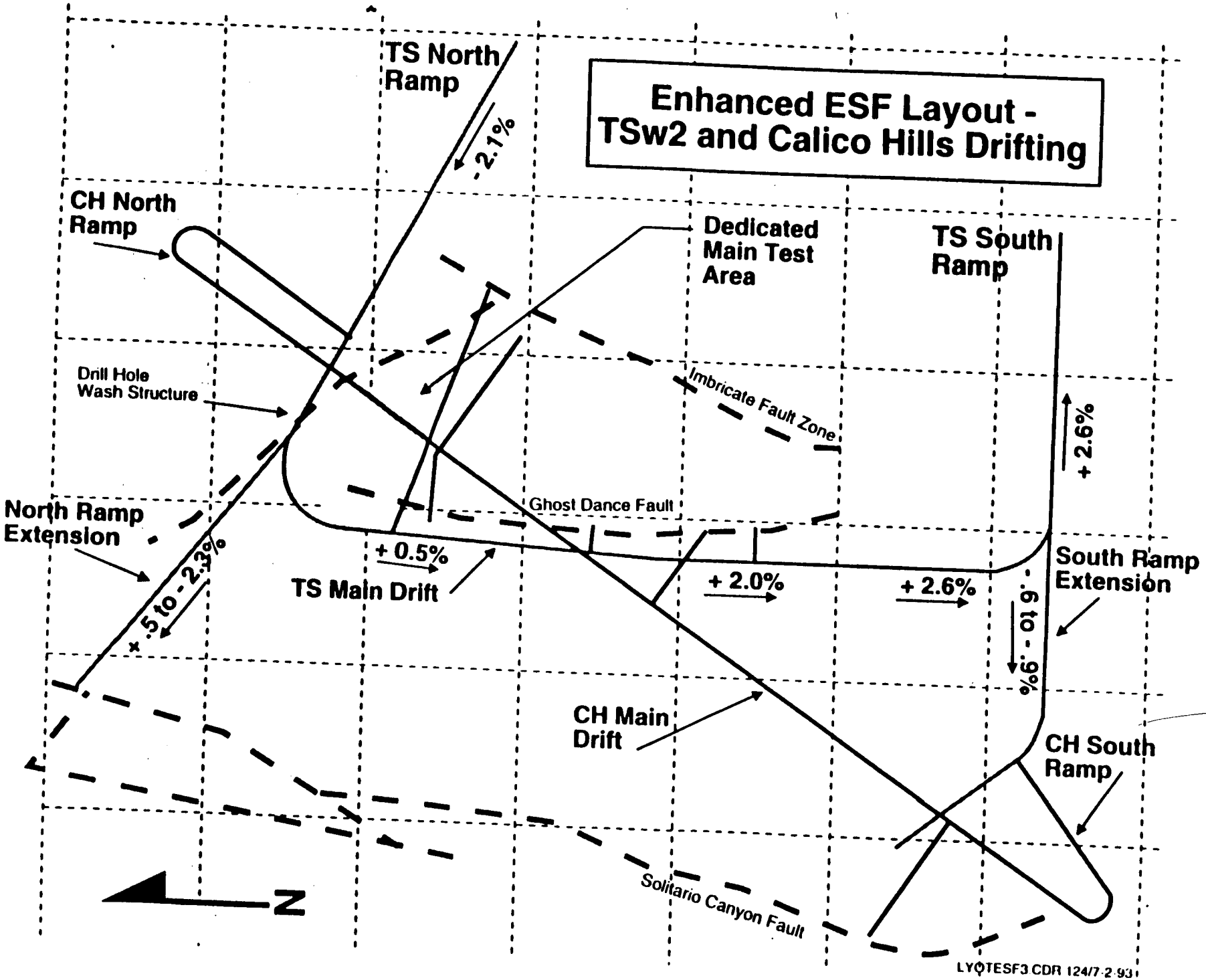
TOTAL LENGTH - 145 METERS (~475 FT.)

YUCCA MOUNTAIN PROJECT

GENERAL INFORMATION ON CTS TBM

GRIPPER SHIELD TBM - MODEL 760

Turning radius	**500 ft**
Weight	**720 tons**
Length	**220 ft (without mapping cars)**
Name plate power:	**3,800 horsepower**


Enhanced ESF Layout -
TSw2 and Calico Hills Drifting
TS North Ramp
-2.1%
CH North Ramp
Dedicated Main Test Area
TS South Ramp
Drill Hole Wash Structure
Imbricate Fault Zone
+2.6%
North Ramp Extension
Ghost Dance Fault
+0.5%
TS Main Drift
+2.0%
+2.6%
South Ramp Extension
-.5 to -2.3%
-.6 to -.9%
CH Main Drift
CH South Ramp
N
Solitario Canyon Fault
LYQTESF3.CDR 12/7/2:93