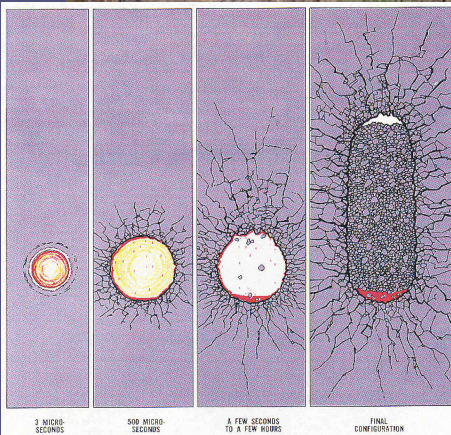




CULTURAL RESOURCES TECHNICAL REPORT NO. 111  
DIVISION OF EARTH AND ECOSYSTEM SCIENCES  
DESERT RESEARCH INSTITUTE  
LAS VEGAS, NEVADA

***THE OFF-SITE PLOWSHARE AND VELA UNIFORM PROGRAMS:  
Assessing Potential Environmental Liabilities through an Examination  
of Proposed Nuclear Projects, High Explosive Experiments,  
and High Explosive Construction Activities***

VOLUME 2 of 3



by

Colleen M. Beck, Susan R. Edwards, and Maureen L. King

with contributions by

Harold Drollinger, Robert Jones, and Barbara Holz

September 2011

## Disclaimer

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

Available for sale to the public from:

U.S. Department of Commerce  
National Technical Information Service  
5301 Shawnee Road  
Alexandria, VA 22312  
Phone: 800.553.6847  
Fax: 703.605.6900  
E-mail: [orders@ntis.gov](mailto:orders@ntis.gov)  
Online ordering: <http://www.ntis.gov/help/ordermethods.aspx>

Available electronically at <http://www.osti.gov/bridge>

Available for a processing fee to the U.S. Department of Energy and its contractors, in paper, from:

U.S. Department of Energy  
Office of Scientific and Technical Information  
P.O. Box 62  
Oak Ridge, TN 37831-0062  
Phone: 865.576.8401  
Fax: 865.576.5728  
E-mail: [reports@adonis.osti.gov](mailto:reports@adonis.osti.gov)

**Cover Illustrations: The Project Bronco Site in northwestern Colorado and a schematic of a nuclear explosive-created rubble chimney. Bronco was a planned but never executed Plowshare project designed for the application of nuclear explosives to fracture underground oil shale deposits for in situ retorting and recovery (Photos by C. Beck, July 2005; Graphic from Lekas et al 1967, Figure 3).**

***THE OFF-SITE PLOWSHARE AND VELA UNIFORM PROGRAMS:  
Assessing Potential Environmental Liabilities through an Examination  
of Proposed Nuclear Projects, High Explosive Experiments,  
and High Explosive Construction Activities***

**VOLUME 2 of 3**

by

**Colleen M. Beck, Susan R. Edwards, and Maureen L. King**

**with contributions by  
Harold Drollinger, Robert Jones, and Barbara Holz**

**Prepared for**

**U.S. Department of Energy  
National Nuclear Security Administration  
Nevada Site Office, Las Vegas, Nevada**

**Cultural Resources Technical Report No. 111  
Division of Earth and Ecosystem Sciences  
Desert Research Institute  
Las Vegas, Nevada**

**September 2011**

The work upon which this report is based was supported by the U.S. Department of Energy under Contract #DE-AC52-06NA26383.

**THIS PAGE INTENTIONALLY LEFT BLANK**

## **CHAPTER 4.0 PROJECT DESCRIPTIONS: FIELD ACTIVITY LEVELS 4 AND 5**

There are 46 Plowshare and Vela Uniform projects (Table 4.0-1) with field activity levels that are designated as low (Levels 4 and 5). Projects categorized as Level 4 have locations where existing facilities, such as mines, wells, and drill holes, were utilized for data collection. Level 5 projects have locations where activity was confined to conceptual designs, background research, and visual field inspections. In cases where there were structured field activities that exceeded casual visual inspections, the project was assigned to a Level 4. None of these projects have potential environmental liabilities.

Seventeen projects are identified as a Level 4. Six are Vela Uniform (Colona Earthquake, Hebgen Lake Earthquake, New Madrid Earthquake, Sand, Tar, and West Virginia Earthquake) and involve using either monitoring equipment to record seismic signals or existing facilities for data collection as part of a nuclear project site selection process. Of the 11 Plowshare projects, 10 were seriously considered for a nuclear application (Aquarius, Carryall, Cochiti Dam, Copper Recovery, Dogsled, Ketch, North Slope Harbor, Red Lake, San Clemente Island, and Sloop. Some even had feasibility studies prepared in anticipation of proceeding with the work. The nuclear applications were water management, highway and railroad construction, quarrying for dam construction, fracturing copper ore, and underground gas storage. One project, Dogsled, was a proposed nuclear cratering experiment in sandstone. The Old Reliable Mine Project was different. The mining company was detonating a large high explosive and the Plowshare involvement was restricted to placing instruments and conducting a study of the seismic effects from the detonation for data to be applied to other mining projects.

There are 29 projects in the Level 5 category and none of these projects were conducted. Only one of these, Groundhog, is a Vela Uniform project. It was a series of proposed high explosives tests related to seismic research. The other 28 are Plowshare projects. Twenty-six of the 28 were proposed nuclear experiments. Twelve different nuclear applications and data acquisition projects are represented in the 26 nuclear experiments: 1) harbor construction (Cape Darby Harbor, Katalla Harbor, Kaunakakai Harbor, Nome Harbor, Point Barrow Harbor, Shemya Island, and South Point Harbor), 2) dam construction (Bruneau Canyon Dam, Rampart Canyon Dam, Spiridon Lake, and Swan Lake), 3) canal or channel construction (Chomly Cutoff, Port Moller Canal, and Tennessee-Tombigbee Waterway), 4) cratering and row charge experiments (Galley, Gondola, and Phaeton), 5) fracturing ore deposits (Copper Ore Chemical Mining and Gold Leaching), 6) petroleum stimulation (Bo-Peep), 7) water management (NAWAPA), 8) navigation hazard removal (Whitestone Narrows), 9) railroad cut (Boca Bypass), 10) sewage disposal (Lake Tahoe Sewage), 11) geothermal power (Geothermal Power Plant), and 12) isotope production (Surrey). The two non-nuclear projects are Caddo Pine Island and Wheelbarrow. Caddo Pine Island was a high explosives experiment for stimulating oil production in existing oil fields. Wheelbarrow was a chemical experiment for mining and petroleum recovery in limestone. A site visit was conducted to the proposed Kaunakakai harbor project location.

The project descriptions are presented in alphabetical order. A brief summary of the data for each project is in Appendix A.

Table 4.0-1. Project Descriptions: Field Activity Levels 4 and 5

<b>Name</b>	<b>Description</b>	<b>Activity Level</b>
Aquarius	Nuclear Explosives for Water Management	Level 4
Carryall	Nuclear Explosives Proposed for Highway and Railroad Construction	Level 4
Cochiti Dam	Nuclear Quarrying for Construction of a Dam	Level 4
Colona Earthquake (Vela Uniform)	Earthquake Seismic Data	Level 4
Copper Recovery	Nuclear Explosives for Fracturing Copper Ore Deposits for In Situ Leaching	Level 4
Dogsled	Nuclear Cratering Experiment in Sandstone	Level 4
Hebgen Lake Earthquake (Vela Uniform)	Earthquake Seismic Data	Level 4
Ketch	Nuclear Explosives for Underground Natural Gas Storage	Level 4
New Madrid Earthquake (Vela Uniform)	Earthquake Seismic Data	Level 4
North Slope Harbor	Nuclear Construction of an Offshore Loading Facility	Level 4
Old Reliable Mine	High Explosives Seismic Study	Level 4
Red Lake Gas Storage	Nuclear Excavation for Underground Gas Storage	Level 4
San Clemente Island	Development of Underground Aquifer Using Nuclear Explosives	Level 4
Sand (Vela Uniform)	Nuclear Explosive Seismic Monitoring Experiment	Level 4
Sloop	Nuclear Cratering Experiment for Leaching Copper Ore	Level 4
Tar (Vela Uniform)	Nuclear Explosive Seismic Monitoring Experiment	Level 4
West Virginia Earthquake (Vela Uniform)	Earthquake Seismic Data	Level 4
Boca Bypass	Nuclear Excavated Railroad Cut	Level 5
Bo-Peep	Nuclear Explosives for Petroleum Stimulation	Level 5
Bruneau Canyon Dam	Nuclear Explosives for Ejecta Dam Construction	Level 5

Table 4.0-1. Project Descriptions: Field Activity Levels 4 and 5 (continued)

Caddo Pine Island	High Explosives Experiment for Oil Stimulation	Level 5
Cape Darby Harbor	Nuclear Excavation of a Harbor	Level 5
Chomly Cutoff	Nuclear Excavation of a Sea-Level Channel	Level 5
Copper Ore Chemical Mining	Nuclear Explosives to Mine Primary Copper Ore Deposits	Level 5
Galley	Row Charge Nuclear Cratering Experiment	Level 5
Geothermal Power Plant	Nuclear Explosives for Geothermal Power	Level 5
Gold Leaching	Nuclear Explosives to Fracture Ore for In Situ Leaching of Gold	Level 5
Gondola	Nuclear Cratering Experiment	Level 5
Groundhog (Vela Uniform)	High Explosive Seismic Monitoring Experiment	Level 5
Katalla Harbor	Nuclear Construction of a Deep-Water Harbor	Level 5
Kaunakakai Harbor	Nuclear Harbor Excavation Experiment	Level 5
Lake Tahoe Sewage	Nuclear Chimneys for Sewage Disposal	Level 5
NAWAPA	Nuclear Explosives for Construction of a Water Containment and Distribution System	Level 5
Nome Harbor	Nuclear Excavation of a Harbor	Level 5
Phaeton	Nuclear Excavation	Level 5
Point Barrow Harbor	Nuclear Excavation of a Harbor	Level 5
Port Moller Canal	Nuclear Explosives for Canal Construction	Level 5
Rampart Canyon Dam	Nuclear Excavation for Dam Construction and Quarry	Level 5
Shemya Island	Nuclear Harbor Excavation	Level 5
South Point Harbor	Nuclear Excavation of a Military Harbor	Level 5
Spiridon Lake	Nuclear Explosives to Construct a Slide Dam	Level 5
Surrey	Isotope Production	Level 5
Swan Lake Dam	Nuclear Construction of a Rock-Fill Dam	Level 5
Tennessee-Tombigbee Waterway	Nuclear Excavation of a Canal	Level 5
Wheelbarrow	Limestone Chemical Experiment for Mining and Petroleum Recovery	Level 5
Whitestone Narrows	Nuclear Explosives to Remove Navigation Hazards	Level 5

**THIS PAGE INTENTIONALLY LEFT BLANK**



## **4.1 AQUARIUS**

### **Plowshare Program Nuclear Explosives for Water Management Arizona**

Project Aquarius was initiated in 1966. Members of the scientific community proposed utilizing nuclear explosives for the development and management of water resources as early as 1959. However, it was not until 1965 that potential nuclear applications were delineated formally. Conceptual models included the use of nuclear detonation for the purposes of: 1) dam construction, utilizing either bulking techniques or nuclear quarrying; 2) enhanced recharge through cratering for subsurface storage, transmission and purification; and 3) aquiclude breaching through the development of a rubble chimney for the purposes of aquifer modification, interconnection, and enhanced recharge. Efforts were made to identify an appropriate location with suitable hydrologic regimes in order to examine the feasibility of nuclear explosives for improving water availability.

The State of Arizona was an ideal place for this investigation because its broad range of geohydrologic variability would allow the investigation of nuclear explosives in different types of water management situations. In 1966, discussions were underway between the Arizona Atomic Energy Commission and the U.S. Atomic Energy Commission regarding the use of Plowshare techniques for the construction of a central Arizona aqueduct as part of the Central Arizona Water Project and included the option of aquifer storage for water runoff. As a result of these and other discussions and the need to focus research on specific locations, the Arizona Atomic Energy Commission funded preliminary research on water management issues throughout Arizona and identified potential sites where nuclear applications might be productive for water resources. A University of Arizona report was presented to Lawrence Radiation Laboratory and the Special Projects Division of the San Francisco Operations Office at a meeting in Berkeley on October 20, 1967, to the Lawrence Radiation Laboratory and the U.S. Geological Survey in Livermore on the same day, and to the U.S. Atomic Energy Commission Nevada Operations Office shortly thereafter. The report focused on two types of projects to reduce the amount of water falling on Arizona which was lost and could not be used. The first was to collect water that was being lost into underground storage in depleted aquifers, and the second was the retention of water in surface reservoirs. Arizona also verbally expressed interest in tunneling for water management and potential applications of nuclear technology for the Central Arizona Project.

The Arizona report identified two prime sites, both approximately 20 miles south of Winslow on Chevelon and Clear creeks. The Lawrence Radiation Laboratory reviewed the Arizona report and conducted some additional analysis of the prime locations in late 1967. The analysis was preliminary and focused on data regarding seismic and fallout effects from both locations, estimates of crater storage volume, and the potential for aquifer recharge. The aquifer in this area is in the Coconino Sandstone. Due to its

permeability, the sites were excluded from serious consideration for aquifer recharge by the laboratory. Surface storage was determined to be the most practical use of nuclear cratering technology with the most attention on a nuclear experiment that would create a dam and reservoir for water storage. This continuing positive dialog with the U.S. Atomic Energy Commission increased the state's interest for participation in nuclear explosive research.

On May 8, 1968, the Governor of Arizona sent a letter to the Chairman of the U. S. Atomic Energy Commission and the U.S. Secretary of the Interior, stating Arizona's interest in entering into an agreement between the Federal government and the State of Arizona for a joint study to investigate the feasibility of using nuclear explosives for water management in Arizona. The Chairman of the U.S. Atomic Energy Commission responded positively to a joint feasibility study in a letter dated May 20, 1968. The Governor's letter had outlined four objectives for the project. These objectives served as guidance for a June 25, 1968 meeting at the U.S. Bureau of Reclamation in Phoenix between federal and state agencies and their contractors. The purpose of the meeting was to discuss and plan a joint study for water management in Arizona with nuclear explosives. Present at this meeting were representatives of the Arizona Atomic Energy Commission; University of Arizona; Arizona Interstate Stream Commission; Arizona State Land Department; Bechtel Corporation; CER Geonuclear Corporation; the U.S. Atomic Energy Commission, San Francisco Operations Office and Nevada Operations Office; Lawrence Radiation Laboratory; U.S. Geological Survey, Denver; Bureau of Reclamation, Phoenix and Boulder City; and the U.S. Public Health Service, Las Vegas. During this meeting, all parties agreed to name this effort Aquarius, after the constellation of the mythical water bearer. After the Bureau of Reclamation pointed out the term "feasibility study" would require specific Congressional approval for their agency and the U.S. Atomic Energy Commission asked the group to avoid the word "project" because it had special implications within the Commission, the official title for this research effort became the Aquarius Study. The group selected two persons to be Co-Chairmen for the study: the Director of the State of Arizona Atomic Energy Commission, and the Project Engineer with the Special Projects Division, the U.S. Atomic Energy Commission, San Francisco Operations Office.

The four study objectives presented in the Governor's letter were: 1) to investigate the feasibility of using nuclear explosives in connection with water management in Arizona; 2) to explore locations in Arizona where experimental nuclear explosions for water management might be conducted; 3) to make a cost analysis of nuclear versus conventional techniques for water management projects; and 4) to prepare recommendations for future actions. At the meeting, a fifth objective was added to the list: 5) to prepare and publish a report describing the study and summarizing its findings and conclusions.

Participants defined work scopes for each of the agencies and contractors in attendance. Subsequent to this meeting, the Arizona Hydrology and Water Resources Office became involved in this study. The group also developed guidelines for the research and a

schedule with task completion dates. The Aquarius Study officially began on July 1, 1968, with a projected completion date of June 30, 1969.

At least 22 localities within the State of Arizona were considered as potential sites for Project Aquarius (Figure 4.1-1). Potential sites were analyzed for safety and hydrology. The principal safety consideration was the distance from population centers. The primary hydrology issue concerned the projected quantity of water that could be developed and managed. For surface water studies, site selection criteria also included the shape of the canyon for landslides, throw-out or rock-fill techniques, canyon meanders for diversion channels, low permeable rock types for minimal radioisotope migration, and the identification of all groundwater that could be affected by the study. For recharge craters, additional issues included adequate subsurface storage space, aquifer characteristics that would support recharge and recovery, presence of subsurface rock types that would aid control of radioisotopes, suspended sediment load in the water, and the estimated efficiency of artificial recharge to natural recharge. Ultimately, two sites were determined to be of sufficient technical, safety, and economic feasibility to warrant further investigation, the San Simon and the Clear Creek sites (Figure 4.1-2).

The San Simon Site is located in the Cave Creek area (E1/2, Sec. 8, T17S R32E) of the San Simon Basin in southeastern Arizona, southeast of Wilcox near the New Mexico border. The site was selected as the potential location for a cratering experiment in which a nuclear detonation and the resultant surface crater would be used to capture surface runoff to enhance groundwater recharge in an alluvial basin (a water-table aquifer). Nuclear quarrying was selected for the study because this technique was projected to produce the minimum water contamination and had fewer uncertainties in the design and cost estimate. In 1965, the State of Arizona Land Department produced a report on the hydrologic data for this area, based on drillers' logs from five water wells. Project Aquarius scientists recognized that these data were not enough to clearly define the groundwater environment. No new wells were developed at this location for Aquarius. By March 27, 1969, the San Simon site was no longer under current consideration for Aquarius.

On March 27, 1969 the Arizona Atomic Energy Commission then issued an announcement that the State of Arizona Atomic Energy Commission, the U.S. Atomic Energy Commission, and the U.S. Department of Interior would be initiating field investigations in April at the Clear Creek Site for safety and cost comparisons of conventional versus nuclear dam construction methods as part of the Aquarius Study, a joint state and federal government effort to evaluate the potential of using nuclear explosives in conjunction with water management in Arizona. This announcement states that the study began in July 1968 and would culminate in a formal report in late 1969.

The Clear Creek Site, midway between Payson and Winslow in central Arizona and immediately downstream of the confluence of Clear Creek and Willow Creek, was the proposed location of a nuclear dam construction project to create the Clear Creek Reservoir (Figures 4.1-3 and 4.1-4). Besides its physical characteristics, this location was

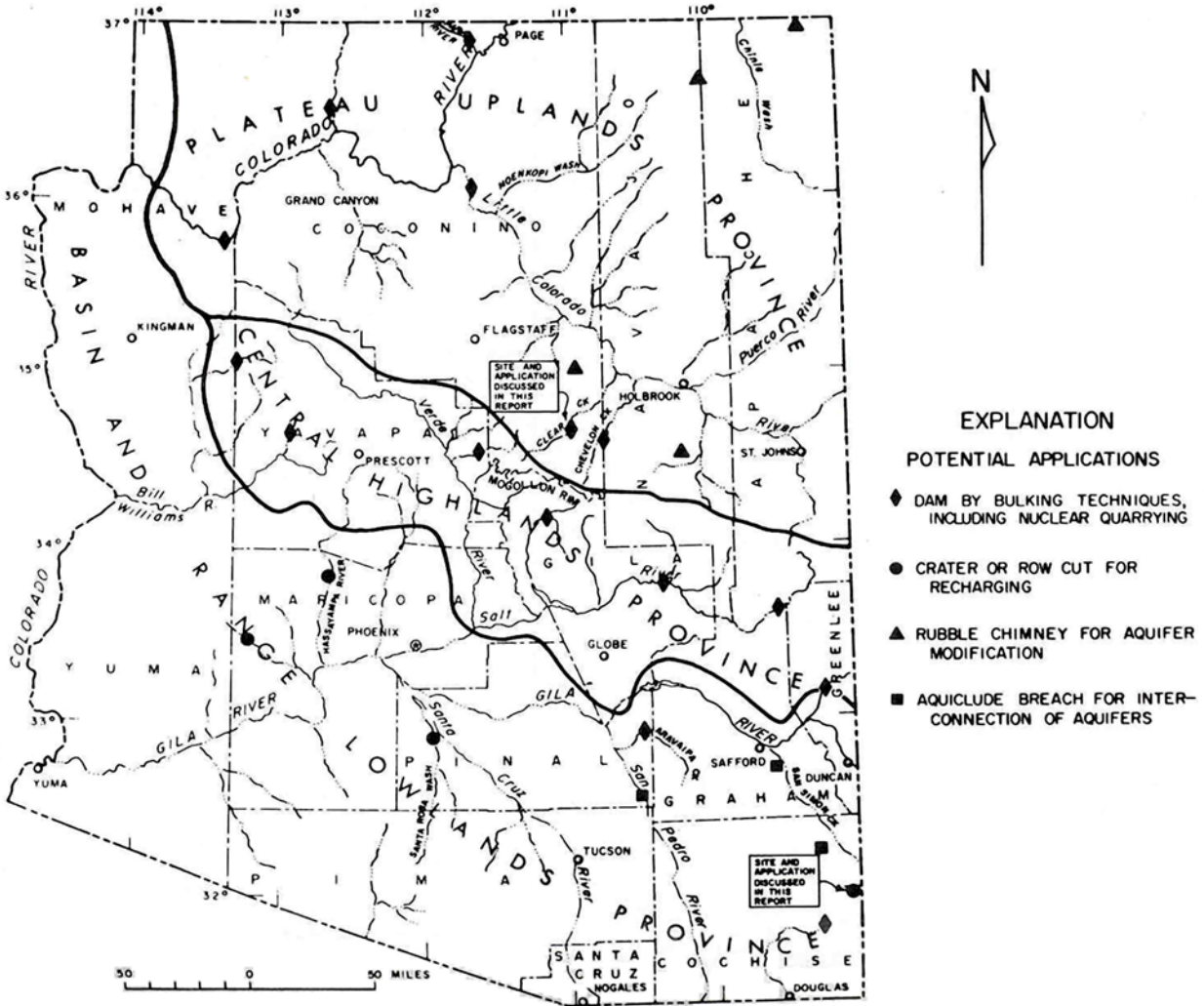


Figure 4.1-1. Location of potential sites in Arizona for Project Aquarius (Ganus 1970a, Figure 1).

avored because the U.S. Bureau of Reclamation had already gathered the available site data for a preliminary design and cost estimate of a conventional dam. The official designation for the proposed conventional dam was the Wilkins Dam site. The proposed dam location spanned a vertical-walled canyon approximately 500 ft deep. Data to characterize the site's geology were obtained from existing oil tests and water wells in the surrounding region. No new wells or boreholes were drilled for Project Aquarius.

Although several nuclear explosive techniques were considered for this project, three were deemed the most appropriate for the location: 1) nuclear quarrying to produce fill material for dam construction; 2) nuclear throwout damming to form an upstream embankment; and 3) nuclear retarc damming, a technique by which an upstream embankment would be formed by the rim of the retarc or mound. Estimated nuclear yields were 15 kt, 100 kt, and 75 kt respectively. Nuclear quarrying for fill material was

selected because it utilized the lowest yielding nuclear explosive, produced the least surface water contamination, and had the least uncertainties regarding feasibility and cost.

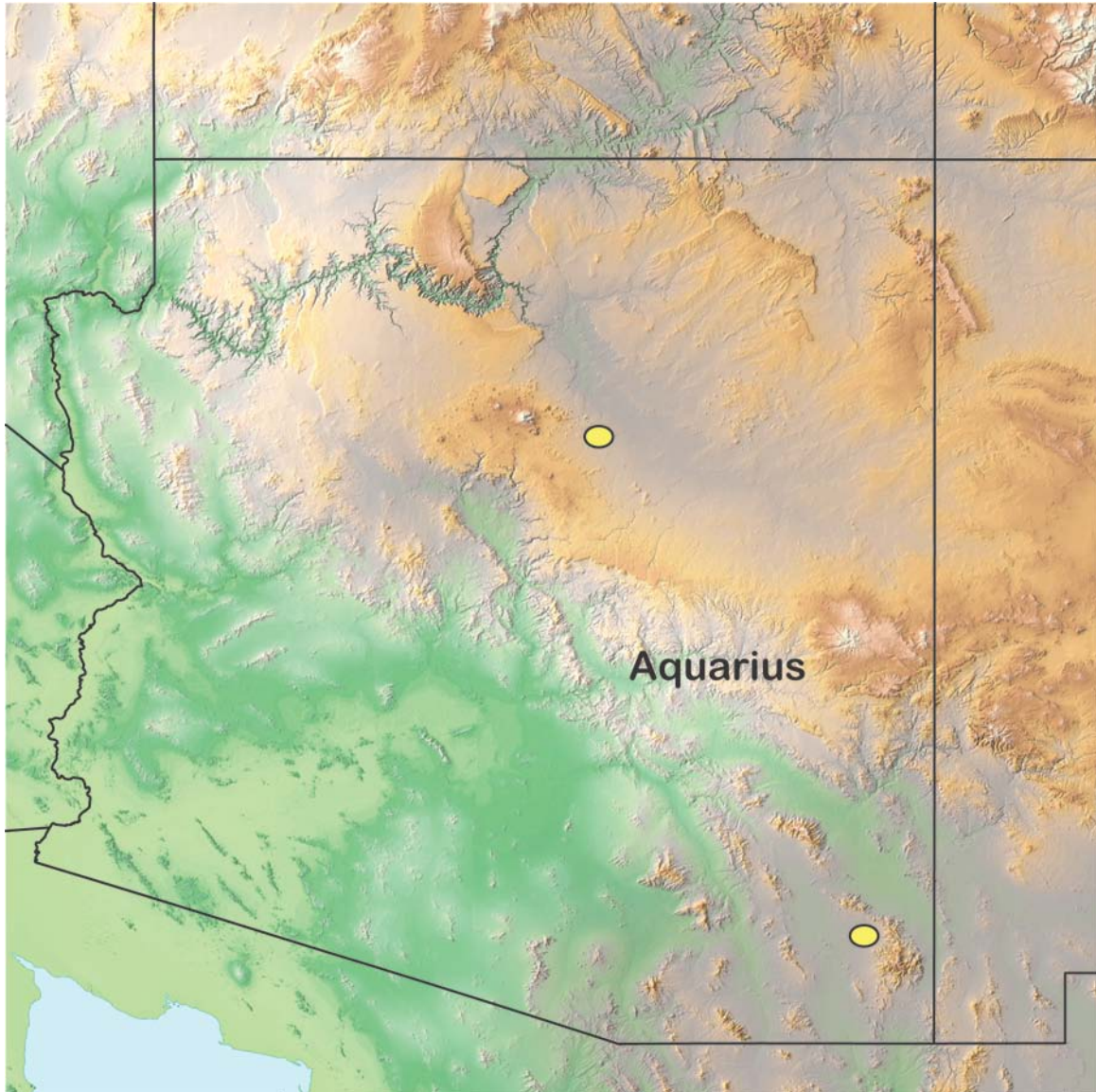


Figure 4.1-2. Proposed locations of Project Aquarius in Arizona. The Clear Creek site is to the north and the San Simon site is to the south (adapted from USA Relief Maps 2004).

A cost estimate comparison was made for creating a rockfill dam at the Clear Creek site with the understanding that the only cost difference between nuclear quarrying and a convention dam would be the cost of producing the rockfill. As the U.S. Bureau of Reclamation had already determined the cost of a thin-arch concrete dam, it was included in the comparison. Direct field cost for nuclear quarrying was \$9,400,000, compared to

\$7,743,000 for a conventional rockfill dam, and \$9,040,000 for a thin-arch concrete dam. Nuclear throwout and retarc damming, although not included in the cost analysis, would have cost considerably more than the nuclear quarrying technique. Some project personnel noted that as the size of a dam increased, the lower the cost differential between nuclear quarrying and conventional rockfill damming strategies. So, theoretically, nuclear quarrying would be financially advantageous at a larger dam site.

In January 1970 at the Symposium on Engineering with Nuclear Explosives in Las Vegas, Nevada, three papers were presented on Project Aquarius. The papers indicate that no final decisions on Aquarius had been made at that time. Although, the report on the Aquarius Study was to be completed by June 30, 1969, the date for completion of the feasibility study report was extended. This report reiterated the cost differential favoring conventional dam construction, identified tritium contamination of the water as the major safety issue, and expressed engineering concerns regarding the feasibility of sealing throwout or landslide dams. In January 1970, Lawrence Radiation Laboratory suggested that more nuclear experiments and engineering studies needed to be conducted to obtain data to resolve these issues.

The U.S. Atomic Energy Commission issued a Plowshare Program Statement on March 5, 1970, as part of Congressional authorization hearings. In this presentation, it was noted that the Aquarius study was nearly complete and that no project was currently being contemplated. This contrasted sharply with the discussions of other Plowshare projects and their potential for additional research. Apparently, a decision had been made by this date that Aquarius would not be pursued any further. The project ceased sometime later in 1970, based on this comment and the absence of documentation after early 1970.

Aquarius was a Level 4 activity. Field activity was confined to visual inspections of project locations and obtaining data from existing wells.

**CROSS SECTION-NUCLEAR QUARRY**  
**15 KT DEVICE**

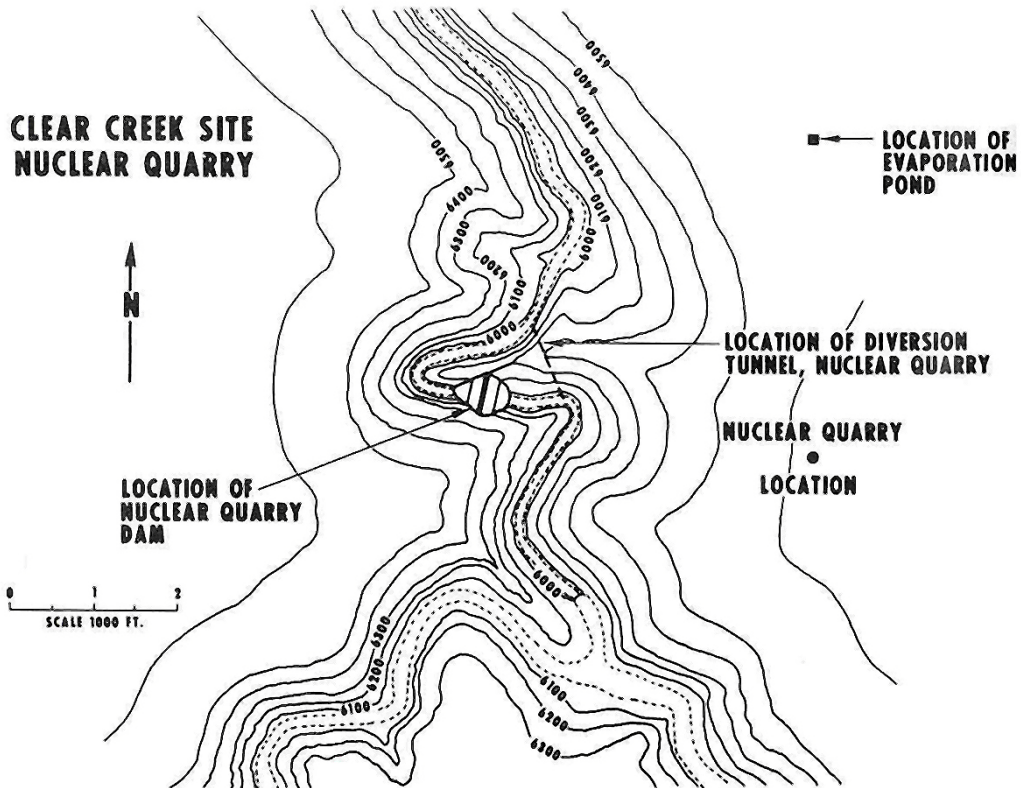
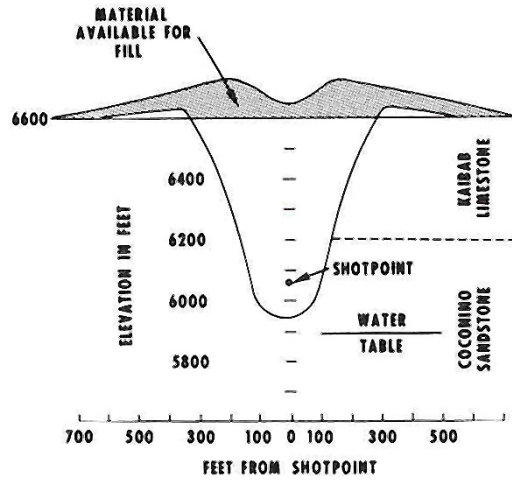


Figure 4.1-3. Cross section and location for the Clear Creek Site nuclear quarry dam (Griffin 1970a, Figures 3 and 4).

**CLEAR CREEK SITE  
CROSS SECTION-THROWOUT DAM  
100 KT DEVICE**

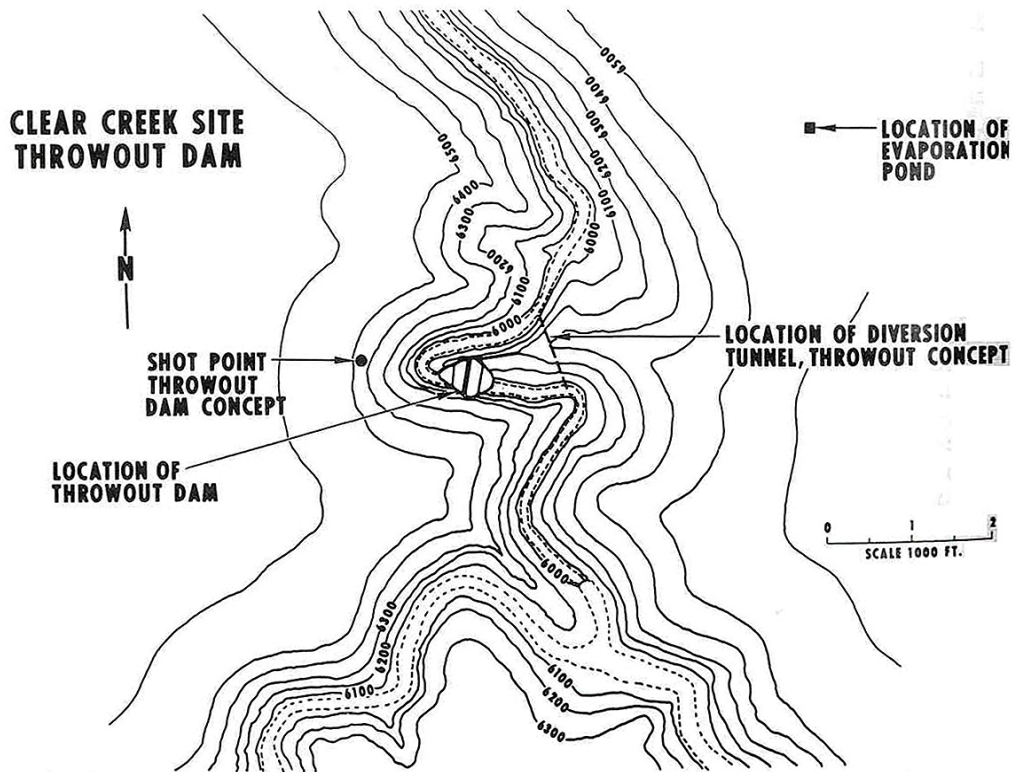
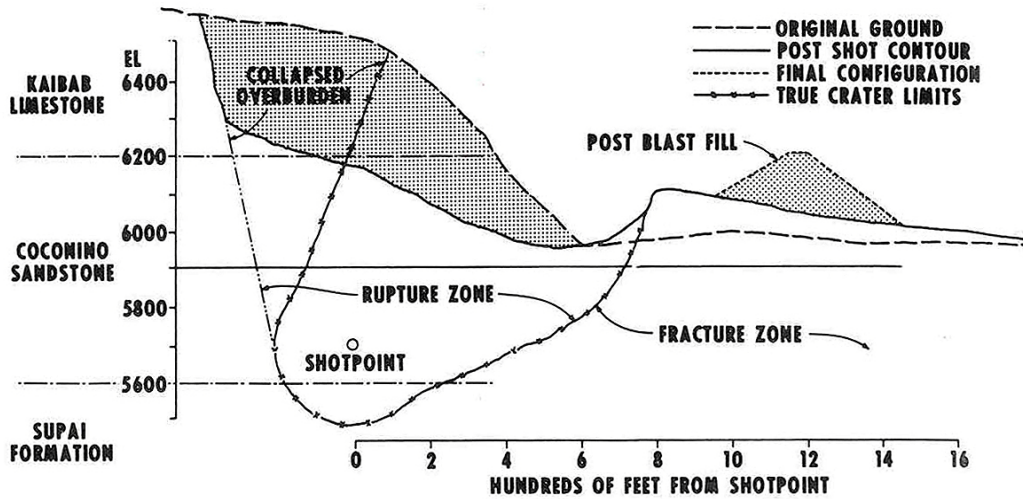


Figure 4.1-4. Clear Creek Site cross section and throwout dam (Griffin 1970a, Figures 5 and 6).



## CHRONOLOGICAL BIBLIOGRAPHY

- Tomei, Lawrence R., 1964. Letter from Lawrence R. Tomei to Mr. Nolan, U.S. Geological Survey, June 3. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.
- Leeson, Edward R., 1964. Letter from Edward R. Leeson to Lawrence R. Tomei, July 29. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.
- Curtis, Harold B., 1966. "Ralph M. Parsons Company Meeting." Memo from H. B. Curtis, U.S. Atomic Energy Commission, San Francisco Office, to John F. Philip, November 2. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-001.
- Curtis, Harold B., 1966. "Atomic Energy Commission Visit." Memo from H. B. Curtis, U.S. Atomic Energy Commission, San Francisco Office, to John F. Philip, December 15. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-001.
- Werth, Glenn C., [between 1966 and 1973]. Handwritten notes on Plowshare program meetings from Glenn C. Werth, U.S. Atomic Energy Commission, Division of Peaceful Nuclear Explosives, 1966-1973. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-118.
- Philip, John F., 1967. Letter from John F. Philip, U.S. Atomic Energy Commission, San Francisco Operations Office, to Glenn C. Werth, January 6. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-001.
- Curtis, Harold B., 1967. "Visit with Arizona Atomic Energy Commission Representatives in Phoenix and Tucson, 3/17 and 3/20." Memo from H. B. Curtis, U.S. Atomic Energy Commission, San Francisco Office, to John F. Philip, April 3. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-001.
- Philip, John F., 1967. Letter from J. F. Philip, U.S. Atomic Energy Commission, San Francisco Office, April 7, to Glenn C. Werth. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-001.
- Arizona Daily Star, 1967. Nuclear Water Pits Sought For State. *Arizona Daily Star*, Section B, p. 1, June 17. Tucson, AZ. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.
- Tucson Citizen, 1967. Atom Blast for Water Basin Probed. *Tucson Citizen*, June 17, Tucson, Arizona.

- Philip, John F., 1967. Letter from John F. Philip, U.S. Atomic Energy Commission, San Francisco Operations Office, to Glenn C. Werth, September 6. On file at Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-001 and PLO-109.
- Nordyke, Milo D., 1967. "Arizona Water Resources Project." Memo from Milo Nordyke, Lawrence Radiation Laboratory, to Gary Higgins and Glenn Werth, October 30. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-001.
- Hague, Richard S., 1967. "Highlights of the AAEC/University of Arizona Visits to SAN/LRL – October 20, 1967 and NTS November 3, 1967." Memo from Richard S. Hague, U.S. Atomic Energy Commission, San Francisco Operations Office, to John F. Philip, November 21. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-001.
- Philip, John F., 1967. "Status Report – Arizona AEC/University of Arizona Plowshare Study of Water Resources Management." Memo from John F. Philip, Atomic Energy Commission, San Francisco Office, to Robert E. Miller, et al., November 22. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-001.
- Trenholme, William M., 1967. Letter from William M. Trenholme, State of Arizona Atomic Energy Commission, to John F. Philip, November 27. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-001.
- Nadolski, M. E., and C. R. Boardman, 1967. "Arizona Water Management and Nuclear Craters." Memo from M. E. Nadolski and C. R. Boardman, Lawrence Radiation Laboratory, to Distribution, November 30. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-109.
- Philip, John F., 1967. "Arizona Atomic Energy Commission Water Resources Management Project." Letter from John F. Philip, U.S. Atomic Energy Commission, San Francisco Operations Office, to Glenn C. Werth, December 15. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-001.
- Philip, John F., 1967. "Arizona Atomic Energy Commission Preliminary Report on Water Resources Management." Letter from John F. Phillip, Special Projects Division, U.S. Atomic Energy Commission, San Francisco Office to W. S. Twenhofel, December 15. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-001.

- Nordyke, Milo D., 1968. Letter from Milo D. Nordyke, Lawrence Radiation Laboratory, to John Philip, January 22. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-001.
- Seaborg, Glenn T., 1968. The Progress of the Peaceful Atom. Paper presented at the Governor's Industrial Safety Conference, February 7, 1968, San Francisco, California. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Las Vegas, NV, Accession No. NV0148558.
- McCool, W. B., 1968. "Atomic Energy Commission Status of Plowshare Industrial Projects." Memo with encl. ("Status of Plowshare Industrial Projects," memo from John S. Kelly, U.S. Atomic Energy Commission, Division of Peaceful Nuclear Explosives, to List) from W. B. McCool, U.S. Atomic Energy Commission to Distribution, April 26. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029 [OUO].
- Williams, Jack, 1968. Letter from Jack Williams, Office of the Governor, Phoenix, Arizona, to Glenn T. Seaborg and Stewart Udall, May 8. On file at: Nuclear Testing Archive, Nevada Site Office, National Security Administration, Las Vegas, NV, Accession No. NV0075926.
- Johnson, W. E., 1968. Letter from W.E. Johnson, U.S. Atomic Energy Commission, to J. Williams, Governor, State of Arizona, May 20. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0075927.
- U.S. Atomic Energy Commission. Nevada Operations Office, 1968. Press Release from U.S. Atomic Energy Commission, May 31. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0325209.
- U.S. Atomic Energy Commission. San Francisco Operations Office, 1968. Press Release from U.S. Atomic Energy Commission, May 31. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.
- Trenholme, William M. and Harold. B. Curtis, 1968. Summary of First Federal-State Meeting on the Aquarius Study, June 25, 1968, Phoenix, Arizona. Report from William M. Trenholme, Arizona Atomic Energy Commission; and Harold B. Curtis, San Francisco Operations Office, July 16. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0161036.
- Rabb, David D., 1968. Plowshare Program, May 1, 1968 – July 31, 1968, Vol. II, No. 1. University of California, Lawrence Radiation Laboratory, *Report UCRL-50008-68-3*, July 31. Livermore, CA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030 [OUO].

- Werth, Glenn C., 1968. "Plowshare Program Status Report." Notes from Glenn C. Werth, Division of Peaceful Nuclear Explosives, U.S. Atomic Energy Commission, September. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-118.
- U.S. Atomic Energy Commission, 1969. Chapter 11 - Peaceful Nuclear Explosions. In *Annual Report to Congress of the Atomic Energy Commission for 1968*, pp.195-202, January. U.S. Government Printing Office, Washington, D.C.
- U.S. Atomic Energy Commission. Nevada Operations Office, 1969. Press Release from U.S. Atomic Energy Commission, to Editors and Correspondents, March 27. On file at Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0325552.
- Arizona Atomic Progress, 1969. Progress on Aquarius Study. *Arizona Atomic Progress*, Vol. 2, No. 1, April 1. Phoenix, AZ. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. 0194664.
- U.S. Atomic Energy Commission, 1970. Chapter 11 - Peaceful Nuclear Explosives. In *Annual Report to Congress of the Atomic Energy Commission for 1969*, pp. 195-203, January. U.S. Government Printing Office, Washington D.C.
- Nordyke, Milo D., 1970. Letter from Milo D. Nordyke, Lawrence Radiation Laboratory, to Fred J. Clark, January 8. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-001.
- U.S. Atomic Energy Commission, 1970. "Plowshare Program Statement, JCSE FY 1971 Authorization Hearings."Statement from U.S. Atomic Energy Commission, March 5. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-028.
- Ganus, William J., 1970a. Geohydrological Investigations. In *Symposium on Engineering with Nuclear Explosives: Proceedings*, Report CONF-700101, Vol. 2, pp. 1174 - 1183, May. American Nuclear Society, Hinsdale, IL.
- Ganus, William J., 1970b. Project Aquarius - Geohydrological Investigation. In *Symposium on Engineering with Nuclear Explosives: Summaries*, pp. 84-85, May. American Nuclear Society, Hinsdale, IL.
- Griffin, Roger F., 1970a. Aquarius Study - Engineering and Economic Considerations. In *Symposium on Engineering with Nuclear Explosives: Proceedings*, Report CONF-700101, Vol. 2, pp. 1184-1197, May. American Nuclear Society, Hinsdale, IL.

- Griffin, Roger F., 1970b. Aquarius Study - Engineering and Economic Considerations. In *Symposium on Engineering with Nuclear Explosives: Summaries*, p. 85, May. American Nuclear Society, Hinsdale, IL.
- Post, Roy G., 1970. Project Aquarius: Control of Radioisotopes and Safety. In *Symposium on Engineering with Nuclear Explosives: Proceedings*, Report CONF-700101, Vol. 2, pp. 1174-1183, May. American Nuclear Society, Hinsdale, IL.
- Post, Roy G., 1970. Project Aquarius - Control of Radioisotopes and Safety. In *Symposium on Engineering with Nuclear Explosives: Summaries*, p.84, May. American Nuclear Society, Hinsdale, IL.
- U.S. Atomic Energy Commission, 1970. *Plowshare Program During 1969: Based on the Annual Report to Congress for 1969 of the U.S. Atomic Energy Commission*. U.S. Atomic Energy Commission, U.S. Government Printing Office, Washington, D.C. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV.
- Whan, Glenn A., 1973. Plowshare Technology Assessment, Final Report, Implications to State Governments. Report to the Western Interstate Nuclear Board, Lakewood, CO, from Glenn A. Whan, Chemical and Engineering Department, University of New Mexico. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV.
- Shafer, David S., William. C. Beck, Dwight Treadwell, and Stephen. A. Mellington, 1995. Inventory of Potential Environmental Restoration Liabilities Associated with Plowshare And Vela Uniform Program Sites. Manuscript, U.S. Department of Energy, Office of Environmental Restoration. On file at: Desert Research Institute, Las Vegas, NV.
- U.S. Department of Energy. Nevada Operations Office, 1997. Plowshare Program Executive Summary. Report from U.S. Department of Energy, December 22.
- U.S. Department of Energy. Nevada Operations Office, n.d. The Plowshare Program (Draft). Report from U.S. Department of Energy.

**THIS PAGE INTENTIONALLY LEFT BLANK**

## **4.2 BOCA BYPASS**

### **Plowshare Program Nuclear Excavated Railroad Cut California**

In the early 1960s, a study group comprised of personnel from the Bechtel Corporation, the Southern Pacific Railroad, and Lawrence Radiation Laboratory, and U.S. Army Engineer Nuclear Cratering Group undertook a preliminary analysis of using nuclear excavation applications to improve railway alignments of the Southern Pacific. The Bechtel Corporation suggested the use of nuclear explosives to excavate railroad cuts and the Plowshare Division at Lawrence Radiation Laboratory was interested because the project might provide a suitable demonstration of large-scale excavation using explosive means. Specifically, the group met to evaluate the possibility of using nuclear explosives to excavate cuts through mountainous or precipitous terrain to provide route alternatives that would improve sections of the main track. In an October 1962 report, "Use of Nuclear Explosives to Improve the Railroad Alignment on the Southern Pacific System," a number of locations were examined (Table 4.2-1), but none were considered economically feasible using nuclear construction.

In November 1962, however, the study group reconvened to reassess a project that would realign a section of track near Boca, California, north of Lake Tahoe. The study group prepared a report that evaluated the use of nuclear explosives to excavate a cut for the Southern Pacific Railroad in an area south of Boca (Figure 4.2-1). An existing 32,000 ft of railroad track along the Truckee River was in need of extensive repairs. The proposal advocated the use of a series of nuclear explosives to produce a linear crater with a maximum depth of 440 ft in an igneous rock medium. The excavated cut would provide a route that eliminated a loop along the Truckee River, thereby bypassing the town of Boca and reducing current track length by 16,000 ft or a little more than 3 miles (Figure 4.2-2). The study group estimated that the return on investment would be sufficient to make the project economically feasible. The tentative schedule for the project listed a July 1963 start date. First, experimental studies would be conducted at the Nevada Test Site to simulate conditions for the bypass. Actual excavation of the bypass corridor would be accomplished in two phases. Low yield nuclear row-charge blasting would begin at the Boca project site in July 1964. Higher yield detonations would follow and continue until July 1965. Construction of the bypass was scheduled to be completed by July 1966. According to the proposal, the nuclear excavation of the cut would be under the technical direction of the Lawrence Radiation Laboratory. Southern Pacific Railway would be responsible for right-of-way and conventional excavation as well as construction of the railroad bypass including ballast, track, two bridges, and signal facilities. The Bechtel Construction Company would assist with engineering aspects of the project. Finally, the project would require approval by the U.S. Atomic Energy Commission.

There is no documentation available to suggest how the preliminary investigation was received. However, the project concept for Boca Bypass was being studied at the same

time as Carryall, a project for using nuclear explosives to excavate a cut for both highway and railroad construction in southern California (see Chapter 4.7). At one point, Project Carryall was thought to have a good chance of being the first nuclear excavation demonstration.

Table 4.2-1. Railroad Route Alternatives Examined in 1962 for a Possible Plowshare Project

<b>Division</b>	<b>Location</b>	<b>Description</b>
Salt Lake	Vicinity of Parran, NV, to vicinity of Battle Mountain, NV	Cut through Stillwater Range
Sacramento	Between Truckee River and Crystal Lake in CA, and south of Boca, CA	Cut a bypass to the south of present route between Truckee and Crystal Lake, and decrease route distance by cutting off loop between Boca and Floreston (Boca Bypass)
San Joaquin	Vicinity of Tehachapi Mountains, CA	Alternate route from current routing over Tehachapi Pass
Los Angeles	Beaumont, CA	Lower elevation of the summit and decrease grade at Beaumont
Tucson-Rio Grande	Gila Mountains, east of Yuma, AZ	Reduce route distance by cutting a pass through the Gila Mountains
Tucson-Rio Grande	Mescal, AZ	Relocation of the route to lower summit and decrease grade
Tucson-Rio Grande	Vicinity of Dragoon, AZ	Lower elevation of the summit and decrease grade
Tucson-Rio Grande	Steins, NM	Lower elevation of the summit and decrease grade
Coast	Santa Margarita, CA	Lower elevation of the summit
Coast	Lompoc Peninsula, CA	Relocate line to circumvent Vandenberg Air Force Base
Shasta Division	Vicinity of Sage Hen, CA	Lower summit, decrease grade and shorten route
Northwest Pacific	Willits, CA	Lower summit and decrease grade near Willits

The review of the archival documents for the Boca realignment revealed some confusion in the correct name for the proposed project. In a 1964 document from the U.S. Atomic Energy Commission, the use of nuclear explosives to realign a segment of the Southern Pacific Railroad through 'Boca Pass' appears as a possible nuclear excavation project.



The name 'Boca Pass' also appears on a list of potential locations for nuclear excavation projects in summary documents issued by Sandia Laboratories and the Lawrence Radiation Laboratory dating to 1969 and 1970. Boca Pass is not a geographic place and was likely mistakenly abbreviated, slightly altering the project concept from a bypass of the railroad south of Boca to realignment through 'Boca Pass.'

Boca Bypass was a Level 5 activity. Activity for this project was limited to conceptual design, background research based on existing data, and possibly visual examination of the proposed project area.



Figure 4.2-1. Location of the proposed Boca Bypass railroad project (adapted from USA Relief Maps 2004).

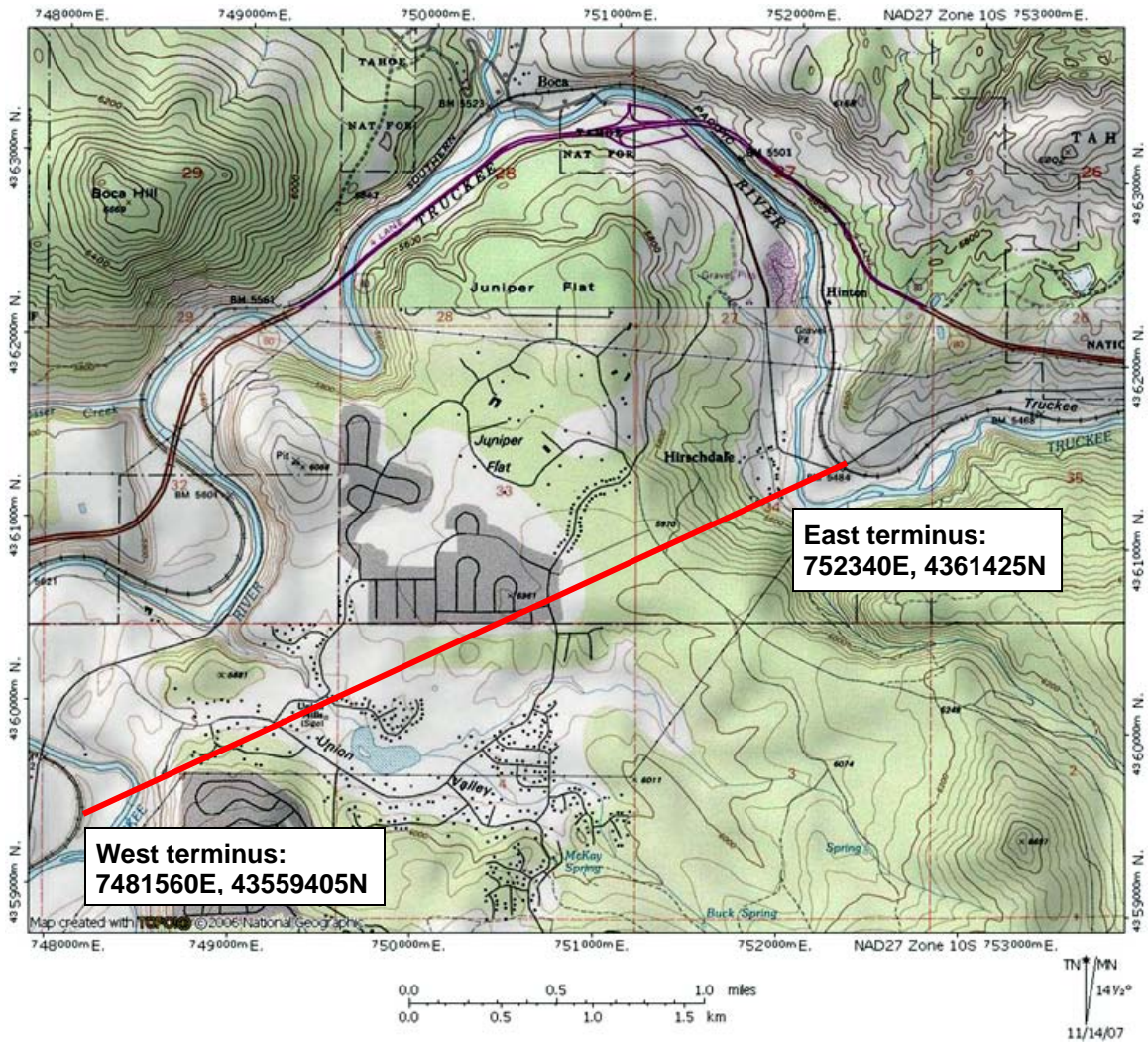


Figure 4.2-2. Map showing the proposed realignment for the Boca railroad bypass. UTM coordinates are provided for both ends of the bypass (adapted from National Geographic Topographic Maps 2006).

## CHRONOLOGICAL BIBLIOGRAPHY

Dickinson, Wade, 1962. Letter with encls. (memo from Wade Dickinson, Bechtel Corporation, to W. K. Davis; and “Use of Nuclear Explosives to Improve the Railroad Alignment on t he Southern Pacific System,” report from Bechtel Corporation) from Wade Dickinson, Bechtel Corporation, San Francisco, CA, to Milo Nordyke, October 29. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-100.

- Gallacher, Barney, Wade Dickinson, Ray Walker, Harlan Zodtner, and Louis Circeo, 1962. Preliminary Investigation, The Use of Nuclear Explosives for the Excavation of the Boca Bypass. Report from Southern Pacific Railway, Bechtel Construction Company, and Lawrence Radiation Laboratory, September 13. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-100.
- U.S. Atomic Energy Commission, 1964. Suggested Nuclear Excavation Projects. Manuscript, Division of Peaceful Nuclear Explosives, July. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.
- Vortman, L. J., 1969. Nuclear Excavation. Report, SC-DC-69-1716, Underground Physics Division, Sandia Laboratories, Albuquerque, NM, March. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-104.
- Toman, John, 1970. Summary of Nuclear-Excavation Applications. Paper prepared for Proceedings of the ANS Topical Meeting, Engineering with Nuclear Explosives, Las Vegas, Nevada, January 14-16, 1970. University of California, Lawrence Radiation Laboratory, *Preprint UCRL-72220*, January 29. Livermore, CA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-104.
- Toman, John, 1970. Summary of Nuclear-Excavation Applications. In *Symposium on Engineering with Nuclear Explosives: Proceedings*, Report CONF-700101, Vol. 1, pp. 245-279, May. American Nuclear Society, Hinsdale, IL.

**THIS PAGE INTENTIONALLY LEFT BLANK**

## **4.3 BO-PEEP**

### **Plowshare Program Nuclear Explosives for Petroleum Stimulation California**

Northern California was the proposed location for Project Bo-Peep. The purpose was to stimulate liquid petroleum production in oil shale in Humboldt County, California (Figure 4.3-1), through the use of a nuclear explosive. This project was first presented during a meeting at the Nevada Operations Office on March 18, 1966. The proponents were industry representatives, B.G. McCabe, President of Magma Power Company (with an associate), B.P. Bayliss, Chief Geological Engineer for Lloyd Corporation, Ltd., and M.M. Bell of Hazleton Nuclear Science Corporation. They met with W.D. Smith, the Director of the Engineering and Construction Division at the Nevada Operations Office. The industrialists stated they controlled 36,000 acres of land in Humboldt County with subsurface deposits of oil shale extending from near surface to a depth of 4,000 ft. Testing of the deposit consisted of one core hole that had been bored and logged. They were interested in using a 10 kt nuclear explosive to fracture the shale, thereby releasing oil that could be pumped to the surface and this group was prepared to invest one to two million dollars to field the project.

Five months later, on August 17, 1966, Gary Higgins of the Lawrence Radiation Laboratory, sent a letter to B.C. McCabe, that described the results from a very preliminary analysis of the possibility of using nuclear explosives to stimulate oil production in Southern Humboldt County. He explained that for a nuclear explosive 25 kt yield, there appeared to be no safety concerns from a radiological and seismic view point for the proposed project area. However, there was not sufficient information available to assess the technical feasibility of oil production. Drilling logs showed no well-defined production zones and the rock formation was very weak, crumbly, or plastic. The Lawrence Radiation Laboratory geologists determined from the data that either areas of drainage to the wells were small or there was very little free oil in the rocks. A nuclear stimulation project would not be successful if there is little oil or if a chimney formed by the explosive were filled with plastic, clayey material.

Higgins also explained that it was not possible to continue a technical assessment until the geologists understood whether or not the oil was coming from the matrix or from the fractures, and if from the fractures, they needed to know the fracture pattern. Based on existing data, the estimates of oil production for the field ranged from 12,000 to 120,000 barrels, a range in need of refinement. He concluded with a request for additional information. More data were needed in order to make a technical evaluation of the feasibility of the project. Higgins' data request contained eight queries, addressing the nature of the oil deposit. He pointed out that a single exploratory hole would be unlikely to answer the questions and that they did not know how many holes would be needed. He



Figure 4.3-1. Proposed location in California for Project Bo-Peep (adapted from USA Relief Maps 2004).

explained, when the data were available, Lawrence Radiation Laboratory could determine whether or not a nuclear stimulation experiment would be justified. He also indicated that a technical memorandum that covered the preliminary analyses would be sent to McCabe the following month. By the end of October 1966, the project had been named Bo-Peep and the Lawrence Radiation Laboratory was waiting for the additional data in order to proceed with the feasibility study. No additional information was located and there is no indication that the project proceeded beyond this stage.

Project Bo-Peep was a Level 5 activity.

## CHRONOLOGICAL BIBLIOGRAPHY

- Miller, Robert E., 1966. "Inquiries to NVOO Regarding Industrial Application of Nuclear Explosives." Memo from Robert E. Miller, U.S. Atomic Energy Commission, Nevada Operations Office, to List, March 23. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.
- Higgins, Gary H., 1966. Letter from Gary H. Higgins, Lawrence Radiation Laboratory, to B. C. McCabe, August 17.
- Rabb, David D., 1966. Plowshare Program, July 16, 1966 – October 31, 1966, V ol. II, No. 3. U niversity of California, Lawrence Radiation Laboratory, *Report UCRL-50008-66-2*, October 31. Livermore, CA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.
- Shafer, David S., William. C. Beck, Dwight Treadwell, and Stephen. A. Mellington, 1995. Inventory of Potential Environmental Restoration Liabilities Associated with Plowshare And Vela Uniform Program Sites. Manuscript, U.S. Department of Energy, Office of Environmental Restoration. On file at: Desert Research Institute, Las Vegas, NV.
- U.S. Department of Energy. Nevada Operations Office, 1997. P lowshare Program Executive Summary. Report from U.S. Department of Energy, December 22.
- U.S. Department of Energy. Nevada Operations Office, n.d. T he Plowshare Program (Draft). Report from U.S. Department of Energy.

**THIS PAGE INTENTIONALLY LEFT BLANK**



## 4.4 BRUNEAU CANYON DAM

### Plowshare Program Nuclear Explosives for Ejecta Dam Construction Idaho

In April 1966, following a request by the Nuclear Cratering Group, the U.S. Army Corps of Engineers North Pacific Division assigned the Walla Walla District to undertake a preliminary study concerning the use of nuclear explosives to construct a dam in the narrow Bruneau River canyon of southwest Idaho (Figures 4.4-1 and 4.4-2). The plan was to build a rock-fill ejecta dam using a bulk construction technique (Figure 4.4-3). With this method a single nuclear explosive would be emplaced in a location in the canyon that, when detonated, would result in production of an embankment by bulking the fractured rock to fill the canyon to the desired height. A bulk dam versus a slide dam approach was considered necessary because the Bruneau River is entrenched in a deep canyon and a slide dam, relying on gravity to form the dam embankment, would not produce a dam to the height of the canyon walls.



Figure 4.4-1. Bruneau Canyon (<http://www.visidaho.org/assets/photos/detail/BruneauCany2.jpg>, last accessed October 2007.)

During May 1967, calibration tests were conducted by the U.S. Army Engineer Nuclear Cratering Group at Lawrence Radiation Laboratory's High Explosive Test Facility, Site 300 to test the nuclear bulk dam approach. The results were summarized in a September 1967 report. The tests consisted of a series of 1 lb high explosives detonated in a moist concrete sand medium. Results suggested that placing an embankment across a narrow, steep-walled canyon using explosives could be accomplished, and the report concluded

that the concept was technically feasible. The laboratory results also demonstrated that a higher embankment could be produced by direct blasting techniques versus landslide techniques. The laboratory scale tests provided the basis for the design concept for the Bruneau Canyon Dam.

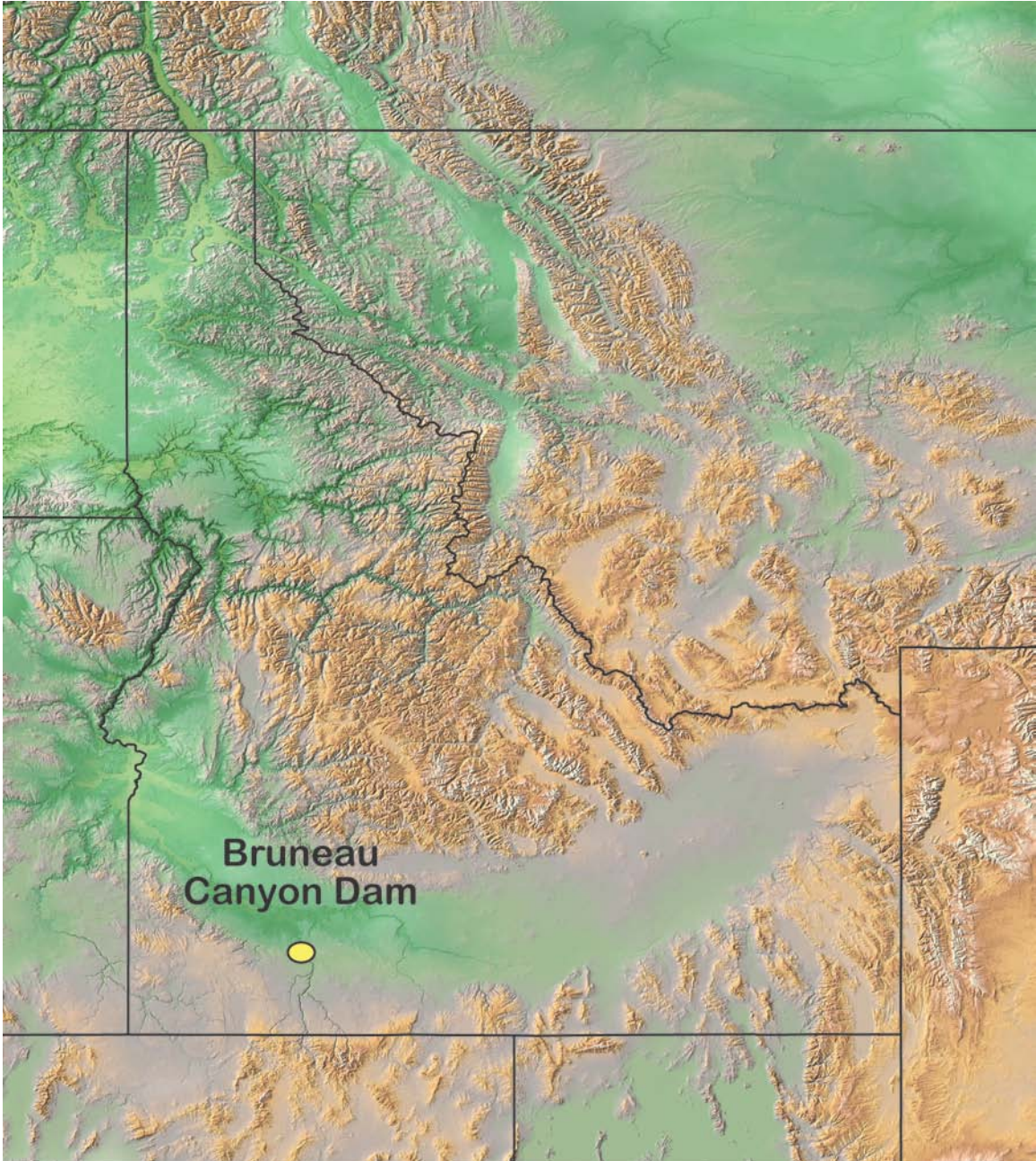


Figure 4.4-2. Location of proposed Bruneau Canyon Dam (adapted from USA Relief Maps 2004).

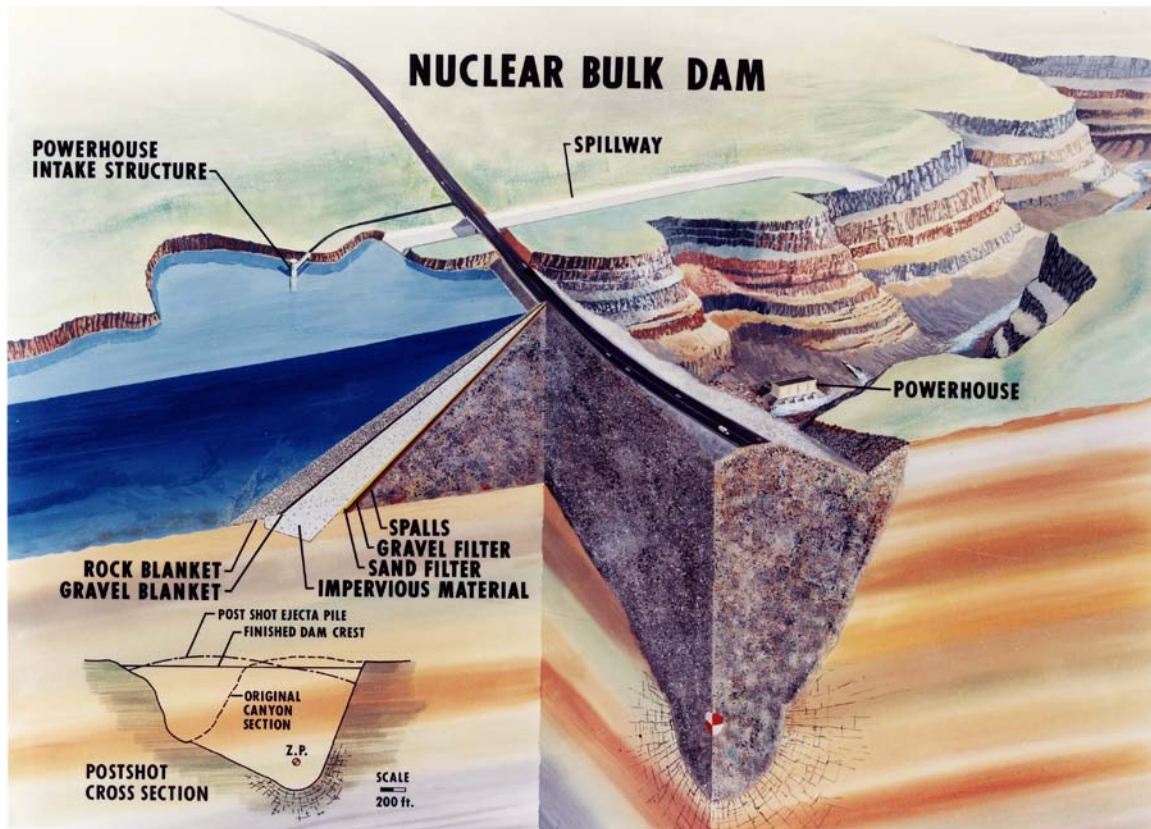


Figure 4.4-3. Schematic illustrating a dam constructed using a nuclear bulk method (Lawrence Livermore National Laboratory n.d.).

In November 1967, the U.S. Army Corps of Engineers, Walla Walla District issued the preliminary feasibility study for the project to the Nuclear Cratering Group. The Bruneau Canyon design concept included a nuclear constructed embankment dam, an unlined rock channel spillway, a diversion tunnel, outlet works, a power facility and the construction of an access road. The location selected for the project was at river mile 30.3 between the mouth of the East Fork at mile 38 and mile 26 where the river leaves the canyon area (Figure 4.4-4).

The feasibility study called for emplacing a 200 kt nuclear explosive in the east wall of the canyon. When detonated, the explosion would produce an estimated 40,682,000 cubic yards of rock-fill. After sufficient time elapsed, to reduce radiation hazard, conventional methods would be used to reconfigure the ejecta into the specified shape for the dam. Finally, an impervious zone would be constructed on the upstream face of the dam. According to the plan the completed dam would be 655 feet in height above the current river level, stretching 3,140 ft across the canyon with a maximum elevation of 3,625 ft above sea level (Figure 4.4-5). The feasibility study recommended that additional data be obtained to support the dam construction method. In particular, the report recommended chemical high explosive calibration tests, possibly in the vicinity of Bruneau Canyon, to assist in extending the concept from laboratory model tests to a nuclear prototype.

According to the study, additional data were needed in a number of areas including information about the impact of a nuclear detonation on the ground water system, projections of project dimensions, information about embankment settlement, and procedures to re-establish a channel through the explosively produced embankment for emergency measures.

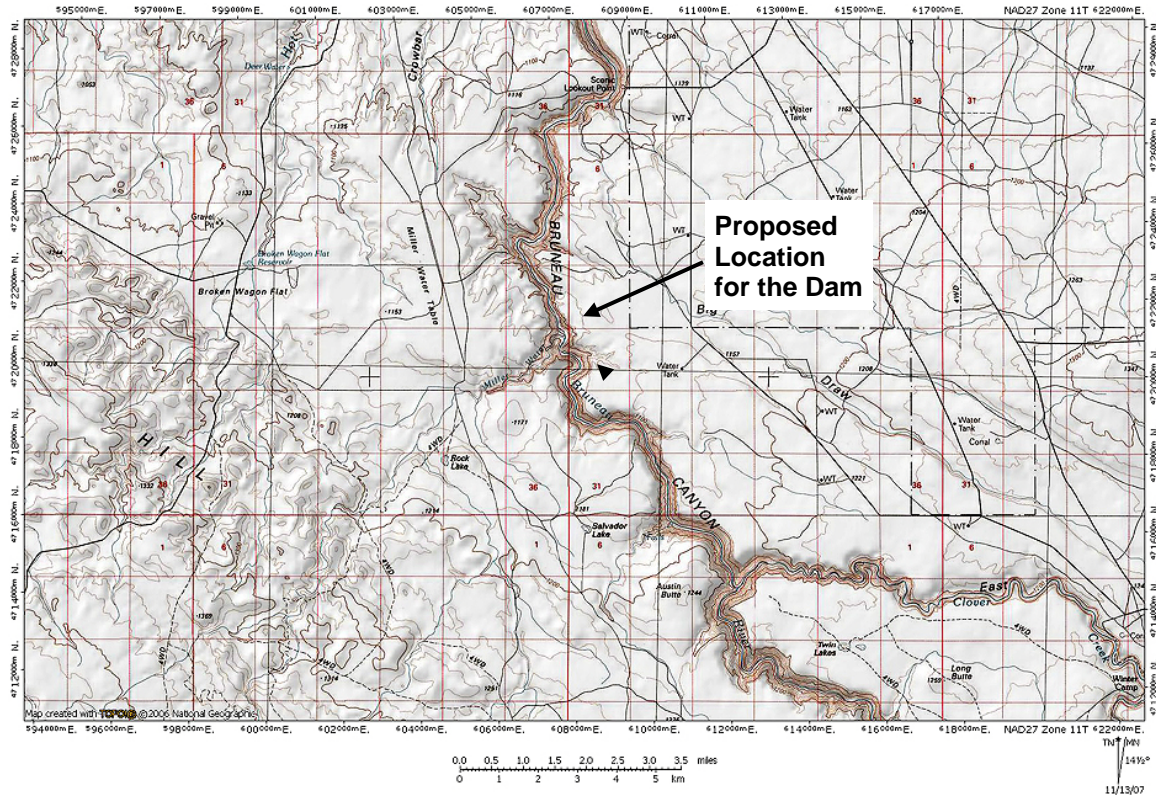


Figure 4.4-4. Proposed location for a dam on the Bruneau River (adapted from National Geographic Topographic Maps 2006).

The feasibility study also outlined economic benefits of the project for the Bruneau River basin. The proposed dam would provide a reservoir with a pool elevation of 3,600 ft above sea level and a storage capacity of approximately 515,000 acre-ft of water. If the water was used for irrigation, approximately 160,000 acre-ft would be available annually for the bench lands on the right bank of the river (Figure 4.4-6). If the dam was used for power production the initial generating capacity would be 22,432 kilowatts with an additional 67,317 kilowatt capacity installed in the future. The two different uses were not considered compatible because of the location of irrigable land, so each use was considered separately in the feasibility study. Other economic benefits of the dam were flood control and recreation development. An economic analysis found that the cost of building the dam using nuclear techniques would be substantially less than conventional ones; however, a benefit-to-cost analysis for irrigation or power generation indicated that the project did not appear to be economically feasible for construction.

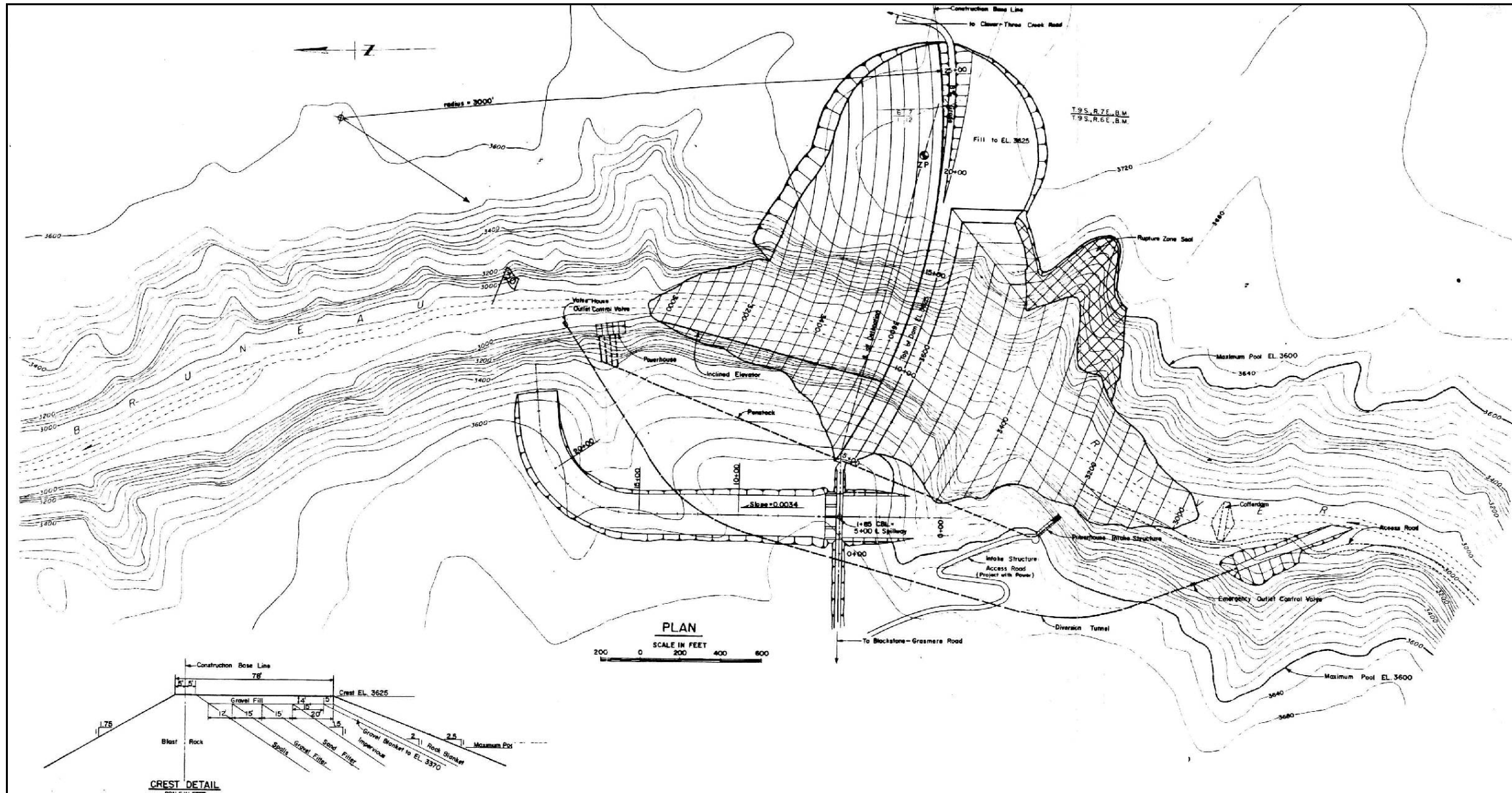


Figure 4.4-5. Plan view of the proposed Bruneau Canyon dam (U.S. Army Corps of Engineers. Walla Walla District 1967).

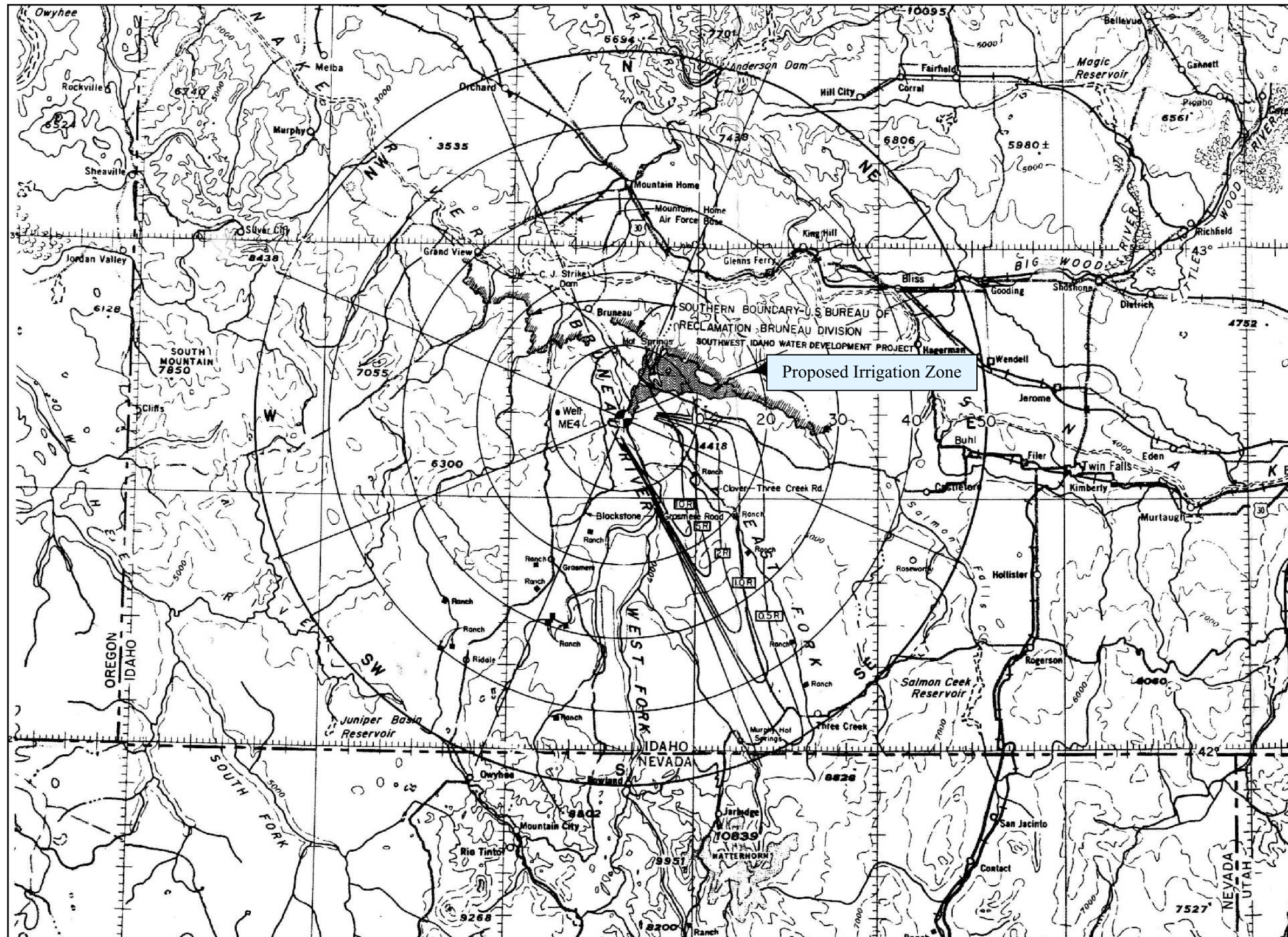


Figure 4.4-6. Location of the proposed dam in Bruneau Canyon showing the zone that would be irrigated by the project (adapted from U.S. Army Corps of Engineers. Walla Walla District 1967).

In the following year, during May 1968, letters from the Director of the Idaho Water Resources Board to the U.S. Army Corps of Engineers and to the U.S. Atomic Energy Commission show that the State of Idaho was interested in applying nuclear construction technology to accomplish water resource development projects in the state. Robert R. Lee, Director of the Water Resources Board, had heard about the study of a dam at Bruneau Canyon through the Bureau of Land Management and wrote to the Walla Walla District Engineer inquiring about the status of the project. He also wrote to the U.S. Atomic Energy Commission expressing interest in the Plowshare Program and possible projects in Idaho, including obtaining water for cultivation from the construction of a dam at Bruneau Canyon and a project to recharge the Snake Plain aquifers by diversion of flood flows. He requested information as to how the state should proceed to receive consideration for a Plowshare application.

During June 1968, personnel from the U.S. Army Engineer Nuclear Cratering Group and the Walla Walla District met with the Idaho Water Resources Board to present an overview of the Plowshare Program and nuclear excavation research. At this meeting, the attendees discussed possible construction projects in the State of Idaho, namely, the Twin Springs Dam project (Project Travois – Chapter 3.21), a nuclear quarrying experiment called Excavator (see Chapter 3.6), and the Bruneau Canyon Dam. Idaho representatives expressed interest in the prospects for development of the Bruneau Canyon region. However, representatives of the Nuclear Cratering Group explained that an economic analysis showed an unfavorable benefit to cost ratio for either an irrigation project or a power project and informed the meeting participants that a dam at Bruneau Canyon was no longer being studied for a nuclear construction application.

Bruneau Canyon Dam was a Level 5 activity. Work on the project included conceptual design and background research.

## **CHRONOLOGICAL BIBLIOGRAPHY**

- Kleist, Erwin H., 1967. Explosively Producing an Embankment across a Narrow, Steep-Walled Canyon. Lawrence Radiation Laboratory, U.S. Army Engineer Nuclear Cratering Group, *NCG Technical Memorandum* No. NCG/TM 67-14, September 28. Livermore, CA.
- Kleist, Erwin H. (editor), 1967. Nuclear Excavation Feasibility Study Construction of Rockfill Embankment for a Dam. Lawrence Radiation Laboratory, U.S. Army Engineer Nuclear Cratering Group, *NCG Technical Memorandum* No. NCG/TM 67-16, September 28. Livermore, CA. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV.

- U.S. Army Corps of Engineers. Walla Walla District, 1967. Bruneau Canyon Project: Feasibility Report on Nuclear Construction Methods. Report to U.S. Army Engineer Nuclear Cratering Group, Livermore, CA, from Walla Walla District, Walla Walla, WA, November. On file at: Engineer Research and Development Center Library, Vicksburg, MS [OUO].
- Hughes, Bernard C., 1968. "Status Report - Nuclear Explosives Studies for Civil Construction (RCS ENGCW-P-6 (R-1))." Letter with encl. ("Status Report, Effective Date: 31 December 1967") from Bernard C. Hughes, Lawrence Radiation Laboratory, U.S. Army Engineer Nuclear Cratering Group, to Chief of Engineers, Department of the Army, January 13. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.
- Lawrence Radiation Laboratory. U.S. Army Engineer Nuclear Cratering Group, 1968. Engineering Applications of Nuclear Explosives, Bi-Monthly Statistics of NCG Technical Reports, Memoranda, and Studies. Manuscript, February 15. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV.
- Lee, Robert R., 1968. Letter from Robert R. Lee, State of Idaho, Idaho Water Resource Board, to Colonel Robert J. Giesen, May 10. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.
- Lee, Robert R., 1968. Letter from Robert R. Lee, State of Idaho, Idaho Water Resource Board, to Glenn T. Seaborg, May 14. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.
- U.S. Atomic Energy Commission, 1968. Letter from Chairman, U.S. Atomic Energy Commission, to Robert R. Lee, May 28. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.
- Hughes, Bernard C., 1968, "Meeting with Director of Idaho Water Resource Board." Memo from Bernard C. Hughes, Lawrence Radiation Laboratory, U.S. Army Engineer Nuclear Cratering Group, to Record, June 11. On file at: Archives and Research, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029 [OUO].
- Lawrence Livermore National Laboratory, n.d. "Nuclear Ejecta Dam." Nuclear ejecta dam\_b drawing. Negative No. GLC-683-2152A. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA.



## **4.5 CADDO PINE ISLAND**

### **Plowshare Program High Explosives Experiment for Oil Stimulation Louisiana**

On April 24 and May 16, 1974, discussions began between Lawrence Livermore Laboratory, Cities Service Oil Company, and Bohannon Oil concerning a possible joint endeavor to conduct an experiment using high explosives to stimulate the recovery of oil from the Caddo Pine Island field. The Caddo field, in Caddo Parish, Louisiana, about 20 miles northwest of Shreveport, Louisiana (Figures 4.5-1 and 4.5-2), covered an area of approximately 27,000 acres and contained oil in a 150 foot thick chalk formation, the Annona Chalk, 1,400 feet below the ground surface. Since the first discovery well in 1905, less than 10 percent of the oil had been produced in place. The main problem was a combination of low permeability of the formation and low reservoir pressure. In 1972, Cities Service Oil Company conducted an unsuccessful one-ton explosive stimulation test. The experimental concept for Caddo Pine Island was to stimulate oil production by using high explosives to increase well bore radius and permeability outside the well bore.

In July 1974, a draft proposal circulated that outlined a program to evaluate the effects of a high explosive detonation on oil production. The experimental program would be implemented in three phases. The first phase involved drilling a conventional production well to obtain baseline data on the specific properties of the reservoir and its potential for oil production. In the second phase, the equivalent of 20 tons of TNT would be emplaced and detonated in a test well. After the detonation, the project's third phase would consist of a series of post-shot analyses and the emplacement well would be reentered to complete it as a production well and conduct production tests. Two additional holes would be drilled to evaluate the validity of the fracture predictions, and to assess post-shot effects on the reservoir and changes in production capability. For the Lawrence Livermore Laboratory the program would provide needed experimental explosive data and experience in carrying out high explosive field operations using slurry explosives. These types of explosives would most likely be used in coal, oil shale, and possible gas-bearing formations. Most importantly, this project provided experience in oil stimulation, a goal of the Plowshare Program.

In the following months meetings were held to review the experimental concept, contract arrangements, research by the laboratory on oil stimulation, and the project schedule. Meetings were held in August 1974 at the U.S. Atomic Energy Commission's San Francisco Operations Office, to discuss and identify interested and contracting parties. The issue was complicated as different sites within the oil field had different owners, lessees, and operators. It was agreed that a contract would be executed between the U.S. Atomic Energy Commission and Petrol Industries, Inc. to conduct the experiment with a separate agreement between Cities Service Oil Company and Petrol Industries. In

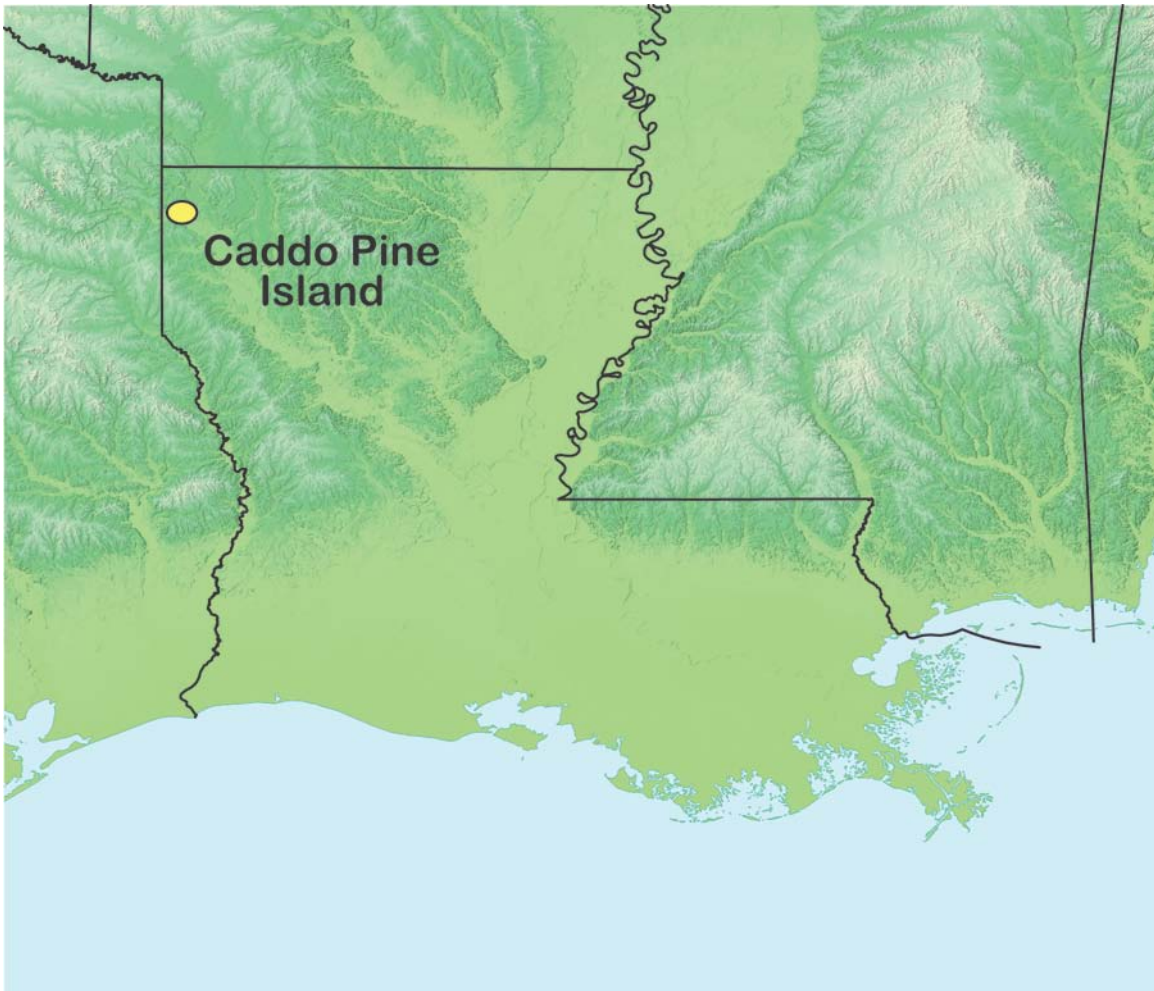


Figure 4.5-1. Location of the proposed Caddo Pine Island Project in northwestern Louisiana (adapted from USA Relief Maps 2004).

December 1974, there was a meeting in Shreveport, Louisiana, regarding the Energy Research and Development Administration (the successor agency to the U.S. Atomic Energy Commission) contract with Petrol Industries, and the only problem identified was Cities Services' issues with a patent assignment. The contract was expected to be signed by all parties by February 1, 1975, but patent issues remained unresolved, and by the end of March 1975, it was apparent that Cities Service and Petrol Industries would no longer participate in the oil stimulation project. Bohannon Oil expressed an interest in the project and a meeting was scheduled for early April to plan future actions. However, the death of a primary person at Bohannon Oil, as well as a lack of Energy Research and Development Administration policy regarding funds and support, postponed the project indefinitely. There is no documentation for the project after April 1975.

Caddo Pine Island was a Level 5 activity. Field activity for the project was confined to conceptual design, background research, and visual field inspections.

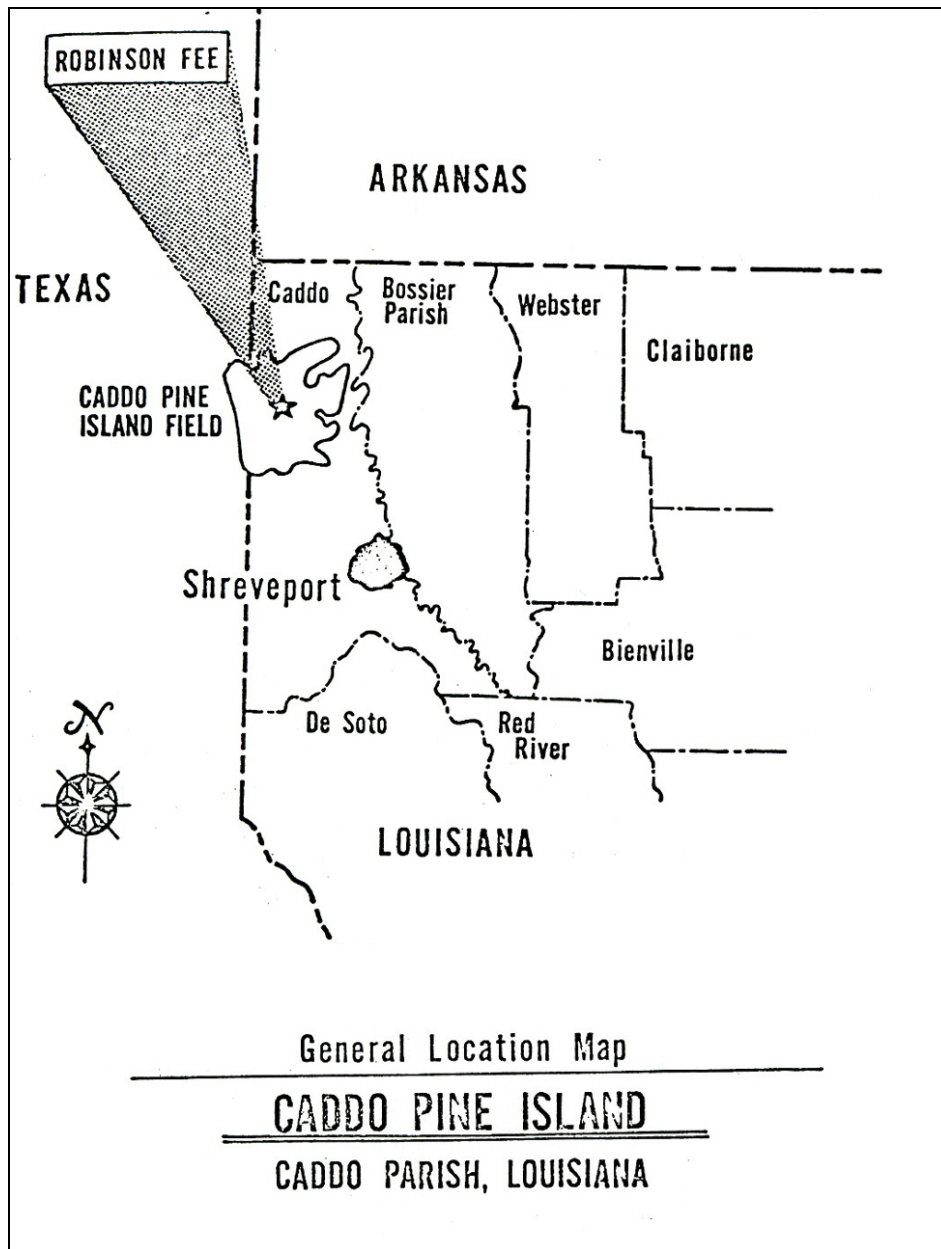


Figure 4.5-2. Map showing location of the Caddo Pine Island Field (General Location of Caddo Pine Island [1975]).

### CHRONOLOGICAL BIBLIOGRAPHY

Holzer, Fred, 1974. "Discussions with Cities Service Oil Company and Bohannon Oil on Oil Stimulation." Memo from Fred Holzer, Lawrence Livermore National Laboratory, to Distribution, June 6. On file at: Lawrence Livermore National Laboratory, Livermore, CA, File PLO-106.

- Cramer, James L., 1974. Caddo-Pine Island Oil Stimulation Proposal. Report from Lawrence Livermore Laboratory, Cities Services, and Energy Oil Corporation. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-106.
- Ballou, Lynden B., 1974. Letter with encl. ("Caddo Pine Island Oil Stimulation Project") from Lynden Ballou, Lawrence Livermore Laboratory, to Larry Brown, July 4. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-106.
- Hornig, Howard, 1974. "Explosive Stimulation of Oil Well by Taly-Frac Corp., Trip Report." Memo from Howard Hornig, Lawrence Livermore Laboratory, Chemical and Materials Science Department, to Distribution. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-106.
- Brown, Larry P., 1974. Letter with encl. ("Caddo Pine Island Oil Stimulation Project (revised draft)") from Larry P. Brown, Cities Service Oil Company, to Lynden Ballou, July 23. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-106.
- Cities Service Oil Company, 1974. Caddo Pine Island Stimulation Project. Agreement between Cities Service Oil Company, Lawrence Livermore Laboratories, and Energy Oil and Gas Corporation. On file at Archives and Research Center, Lawrence Livermore National Laboratories, Livermore, CA, PLO-106.
- Hughey, Robert W., 1974. "Meeting of LLL/SAN/Cities Service Oil Company on Proposed Joint Project in Louisiana on Oil Stimulation, August 9, 1974 a t LLL." Letter from Robert W. Hughey, U.S. Atomic Energy Commission, San Francisco Office, to Files, August 13. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-106.
- Hughey, Robert W., 1974. Meeting at SAN on Proposed Joint AEC/Industry Project in Louisiana for Oil Stimulation, August 26, 1974 - (Reference: Memo to Files by R. W. Hughes Dated August 13, 1974, R e: Meeting with Cities Service Company on August 9, S ame Subject)." Letter from Robert W. Hughey, U.S. Atomic Energy Commission, San Francisco Office, to Files, August 26. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-106.
- Ballou, Lynden B., 1974. Approximate Chronology of LLL Relationship with Cities Service Oil Company and Ross Bohannon and Associates. Report from Lawrence Livermore Laboratory, August 27. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-106.

- Bohannon, Ross, 1974. "Proposed Joint AEC-Industry Project in Louisiana for Oil Stimulation." Letter from Boss Bohannon, Energy Oil and Gas Corporation, to Edward H. Fleming, September 4. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-106.
- Brown, Larry P., 1974. Letter with encl. ("Caddo Pine Island Oil Stimulation Project") from Larry P. Brown, Cities Service Oil Company, to John Toman, September 25. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-106.
- Sisemore, Clyde, 1974. "Estimated Seismic Damage Range for the Caddo Pine Island Project." Memo from Clyde Sisemore, Lawrence Livermore Laboratory, to Distribution. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-106.
- Garbarini, Gail R., 1975. "Meeting at Petrol Industries, Inc., Shreveport, Louisiana, on Proposed Joint AEC/Petrol Project in Louisiana for Oil Stimulation, December 17 and 18, 1974." Letter from Gail R. Garbarini, U.S. Atomic Energy Commission, San Francisco Operations Office, to Files, January 3. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-106.
- Sisemore, Clyde, 1975. "Trip Report: Trip to Shreveport, Louisiana, to Discuss the Caddo Pine Island Oil Stimulation Experiment with Petrol Industries and City Services Inc." Memo from Clyde Sisemore, Lawrence Livermore Laboratory, to J. Kahn, January 9. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-106.
- Hughey, Robert W., 1975. "Meeting with Cities Service, Tulsa, February 11, 1975." Letter from Robert W. Hughey, U.S. Energy Research and Development Administration, San Francisco Operations Office, to File, February 21. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-106.
- Toman, John, 1975. Letter with encls. ("Proposed New Release on Lawrence Livermore Laboratory - Industry Proposed High-Explosive, Oil-Simulation Project in Louisiana," letter and release from William Gouse to Ben McCarty, February 11; "Contract No. AT(04-3)-1047;" "Appendix A, Scope of Work) from John Toman, Lawrence Livermore Laboratory, to John Kelly, March 11. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-106.
- Kelly, John S., 1975. "Discussion on the Caddo-Pine Island Proposal." Memo from John S. Kelly, Lawrence Livermore Laboratory, to John Toman, March 25. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-106.

- Heusinkveld, M., 1975. "Computer Calculations for the Caddo Pine Island Oil Stimulation Project." Memo from M. Heusinkveld, Lawrence Livermore Laboratory, to John Toman, March 31. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-106.
- Kelly, John S., 1975. "Discussions on C addo-Pine Island Oil Stimulation Proposal." Memo from John S. Kelly, Consultant to Lawrence Livermore Laboratory, to John Toman, April 3. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-106.
- Kelly, John S., 1975. "Developments on the Caddo-Pine Island Concept." Memo from John S. Kelly, Consultant to Lawrence Livermore Laboratory, to John Toman, April 8. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-106.
- Caddo Pine Island, [1975]. Caddo Pine Island report on plan to stimulate oil production. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-106.
- Caddo Pine Island Field Report, [1975]. Caddo Pine Island Field Report. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-106.
- General Location of Caddo Pine Island, [1975]. General location of Caddo Pine Island, Caddo Parish, Louisiana. Map. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-106.
- Petrol Industries, Inc., [1975]. Proposal for Drilling Program, Caddo Pine Island. Report from Petrol Industries, Inc. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-106.

## **4.6 CAPE DARBY HARBOR**

### **Plowshare Program Nuclear Excavation of a Harbor Alaska**

Cape Darby was one of four locations examined in the late 1950s for an experimental nuclear harbor excavation on the northwest Alaskan coast (also Cape Thompson, Nome – Chapter 4.26 and Point Barrow – Chapter 4.30). As part of the Plowshare program, Lawrence Radiation Laboratory was searching for an experiment to develop technology for nuclear excavation as well as investigate technical issues of harbor construction. In 1958, the E. J. Longyear Company from Minneapolis, Minnesota, was subcontracted to prepare a report on the economic mineral potential of northwestern Alaska in relation to possible deep water harbor locations. The development of mineral resources was identified as a goal in the economic development of the new state of Alaska. Most of the valuable mineral resources, namely, oil and coal, would require a harbor installation that could accommodate large ocean-going ships for transport of resources, as well as facilities for storage and loading.

The Longyear Company delivered their report in April 1958. Based on their analysis, the first choice for a harbor was at Cape Thompson and the second choice was a harbor at Cape Darby on the Norton Sound (Figures 4.6-1 and 4.6-2). A harbor at Cape Darby would serve the city of Nome as well as interior regions of Alaska. The shipping season at Cape Darby would be longer by several weeks than Cape Thompson, but the Norton Sound region, while having potential for mineral development, was more distant from the anticipated locations for the production of oil and coal. There was some expectation that 400 miles of oil pipeline could be run from the Arctic Slope to Cape Darby, but an overland haul of coal would not be economically viable. Prospective metal mines in the Noatak-Kobuk region could have transported metal to Cape Darby as cheaply as to Cape Thompson.

During the summer of 1958, scientists from the U.S. Atomic Energy Commission and Lawrence Radiation Laboratory, headed by Edward Teller, traveled to Alaska. At a series of meetings in Juneau and Anchorage, and at a conference in Fairbanks a number of nuclear excavation projects were discussed for Alaska, including a harbor near Nome or at Cape Darby. By the end of 1958, Cape Thompson was selected over Cape Darby for an experimental harbor excavation study—named Project Chariot. Forty separate pre-test environmental studies were undertaken for Project Chariot between 1959 and 1962, and the U.S. Geologic Survey conducted a tracer experiment in 1962. Studies and plans for Project Chariot were suspended in 1962 due to increasing public sentiment from local communities to discontinue the project. No documentation has been located that mentions Cape Darby as a possible location for nuclear excavation of a harbor after 1958.

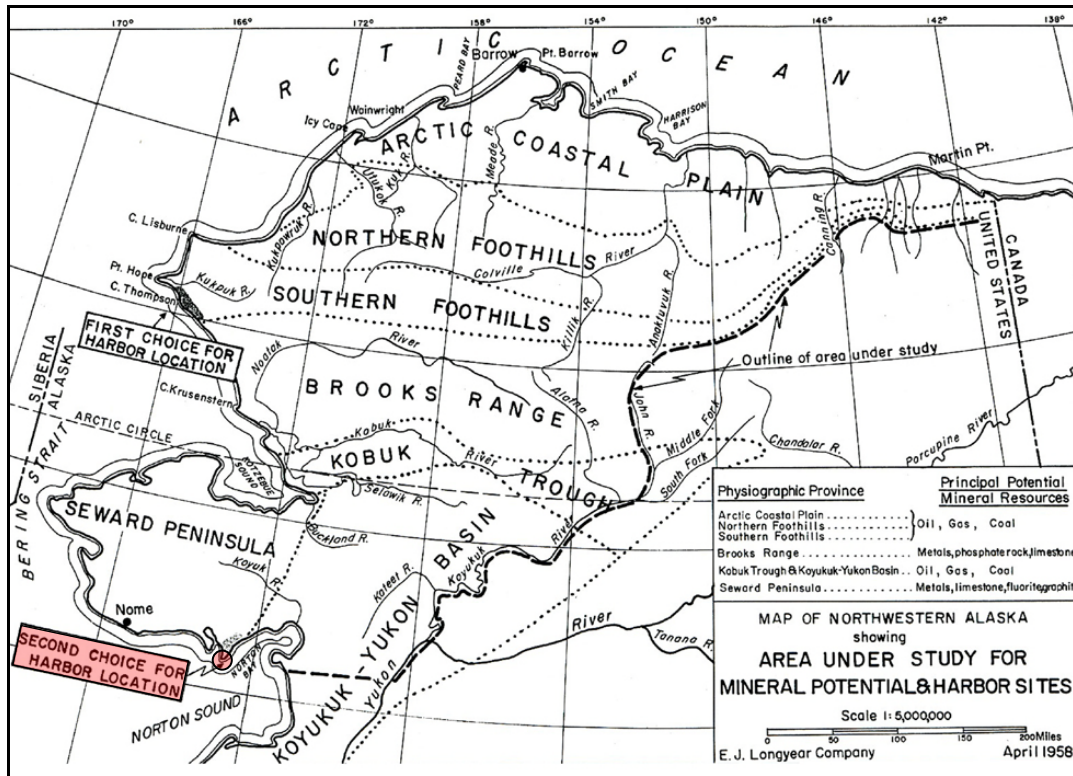


Figure 4.6-1. Map of northwestern Alaska showing area studied for harbor locations. Cape Darby was the second choice for a nuclear excavated harbor (adapted from E.J. Longyear Company 1958).



Figure 4.6-2. Location of proposed Cape Darby Harbor on Norton Sound (adapted from USA Relief Maps 2004).



Cape Darby was a Level 5 activity. Activity for the project was confined to background research.

### **CHRONOLOGICAL BIBLIOGRAPHY**

E. J. Longyear Company, 1958. The Mineral Potential and Proposed Harbor Locations in Northwestern Alaska. Report to University of California Radiation Laboratory from E. J. Longyear Company, April 18. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.

Anchorage Daily News, 1958. Atom Scientists Here Tell Plans to Blast Harbor. Anchorage Daily News, July 15. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.

Daily New Miner, 1958. Physicists Here For Discussion: Dam at Rampart, Harbors Along Arctic Possible. Daily New Miner, Vol. 36, July 16. Fairbanks, AK. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.

Daily New Miner, 1958. Alaska Can Have Massive Nuclear Engineering Job. Daily News Miner, July 17. Fairbanks, AK. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.

**THIS PAGE INTENTIONALLY LEFT BLANK**

## **4.7 CARRYALL**

### **Plowshare Program Nuclear Explosives Proposed for Highway and Railroad Construction California**

Project Carryall was a proposed nuclear excavation project that began in the early 1960s when the Atchison, Topeka, and Santa Fe Railway Company wanted to improve the railroad between Barstow and Needles in the Mohave Desert in California. In this area, the railroad did not go directly west, but curved south to avoid the Bristol Mountains. The existing route, besides being longer than a direct route, lost more than 1,000 ft of elevation into the Amboy-Cadiz area and then had to regain the altitude in order to realign with its western-traveling trajectory. Attempting to create faster schedules and decrease operating costs, the Atchison, Topeka and Santa Fe Railway Company was conducting preliminary studies for a new double track railroad through the Bristol Mountains, a route 15 miles shorter and 50 minutes faster. In order to build this new railroad, construction would involve major topographic changes. Under consideration were three alternatives: 1) a two-mile tunnel; 2) excavation through a large mountain with solid rock cuts up to depths of 500 ft; or 3) a 2.5-mile detour requiring heavy cuts and fills. The Atchison, Topeka and Santa Fe Railway realized these alternatives would be expensive with conventional methods and so the company approached the U.S. Atomic Energy Commission regarding using nuclear explosives for the construction.

At the same time, the State of California Division of Highways was working on upgrading the two-lane highway between Barstow and Needles to freeway standards for Interstate 40. As with the railroad route, the highway took a southerly detour around the Bristol Mountains and lost and gained 1,000 ft of altitude in a short distance. The Division of Highways proposed a 10-mile shorter alignment between Ludlow and Mountain Springs through the Bristol Mountains, about 13 miles north of the existing highway route through Amboy. The new route would address design gradients and other upgrades needed to meet the freeway standards, including increased vehicle speeds.

After the Atchison, Topeka and Santa Fe Railway approached the U.S Atomic Energy Commission, contact was made with the California Division of Highways regarding the possibility of a joint project between the railroad and the highway division for the nuclear excavation of a route through the Bristol Mountains. The California Division of Highways was interested in this proposal and two highway engineers and several railroad officials visited two nuclear testing craters at the Nevada Test Site to assess the compaction of soil and rock in order to determine the feasibility of nuclear excavation to highway and railroad projects. In the summer of 1963, a group was created to conduct the first-phase feasibility study. The California State Division of Highways, the Atchison, Topeka and Santa Fe Railway Company, the U.S. Atomic Energy Commission San Francisco Operations Office, and the Lawrence Radiation Laboratory were involved in the study group.

The first phase feasibility study was completed in November 1963 and determined that by shifting the proposed highway alignment south and the railroad to the north that both could utilize the same excavation area (Figure 4.7-1). The study area was in Sec. 10 through 13, T7N R11E, about 11 miles north of the small town of Amboy (Figure 4.7-2). The design to excavate a channel for the proposed route changes consisted of a row of 22 nuclear explosives. The excavation was planned in two stages, each consisting of 11 devices detonated simultaneously. The detonations would create a series of interconnected craters. The railroad required a lower gradient than the highway, so the railroad standards were used for planning purposes. Inside the channel, one direction of the divided highway would be along the bottom with the other direction slightly higher on the northern slope and the railroad on the southern slope (Figures 4.7-3 and 4.7-4). The channel would be 11,000 ft long to a maximum depth of 360 ft with a width ranging between 600 and 1,300 ft across the top. In order to achieve the construction design, Plowshare technology would involve detonating devices ranging in yield from 20 to 200 kt with a total yield of 1,730 kt, excavating approximately 68 million cubic yards of material. Also, a nuclear crater was proposed to serve as a detention basin for drainage from the Orange Blossom Wash, a major wash that crossed the proposed excavation channel (Figure 4.7-5). A conceptual model of the project appears in Figure 4.7-3.

The second phase would involve geological surface mapping, the determination of groundwater characteristics, and the drilling of four exploratory core-drill holes to verify the assumptions used in the preliminary feasibility study. Additional investigations were to include a study of the weather data for the region and a survey of the number and locations of all persons and structures in the area.

The third phase was to include more exploratory drilling at each location for the 23 emplacement holes (22 row charges and 1 crater for water detention) (Figure 4.7-6). Graded roads were to be constructed as well as leveled work zones at each charge location. The operational period was to follow the third phase. Operations would consist of pre-shot safety studies, the emplacement and firing of the devices, and post-shot safety. At the time of the detonations, a device assembly area would be required as well as an operational control area for up to 10 trailers. The device assembly area was envisioned as six 10 x 10 foot earth-covered igloos for storage of components and an assembly building with a 15-ton overhead crane. Communications would include three separate radio nets and a telephone system.

During the detonation, the U.S. Atomic Energy Commission would be responsible for public safety, on-site control, and radiological safety control during emplacement and detonation. It would be up to the U.S. Atomic Energy Commission to open the area for construction purposes after the detonations. Radiological safety also included the cloud resulting from the shots. It was expected that the cloud would obscure vision for the first 100 miles and any highways in the area would have to be closed during, and for some time after, the explosions. No negative effects were expected to occur in the town of



Figure 4.7-1. Location of Project Carryall in California (adapted from USA Relief Maps 2004).

Amboy, but there was concern the aboveground gas lines would be vulnerable to damage during the explosions. Using data from the Sedan test, it was estimated that post-shot work in the area could begin after four days. At that time, it was expected that conventional post-shot engineering of the channel would take place for the highway and railroad.

The cost estimate for the Atchison, Topeka and Santa Fe Railway Company to construct the originally proposed new railroad alignment and tunnel by conventional methods and the proposed highway route was 21.8 million dollars. The nuclear excavation method combined with conventional methods on the proposed new route alongside the mountain was estimated at 13.8 million dollars, but did not include the cost of building the nuclear

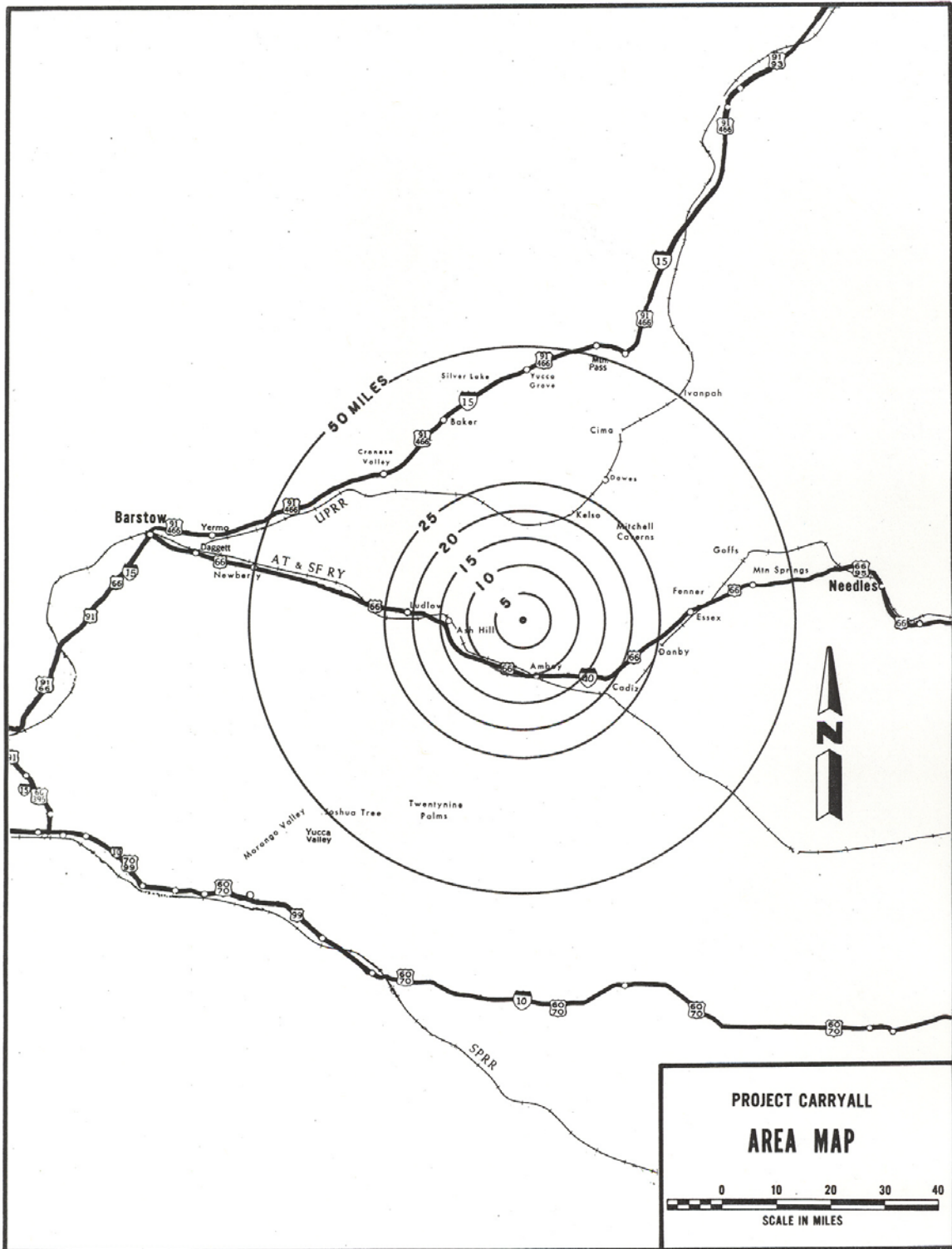


Figure 4.7-2. Area map for Project Carryall (after Prentice 1964, Figure 1).



Figure 4.7-3. Model of the proposed railway and highway cut (Fry et al. 1964, Figure 1).



Figure 4.7-4. Rendition of the completed Carryall Project (Lawrence Livermore National Laboratory n.d., Carryall-c).

explosives. If these channel excavations were done by conventional methods, it would have cost more than 50 million dollars.

The preliminary study concluded that the Carryall Project was feasible technically and that it could be done safely and within the timeframes needed by the Atchison, Topeka and Santa Fe Railway and the California Division of Highways. The nuclear approach was deemed economically beneficial with the assumption that the government's charges for the nuclear devices would be less than the 8-million dollar difference between nuclear and conventional excavation techniques.

In 1964, continuation of the project was under consideration by the U.S. Atomic Energy Commission, the California Division of Highways and the Atchison, Topeka and Santa Fe Railway. The schedule called for the location to be ready for the nuclear devices by 1965. The detonations were scheduled for early 1966; the engineering and final designs would follow with construction underway by 1968; and the highway and railroad functioning by mid-1969. However, in September of 1966, the U.S Atomic Energy



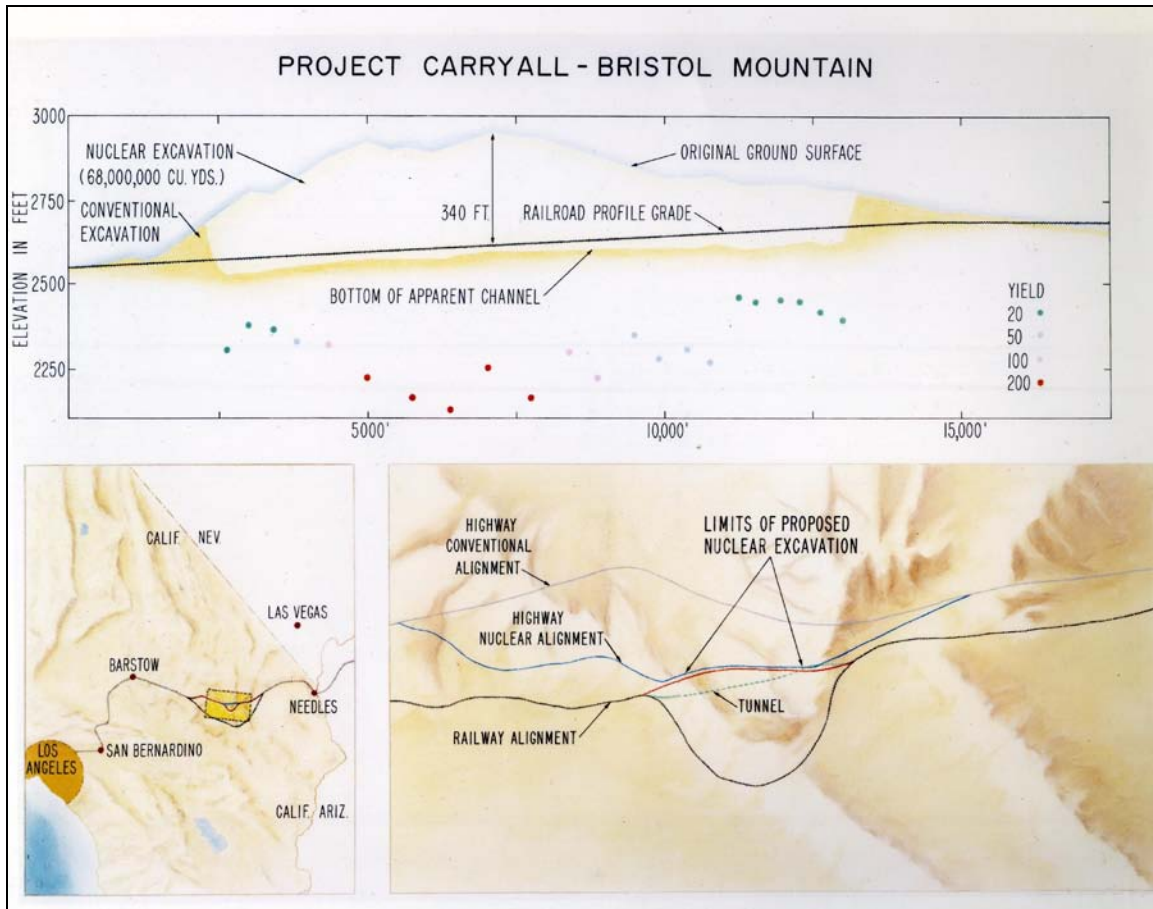


Figure 4.7-5. Project Carryall nuclear and conventional excavation plan (top and bottom right) and project location (bottom left) (Lawrence Livermore National Laboratory n.d.).

Commission announced that the California Division of Highways had decided to go ahead with freeway construction using conventional methods. The schedule for completing tests at the Nevada Test Site necessary for effective project execution was not compatible with the deadline for the interstate highway. Today, Interstate Highway 40 between Needles and Barstow follows a route that crosses the Bristol Mountains at a point approximately one mile north of the proposed Carryall route.

The Santa Fe Railway continued to express interest in the nuclear excavation method for the realignment of its railroad. In May of 1970, the Office of Peaceful Nuclear Explosives at the Nevada Operations Office expected that the next Plowshare excavation project would be a demonstration project, i.e., a practical application of nuclear excavation technology. Carryall was one of three projects mentioned as a possibility. It is not known exactly when the project was abandoned, but it is not mentioned in subsequent documents. It is not known when the railroad was completed with conventional methods.

## CRATER PROFILES vs. DEPTH OF BURST

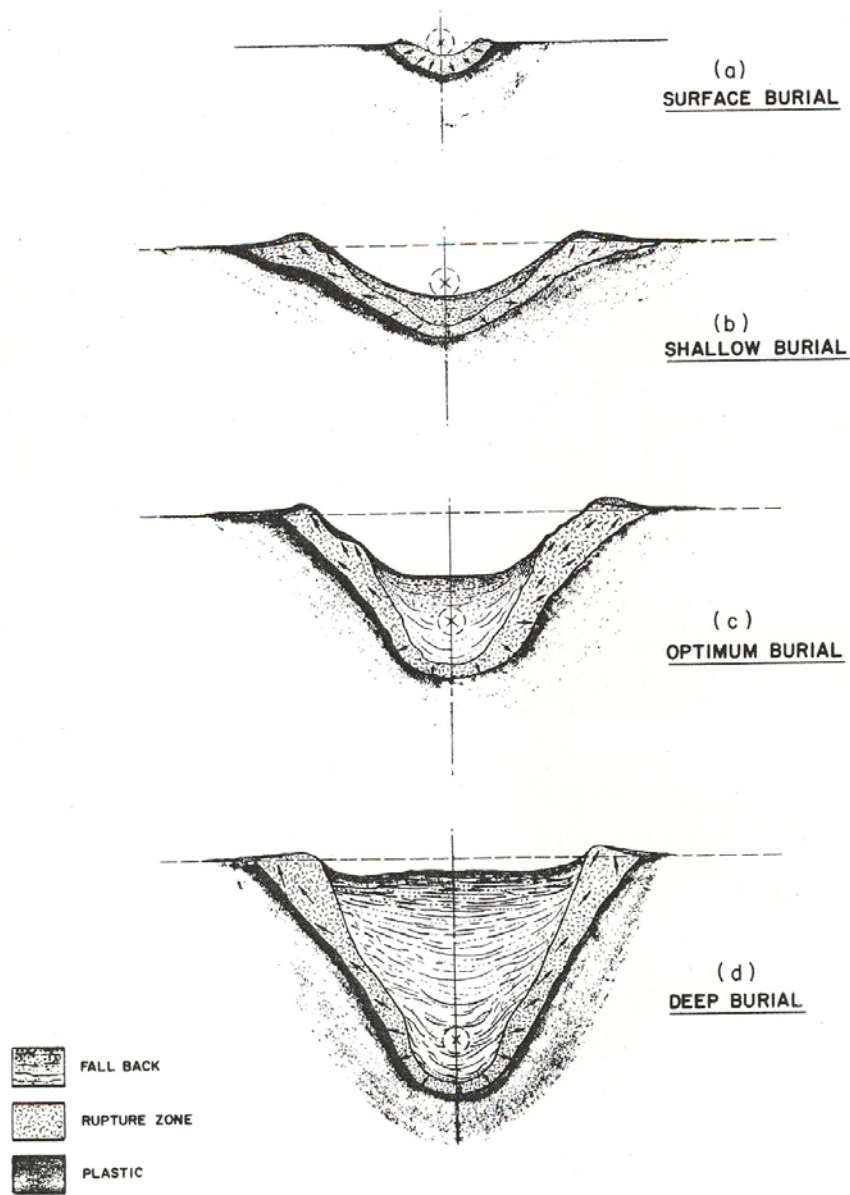


Figure 4.7-6. Projected crater profiles and burst depth (Perry et al. 1963, Figure 2.2).

Project Carryall was a Level 4 activity with field data collection, a conceptual design, and utilization of existing data.

## **CHRONOLOGICAL BIBLIOGRAPHY**

Philip, John F., 1963. Letter from John F. Philip, U.S. Atomic Energy Commission, San Francisco Office, to Harlan Zodtner, June 21. On file at: Lawrence Berkeley National Laboratory, University of California, Berkeley, CA, File 434-900157, 18/18 [OUO].

San Bernardino Telegram, 1963. A-Blasts May Help Build Desert Roads. *San Bernardino Telegram*, June 26.

San Bernardino Sun, 1963. First Civilian A-Blast May Be in County. *San Bernardino Sun*, June 26.

San Bernardino Sun, 1963. Highways Officials Mum on Peaceful Use of Atom Bomb. *San Bernardino Sun*, June 27.

San Bernardino Telegram, 1963. Highways Officials Mum on Peaceful Use of Atom Bomb. *San Bernardino Telegram*, June 27.

Southwick, Rodney L., 1963. "Stories on Amboy, California, Plowshare Study." Memo from Rodney L. Southwick, U.S. Atomic Energy Commission, San Francisco Operations Office, to Tom MacCaulty, July 2. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.

Shute, E. C., 1963. Letter with encl. ("Draft Agreement") from E. C. Shute, U.S. Atomic Energy Commission, San Francisco Office, to W. B. Reynolds, July 10. On file at: Lawrence Berkeley National Laboratory, University of California, Berkeley, CA, File 434-900157, 18/18.

Defense Atomic Support Agency, 1963. Peaceful Uses of Nuclear Explosives: Project Plowshare. Report from Defense Atomic Support Agency, Sandia Base, Albuquerque, NM, September 1. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV [OUO].

Graves, Ernest, 1963. "Program and Budget Justification, Nuclear Explosives Studies." Letter with encl. ("FY 1964 Program") from Ernest Graves, Lawrence Radiation Laboratory, U.S. Army Engineer Nuclear Cratering Group, to Chief of Engineers, Department of the Army, September 20. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029 [OUO].

Plowshare Advisory Committee, 1963. Plowshare Advisory Committee Meeting. Agenda from Plowshare Advisory Committee, October 28-29. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV.

- Plowshare Advisory Committee, 1963. Plowshare Advisory Committee, Report on Eleventh Meeting. Meeting held at Lawrence Radiation Laboratory, Livermore, CA, October 28-29. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.
- Perry, O. W., H. C. Prentice, J. L. Peterson, Jr., John G. Fry, Roy A. Stane, Wm. H. Crutchfield, Jr., John F. Phillip, Harold B. Curtis, Milo D. Nordyke, Harlan H. Zodtner, and Louis J. Cicero, 1963. Project Carryall Feasibility Study. Report from California State Division of Highways, Atchison, Topeka and Santa Fe Railway Company, and U.S. Atomic Energy Commission, November. On file at: Technical Reports Library, Lawrence Livermore National Laboratory, Livermore, CA.
- Carryall Project, 1963. Carryall Project. Announcement of Results. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Operations Office, Las Vegas, NV, Accession No. NV0184658.
- Fry, John G., Roy A. Stane, and W. H. Crutchfield, 1964. Preliminary Design Studies in a Nuclear Excavation - Project Carryall. In *Symposium on Nuclear Excavation Abridgments* presented at the 43rd Annual Meeting of the Highway Research Board, National Academy of Sciences - National Research Council, Washington, D.C., January, pp. 11-16. University of California, Lawrence Radiation Laboratory, *Report UCRL-7632*. Livermore, CA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-34.
- Prentice, H. C., and E. J. L. Peterson, Jr., 1964. Construction and Feasibility Associated with Nuclear Excavation. In *Symposium on Nuclear Excavation Abridgments* presented at the 43rd Annual Meeting of the Highway Research Board, National Academy of Sciences - National Research Council, Washington, D.C., January, pp. 21-24. University of California, Lawrence Radiation Laboratory, *Report UCRL-7632*. Livermore, CA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-034.
- U.S. Atomic Energy Commission, 1964. Plowshare Program. In *Annual Report to Congress of the Atomic Energy Commission for 1963*, pp. 207-228, January. U.S. Government Printing Office, Washington D.C.
- Zodtner, Harlan H., 1964. Operations and Safety Problems Associated with a Nuclear Excavation Project. In *Symposium on Nuclear Excavation Abridgments* presented at the 43rd Annual Meeting of the Highway Research Board, National Academy of Sciences - National Research Council, Washington, D.C., January, pp: 17-20. University of California, Lawrence Radiation Laboratory, *Report UCRL-7632*. Livermore, CA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-034.

- Zodtner, Harlan H., 1964. Operations and Safety Problems Associated with a Nuclear Excavation Project. University of California, Lawrence Radiation Laboratory, *Report UCRL-7656*, February 10. Livermore, CA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-034.
- Prentice, H. C., 1964. Application of Nuclear Explosives for a Mountain Pass Highway and Railroad. In *Engineering with Nuclear Explosives, Proceedings of the Third Plowshare Symposium*, April 21-23, University of California, Lawrence Radiation Laboratory, Report TID-7695, pp. 309-319. Livermore, CA.
- Lawrence Livermore National Laboratory, 1964. Status of Plowshare Field Programs. Report from Lawrence Livermore National Laboratory, May 6. On file at: Technical Reports Library, Lawrence Livermore National Laboratory, Livermore, CA.
- U.S. Atomic Energy Commission, 1964. Suggested Nuclear Excavation Projects and Possible Nuclear Excavation Projects. Manuscript, Division of Peaceful Nuclear Explosives, July. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.
- Defense Atomic Support Agency, 1964. Peaceful Uses of Nuclear Explosives: Project Plowshare. Report From Defense Atomic Support Agency, Sandia Base, Albuquerque, NM, September 1. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV [OUO].
- Korver, John A., 1964. "Ground Water Conditions at the Carryall Site." Memo from John A. Korver, Lawrence Radiation Laboratory, to Distribution, September 29. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-007.
- Southwick, Rodney L., 1964. Letter with encls. from Rodney L. Southwick, U.S. Atomic Energy Commission, San Francisco Operations Office, to Multiple Recipients, December 11. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.
- Project Carryall Time Schedule, [1964]. "Project Carryall Time Schedule." Drawing (graph). On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV.
- U.S. Atomic Energy Commission, 1965. Plowshare Program. In *Annual Report to Congress of the Atomic Energy Commission for 1964*, pp. 155-176, January. U.S. Atomic Energy Commission, U.S. Government Printing Office, Washington D.C.
- Seaborg, Glenn T., 1965. Statement by Dr. Glenn T. Seaborg, Chairman, U.S. Atomic Energy Commission on Plowshare Program before the Joint Committee on Atomic Energy, January 5. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-028.

- Plowshare Advisory Committee, 1965. Plowshare Advisory Committee, Report on Thirteenth Meeting. Meeting held at Lawrence Radiation Laboratory, Livermore, CA, January 12-13. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029 [OUO].
- Nordyke, Milo D., 1965. Principles of Nuclear Excavation. University of California, Lawrence Radiation Laboratory, *Report UCRL-14171*. Livermore, CA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-104.
- Plowshare Advisory Committee, 1965. Plowshare Advisory Committee, Report on Fourteenth Meeting. Meeting held at Lawrence Radiation Laboratory, Livermore, CA, November 9-10. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029 [OUO].
- U.S. Atomic Energy Commission, 1966. Chapter 12 - The Plowshare Program. In *Annual Report to Congress of the Atomic Energy Commission for 1965*, pp. 191 -209, January. U.S. Atomic Energy Commission, U.S. Government Printing Office, Washington D.C.
- Lawrence Livermore National Laboratory, 1966. Status Report, Plowshare Program. University of California, Lawrence Livermore National Laboratory, *Report UCRL-ID-126143*, February 1. Livermore, CA.
- National Academy of Sciences. National Research Council., 1966. Application of the Plowshare Program of Nuclear Excavation Experimentation to Highway Construction. U.S. Atomic Energy Commission, San Francisco Operations Office, Report PNE 3003, April. Washington, D.C.
- Las Vegas paper, 1966. A-Blast on Road Project Shelved. Las Vegas paper, September 7. Las Vegas, NV.
- Rios-Carvajal, J., 1967. Project Carryall. In *Puerto Rico Nuclear Center Plowshare Workshop*, July 1 - August 15, 1967, Knud B. Pedersen, editor, pp. 92-95. Puerto Rico. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV.
- Carryall Project, [1967]. Carryall Project - railroad and highway alignment. Drawing, July. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV.
- Applied Nuclear Company, [Post 1967]. Applied Nuclear Company and Plowshare. Report to U.S. Atomic Energy Commission from Applied Nuclear Company, La Jolla, CA. On file at: Technical Reports Library, Lawrence Livermore National Laboratory, Livermore, CA.

- Vortman, L. J., 1969, Nuclear Excavation. Report, SC-DC-69-1716, Underground Physics Division, Sandia Laboratories, Albuquerque, NM, March. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-104.
- Toman, John, 1970. Summary of Nuclear-Excavation Applications. Paper prepared for Proceedings of the ANS Topical Meeting, Engineering with Nuclear Explosives, Las Vegas, Nevada, January 14-16, 1970. University of California, Lawrence Radiation Laboratory, *Preprint UCRL-72220*, January 29. Livermore, CA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-104.
- Toman, John, 1970. Summary of Nuclear-Excavation Applications. In *Symposium on Engineering with Nuclear Explosives: Proceedings*, Report CONF-700101, Vol. 1, pp. 245-279, May. American Nuclear Society, Hinsdale, IL.
- Evans, Roy B., and David E. Bernhardt, 1970. "Probable Scheduling of Plowshare Events." Memo from Roy B. Evans and David E. Bernhardt, U.S. Department of Health, Education, and Welfare, Southwestern Radiological Health Laboratory, to Francis N. Buck, May 8. On file at Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0173142 [OUO].
- Rowen, Henry, 1976. The Economics for Peaceful Nuclear Explosions. Report to International Atomic Energy Authority from Stanford University, February. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-028.
- Drago, Jim, 1988. Amazing But True Department Engineers Considered the "Nuclear Option" to Clear the Way for Route 66's Successor. *Going Places*, pp. 229-233, March/April. Caltrans.
- Shafer, David S., William C. Beck, Dwight Treadwell, and Stephen A. Mellington, 1995. Inventory of Potential Environmental Restoration Liabilities Associated with Plowshare And Vela Uniform Program Sites. Manuscript, U.S. Department of Energy, Office of Environmental Restoration. On file at: Desert Research Institute, Las Vegas, NV.
- U.S. Department of Energy. Nevada Operations Office, 1997. Plowshare Program Executive Summary. Report from U.S. Department of Energy, December 22.
- Wilshire, Howard, 2001. Building a Radioactive Highway. *Desert Report*, Spring edition, pp. 9,14. Sierra Club California/Nevada Desert Committee.

Carryall Infinite Dose from Arrival, n.d. "Carryall Infinite Dose from Arrival." Drawing. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV.

Carryall Project, n.d. Carryall Project - profile. Drawing. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV.

Lawrence Livermore National Laboratory, n.d. Carryall-b model. "Carryall Feasibility Study" Carryall-b1 text. Negative No. GLB-6312-7051. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA.

Lawrence Livermore National Laboratory, n.d. Carryall-c drawing. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA.

Lawrence Livermore National Laboratory, n.d. Carryall-d area photo. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA.

Lawrence Livermore National Laboratory, n.d. Carryall-f drawing. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA.

Lawrence Livermore National Laboratory, n.d. Carryall rad map, c1188. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA.

Lawrence Livermore National Laboratory, n.d. "Project Carryall - Bristol Mountain." Carryall map/drawing-05-A, A1. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA.

Lawrence Livermore National Laboratory, n.d. "Project Carryall Study Limits." Carryall-a map. Negative No. GLB-6312-7051. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA.

Map of Project Carryall, n.d. Map of Project Carryall showing railway, highway, apparent edge of channel, crest of lip, and edge of throwout. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV.

Project Carryall, n.d. Project Carryall. Report. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV.

U.S. Department of Energy. Nevada Operations Office, n.d. The Plowshare Program (Draft). Report from U.S. Department of Energy.



## 4.8 CHOMLY CUTOFF

### Plowshare Program Nuclear Excavation of a Sea-Level Channel Alaska

In the later part of 1963, the Alaska District of the U.S. Army Corps of Engineers began collecting topographic, geologic, and economic data to study the feasibility of using nuclear explosives to construct a small to medium boat channel in southeastern Alaska, approximately 35 miles east of Ketchikan (Figure 4.8-1). Status reports from the U.S. Army Engineer Nuclear Cratering Group indicate that preliminary work on the feasibility study continued through 1964, and a draft report for Chomly Cutoff was submitted by the end of the year. The final report was completed in June of 1967 and had technical guidance from the Nuclear Cratering Group, however, the document had limited distribution and a copy has not been located.



Figure 4.8-1. Location of the proposed Chomly Cutoff in southeastern Alaska (adapted from USA Relief Maps 2004).

In 1966, Chomly Cutoff was one of the projects submitted by District Engineers to the Chief of Engineers as a civil works project that had potential for accomplishment using nuclear explosives. The demonstration project summary briefly describes Chomly Cutoff as the construction of a channel extending from the west arm of Cholmondeley Sound near the abandoned town of Chomly, to Hetta Inlet which opens onto Cordova Bay and the Pacific Ocean (Figure 4.8-2).

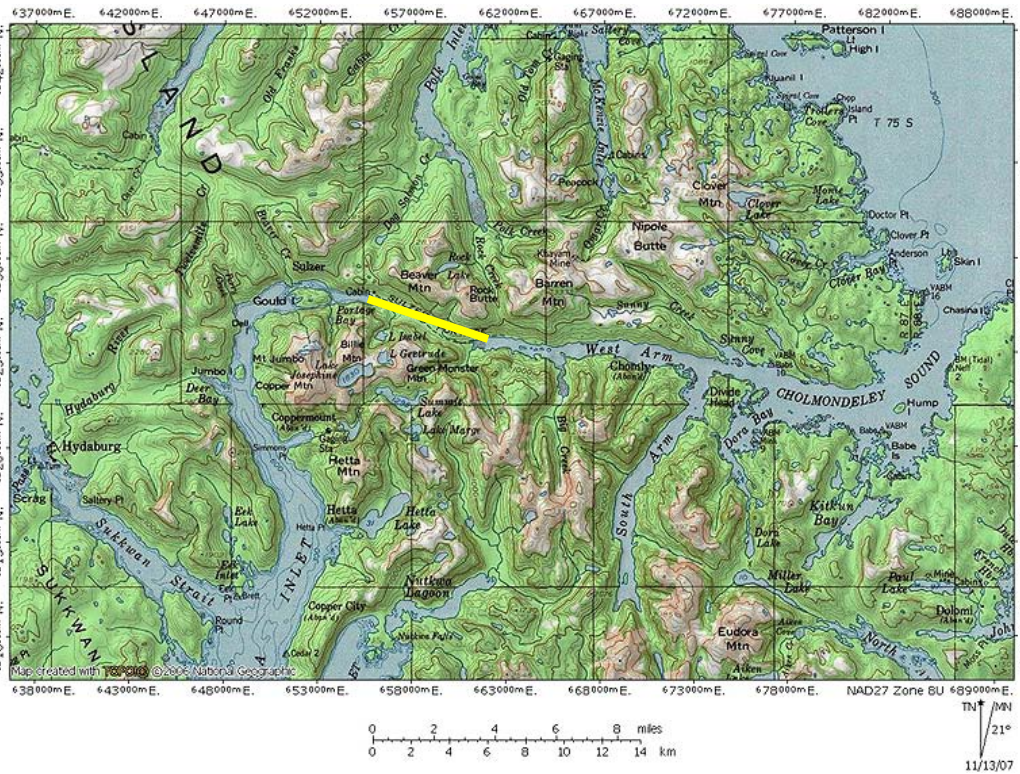


Figure 4.8-2. Map showing location of proposed channel for the Chomly Cutoff (solid yellow line) (adapted from National Geographic Topographic Maps 2006).

The plan for Chomly Cutoff called for nuclear excavation of a narrow, steep-sided valley, resulting in a channel four miles long and 100 ft wide with a depth of 15 ft. The maximum depth of cut was estimated at 275 ft at the midpoint of the proposed channel. The simultaneous detonation of a row of 54 buried nuclear explosives with yields ranging from 10 t to 200 kt s, and a total yield estimated at 2.66 megatons, was considered necessary to excavate the channel. According to a 1969 description of the project, nuclear excavation was more cost effective than conventional methods, but still exceeded costs necessary for an economically feasible project. The 1969 document also mentions that the initial study for Chomly Cutoff referred to the need for more data on the effects of steep slopes on crater dimensions, the distribution and stability of ejecta material on steep slopes, and the effects of wave action in a narrow pass to evaluate the technical feasibility of the project.

Chomly Cutoff was a Level 5 activity. The primary document for this project has not been located, but there is no documentation to suggest that the project moved beyond the conceptual design phase.

## CHRONOLOGICAL BIBLIOGRAPHY

- Graves, Ernest, 1964. "Status Report – Nuclear Explosives Studies for Civil Construction (Reports Control Symbol ENGCE-E-9)." Letter with encl. ("Status Report, Effective Date: 31 December 1963 – ENGCE-E-9") from Ernest Graves, Lawrence Radiation Laboratory, U.S. Army Engineer Nuclear Cratering Group, to Chief of Engineers, Department of the Army, February 4. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.
- Graves, Ernest, 1964. "Status Report – Nuclear Explosives Studies for Civil Construction (Reports Control Symbol ENGCE-E-9)." Letter with encl. ("Status Report, Effective Date: 31 March 1964 – ENGCE-E-9") from Ernest Graves, Lawrence Radiation Laboratory, U.S. Army Engineer Nuclear Cratering Group, to Chief of Engineers, Department of the Army, April 23. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.
- Slazak, Walter J., 1965. "Status Report – Nuclear Explosives Studies for Civil Construction (Reports Control Symbol ENGCE-E-9)." Letter with encl. ("Status Report, Effective Date: 31 December 1964 – ENGCE-E-9") from Walter J. Slazak, Lawrence Radiation Laboratory, U.S. Army Engineer Nuclear Cratering Group, to Chief of Engineers, Department of the Army, January 15. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.
- Hughes, Bernard C., 1965. "Status Report – Nuclear Explosives Studies for Civil Construction (Reports Control Symbol ENGCE-E-9)." Letter with encl. ("Status Report, Effective Date: 31 March 1965 – ENCGW-P-6(R1)") from Bernard C. Hughes, Lawrence Radiation Laboratory, U.S. Army Engineer Nuclear Cratering Group, to Chief of Engineers, Department of the Army, April 13. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.
- Lawrence Radiation Laboratory. U.S. Army Engineer Nuclear Cratering Group, [1966]. Demonstration Project Summary. Manuscript. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-103 [OUO].
- Kurtz, Maurice K., 1967. Letter from Maurice K. Kurtz, Jr., U.S. Army Engineer Nuclear Cratering Group, to Glenn Werth, August 2. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029 [OUO].

Lawrence Radiation Laboratory. U.S. Army Engineer Nuclear Cratering Group, 1968. Engineering Applications of Nuclear Explosives, Bi-Monthly Statistics of NCG Technical Reports, Memoranda, and Studies. Manuscript, February 15. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV.

Hughes, Bernard C., 1969. History of the U.S. Army Engineer Nuclear Cratering Group, January. Lawrence Radiation Laboratory, January. Livermore, CA.

## **4.9 COCHITI DAM**

### **Plowshare Program Nuclear Quarrying for Construction of a Dam New Mexico**

In 1962, the U.S. Army Engineer Nuclear Cratering Group engaged in a study program to develop technology that would be required to use nuclear explosives in the construction of large-scale civil projects. Following a May 1963 meeting at the Lawrence Radiation Laboratory, a variety of U.S. Army Corps of Engineers construction projects were considered that might be suitable for demonstration using nuclear explosive technology. These projects had already either been studied or were in the survey report stage for construction using conventional means. By May 1966, the Chief of Engineers made a request to District Engineers to submit civil engineering projects that would have potential for accomplishment using nuclear excavation. An undated document provides information about 17 potential demonstration projects. Of these, five were quarrying projects.

The concept of using nuclear explosives to produce vast quantities of fractured rock that could be quarried with relative ease for rock-fill or aggregate was identified as having immediate application. Field visits were made to the five project locations, and the site for Cochiti Dam along with the sites for Buchanan Dam and Twin Springs Dam were selected for further study. The Lawrence Radiation Laboratory completed a plan for accomplishing a quarry project by August 1966. The plan outlined the requirements of the project as well as a summary of each of the three proposed project locations. During the subsequent study phase the U.S. Atomic Energy Commission conducted engineering feasibility studies and safety evaluations for each location to determine the most suitable nuclear quarrying demonstration project.

Cochiti Dam was planned for a location on the Rio Grande mainstream, in Sandoval County, northern New Mexico (Figure 4.9-1). The dam was a U.S. Army Corps of Engineers project authorized for flood reduction and sediment control under the Flood Control Act of 1960. During the planning phase three potential nuclear quarrying sites were identified approximately three miles northeast of the proposed Cochiti Dam location. The quarry sites are within a mile of each other in T16N R6E, and are located in a series of basalt flows along the eastern side of the Santa Fe River canyon. The city of Santa Fe is approximately 20 miles east-northeast, Los Alamos is due north and Albuquerque is to the south.

In December 1966, the Corps of Engineers, Albuquerque District issued a feasibility study for the project; however, the report had limited distribution and has not been located. At about the same time that the feasibility study was underway the Nevada Operations Office requested that the U.S. Geological Survey prepare a study of the water conditions and hydrologic safety at the three dam project locations to identify favorable

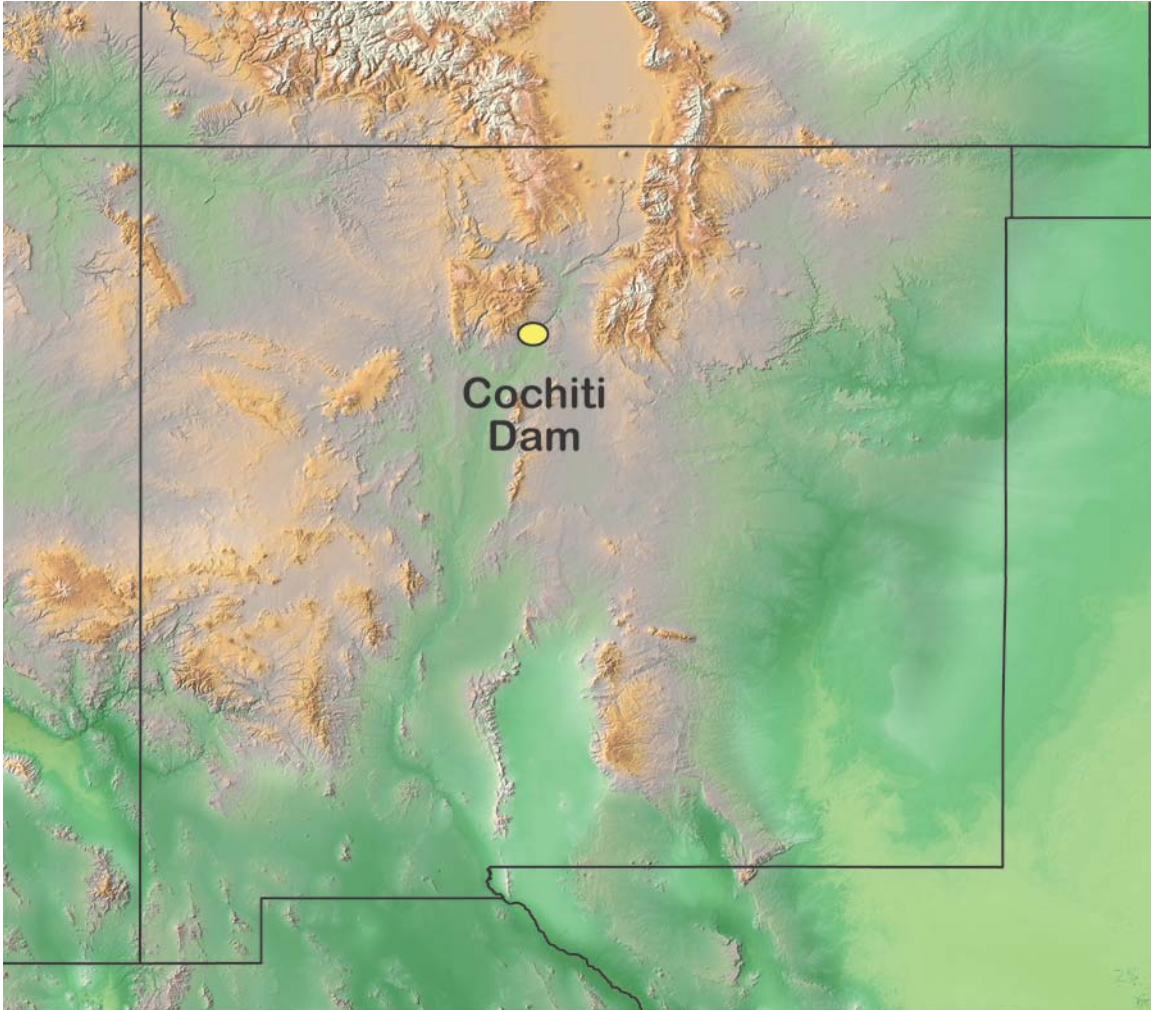


Figure 4.9-1. Location of the proposed nuclear quarrying project for Cochiti Dam in New Mexico (adapted from USA Relief Maps 2004).

and unfavorable conditions for a nuclear quarry project. The study concluded that the hydrology in the vicinity of Cochiti Dam presented a slight advantage over the other locations because at Cochiti there was a deeper water table; and a deeper water table would reduce the time for groundwater to transport radionuclides to a perennial stream. However, a report evaluating off-site public health and safety mentions that the dam is located central to the most populated area of New Mexico. The report questions whether it would be possible to contain effluent northwest of Santa Fe and the surrounding area without some radiation exposure. There was also concern about dairies in the area and possible contamination of milk from a radiation release.

A status report from the U.S. Army Engineer Nuclear Cratering Group with an effective date of December 31, 1967, indicates that by the end of 1967 Cochiti Dam was no longer under consideration as a potential nuclear quarrying demonstration project. By that time construction of the dam was underway using conventional methods, and Buchanan Dam

and Twin Springs were selected as preferable locations for a nuclear quarrying demonstration (see Project Travois – Chapter 3.21). Cochiti dam was completed in 1973 (Figure 4.9-2).

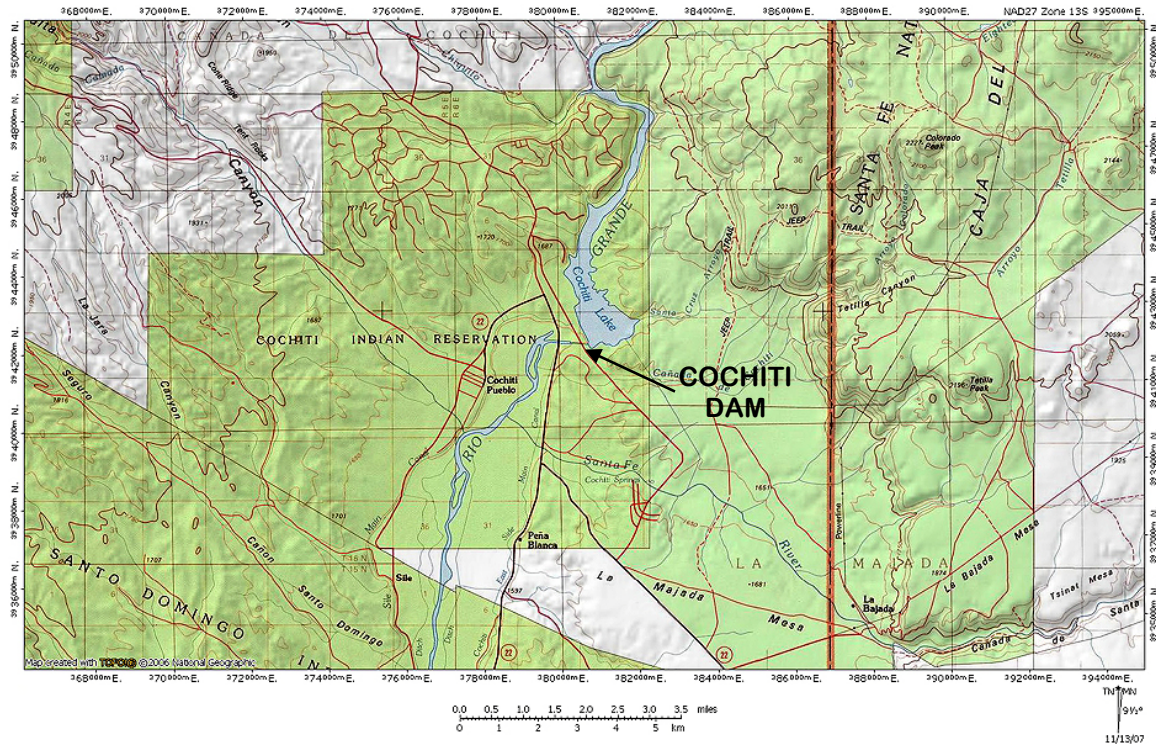


Figure 4.9-2. Location of Cochiti Dam on the Rio Grande River (adapted from National Geographic Topographic Maps 2006).

Cochiti Dam was a Level 4 activity. The extent of field work for the feasibility study is not known, however some drilling was conducted for site selection/characterization studies.

## CHRONOLOGICAL BIBLIOGRAPHY

Lawrence Radiation Laboratory. U.S. Army Engineer Nuclear Cratering Group, 1966. Plan for Accomplishment of a Demonstration of the Application of Nuclear Excavation in Civil Works Projects. Manuscript, August 27. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-100.

Slazak, Walter J., 1966. Letter with encl. (“Summary of Possible Quarrying Projects”) from Walter J. Slazak, Lt. Colonel, Lawrence Radiation Laboratory, U.S. Army Engineer Nuclear Cratering Group, to Michael M. May, September 20. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.

- Lawrence Radiation Laboratory. U.S. Army Engineer Nuclear Cratering Group, [1966]. Demonstration Project Summary. Manuscript. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-103 [OUO].
- U.S. Department of the Interior. Geological Survey, [1966]. Summary of Water Conditions and Suggested Programs for Evaluation of Hydrological Safety of Nuclear Excavation at Three Proposed Dam Sites: Buchanan Damsite, California; Twin Springs Damsite, Idaho; and Cochiti Damsite, New Mexico. Report to U.S. Atomic Energy Commission from Geological Survey. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV [OUO].
- U.S. Public Health Service. Department of Health, Education and Welfare, [1966]. PHS Off-Site Evaluation of Cochiti Dam and Reservoir Project, Cochiti, New Mexico. Manuscript, Las Vegas, NV. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV.
- Lawrence Radiation Laboratory. U.S. Army Engineer Nuclear Cratering Group, 1968. Engineering Applications of Nuclear Explosives: Bi-Monthly Statistics of NCG Technical Reports, Memoranda, and Studies. Manuscript, February 15. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV.
- Hughes, Bernard C., 1969. History of the U.S. Army Engineer Nuclear Cratering Group, January. Lawrence Radiation Laboratory, January. Livermore, CA.
- Vortman, L. J., 1969. Nuclear Excavation. Report, SC-DC-69-1716, Underground Physics Division, Sandia Laboratories, Albuquerque, NM, March. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-104.
- Toman, John, 1970. Summary of Nuclear-Excavation Applications. Paper prepared for Proceedings of the ANS Topical Meeting, Engineering with Nuclear Explosives, Las Vegas, Nevada, January 14-16, 1970. University of California, Lawrence Radiation Laboratory, *Preprint UCRL-72220*, January 29. Livermore, CA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-104.
- Toman, John, 1970. Summary of Nuclear-Excavation Applications. In *Symposium on Engineering with Nuclear Explosives: Proceedings*, Report CONF-700101, Vol. 1, pp. 245-279, May. American Nuclear Society, Hinsdale, IL.



## 4.10 COLONA EARTHQUAKE

### **Vela Uniform Program Earthquake Seismic Data Colorado**

Established to improve U.S. seismic detection capabilities for nuclear explosions, the Vela Uniform Program has been a major sponsor of seismic research since its inception in 1959. Its primary purpose was to record and analyze both short- and long-period seismic data from a series of planned underground nuclear tests with the ultimate goal of developing techniques and instrumentation capable of distinguishing between explosive and natural seismic sources. Toward this end, comparative studies using seismic data from nuclear detonations, conventional explosives, and natural events were essential. The Long Range Seismic Measurements Program, designated Project 8.4, was a fundamental component of the Vela Uniform Program. Administered by the Nuclear Test Detection Office of the Advanced Research Projects Agency, the Long Range Seismic Measurements program set up a network of seismic instrumentation stations to accomplish its data-gathering mission.

Project Colona Earthquake, sponsored by the Long Range Seismic Measurements Program, involved the comparative analysis of monitoring data derived from the February 5, 1962 earthquake that occurred in southwestern Colorado near the community of Colona (Figure 4.10-1). The quake's epicenter was at approximately 38°12' N Latitude 107°36' W Longitude at a depth of 25 km below the surface. The seismic event occurred at 14:45:51 GMT with a magnitude of 4.2 on the Richter scale.

Equipment involved in the Colona Earthquake Project consisted of 36 mobile seismic stations distributed at various locations throughout the continental United States. Geotechnical Corporation of Dallas, Texas, provided the instrumentation for the mobile units. Equipment in the mobile vans consisted of three-component short-period Benioff seismographs and three-component long-period Sprengnether seismographs. Both types of instruments recorded the data on 35-mm film and magnetic tape.

At the time of the quake, most of the mobile stations were concentrated in the western United States south and west of the Colorado epicenter, but six were located east of the 95<sup>th</sup> meridian (Figure 4.10-2). None of the eastern stations registered any seismic signals from the quake. Twenty-seven of the other locations registered short-period signals, but none recorded long period seismic phases. The seismic signals recorded during the Colona Earthquake were of a higher frequency than those produced by most nuclear explosives. The comparative study also revealed differences in the rate of attenuation of the higher frequency signals when compared to readings obtained from underground nuclear detonations. Additionally, results from Project Colona Earthquake demonstrated that at least eight of the mobile sites might provide useful data for future seismic studies at the Nevada Test Site.

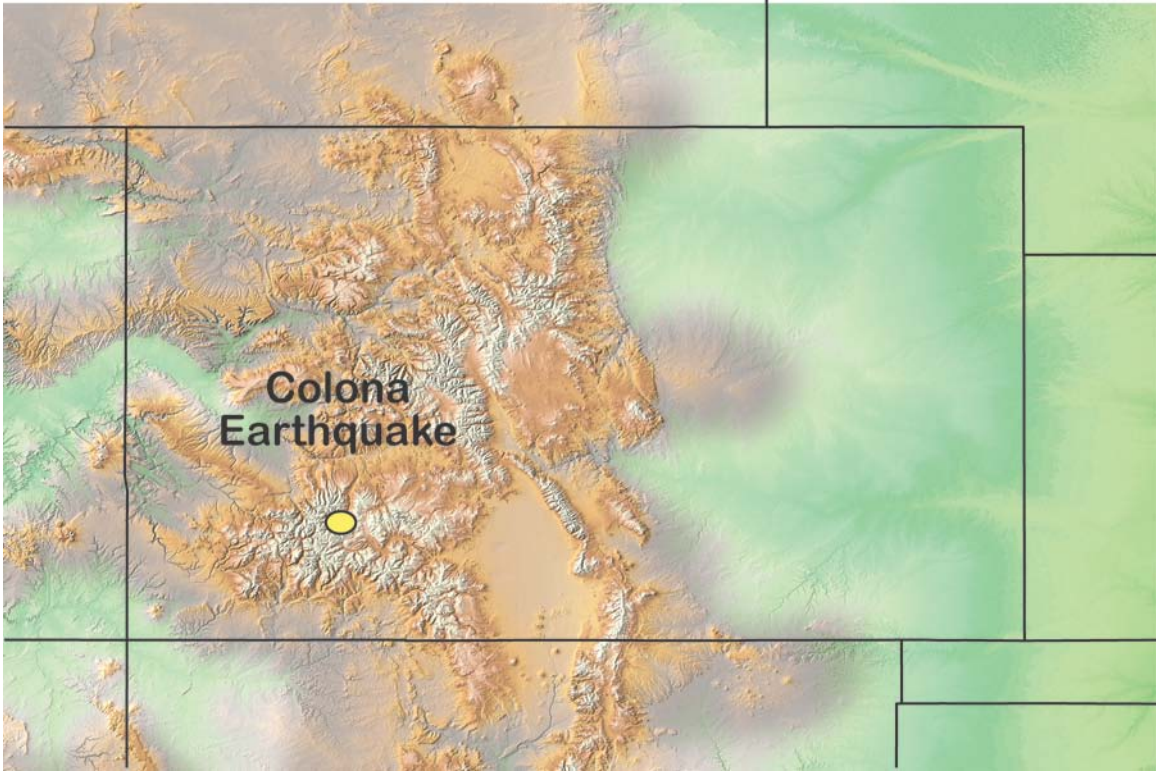


Figure 4.10-1. Location of Project Colona Earthquake in southwestern Colorado (adapted from USA Relief Maps 2004).

These included stations at Durango, Colorado; Pole Mountain, Wyoming; Fillmore, Utah; Flagstaff, Arizona; Las Cruces, New Mexico; Hailey, Idaho; and Mina and Winnemucca, Nevada.

Long range seismic measurements data analysis for Project Colona Earthquake appears to have been completed by February 1963. No reports issued after that date have been found. Field activity was limited to the temporary placement of the mobile seismic monitoring vans. Most of the units were relocated shortly after the Colona earthquake, while a few remained in place for future use (see Project Chase V and Project West Virginia Earthquake in this volume).

The Colona Earthquake was a Level 4 activity with data obtained from existing monitoring stations.

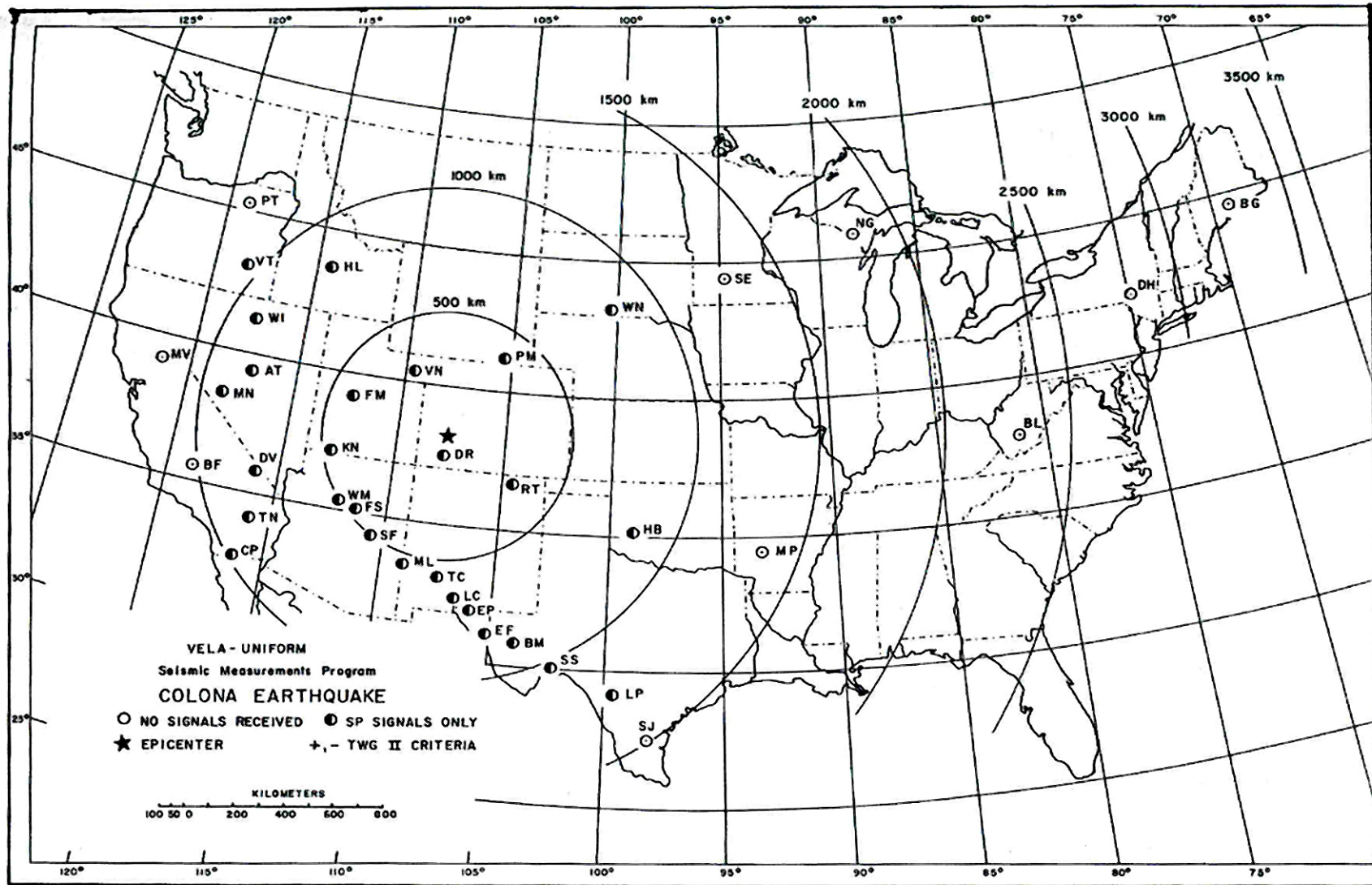


Figure 4.10-2. Distribution of mobile recording stations and seismic signals received for the Colona Earthquake (United Electroynamics, Inc. United Earth Sciences Division, 1963, Figure 1).

## **CHRONOLOGICAL BIBLIOGRAPHY**

United Electroynamics, Inc. United Earth Sciences Division, 1963. Long Range Seismic Measurements, Project 8.4, Colona Earthquake (Colorado). Report to Air Force Technical Applications Center from United Electroynamics, Inc. February 8, Alexandria, VA.

## **4.11 COPPER ORE CHEMICAL MINING**

### **Plowshare Program**

#### **Nuclear Explosives to Mine Primary Copper Ore Deposits**

**Alaska, Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, Washington**

By late 1969, scientists at the Lawrence Radiation Laboratory had begun laboratory experiments to test procedures for leaching primary copper deposits. Most mining of copper ore was based on mining the oxidized zone of the deposit, and in some cases in-situ leaching of oxidized sulfides. Applications for mining these deposits using nuclear explosives for rock fracturing had previously been investigated (see Copper Recovery – see Chapter 4.12, this volume and Sloop – see Chapter 4.37, this volume). Primary copper deposits consist of copper minerals in unoxidized zones that have not been altered by weathering or other processes. Mining of primary copper ore was not considered economical using conventional techniques as the deposits were usually too deep and/or too small for strip mining, and of a low grade. In addition, an economical procedure for leaching these deposits in place had not yet been developed. In a paper issued on December 22, 1969, prepared for a symposium on Engineering with Nuclear Explosives, A. E. Lewis introduced the concept of mining deep primary copper sulfide deposits. Copper ore chemical mining was based on the idea that nuclear explosives could be used to break ore deposits in contained explosions beneath the water table. The resulting chimneys would be filled with water and additional water would be introduced under pressure at the bottom of the chimney. Hypothetically, hydrostatic pressure would increase the solubility of oxygen thereby dissolving primary copper minerals in a sulfuric acid system. The solution would be pumped to the surface for separation of the copper (Figure 4.11-1). Thus, the project concept had two major technological components: 1) the use of contained underground nuclear explosions beneath the water table to break rock in primary copper bearing deposits, and 2) recovery of copper minerals from the chimney using a leaching procedure based on circulating oxygen through the flooded rubble. During the early 1970s numerous locations in the western United States were considered for this project concept (Figure 4.11-2).

The Newmont Mining Corporation requested that their Copper Creek property in Pinal County, Arizona be evaluated for a chemical mining experiment. The Lawrence Radiation Laboratory completed a project concept document on August 10, 1970. The project concept proposed that the Copper Creek ore body be the subject of a field experiment to investigate in situ leaching or a primary copper deposit using nuclear explosives to fracture the rock. The objectives of the experiment were to: produce and define the limits of the chimney; to determine the rate of solution of copper from the ore resulting from the introduction of oxygen; and to evaluate the results in terms of a commercial process. To accomplish these objectives, an experimental plan was proposed with three major phases: 1) pre-shot studies and construction, 2) detonation of explosive, and 3) post-shot construction and experimentation. Safety issues and possible seismic

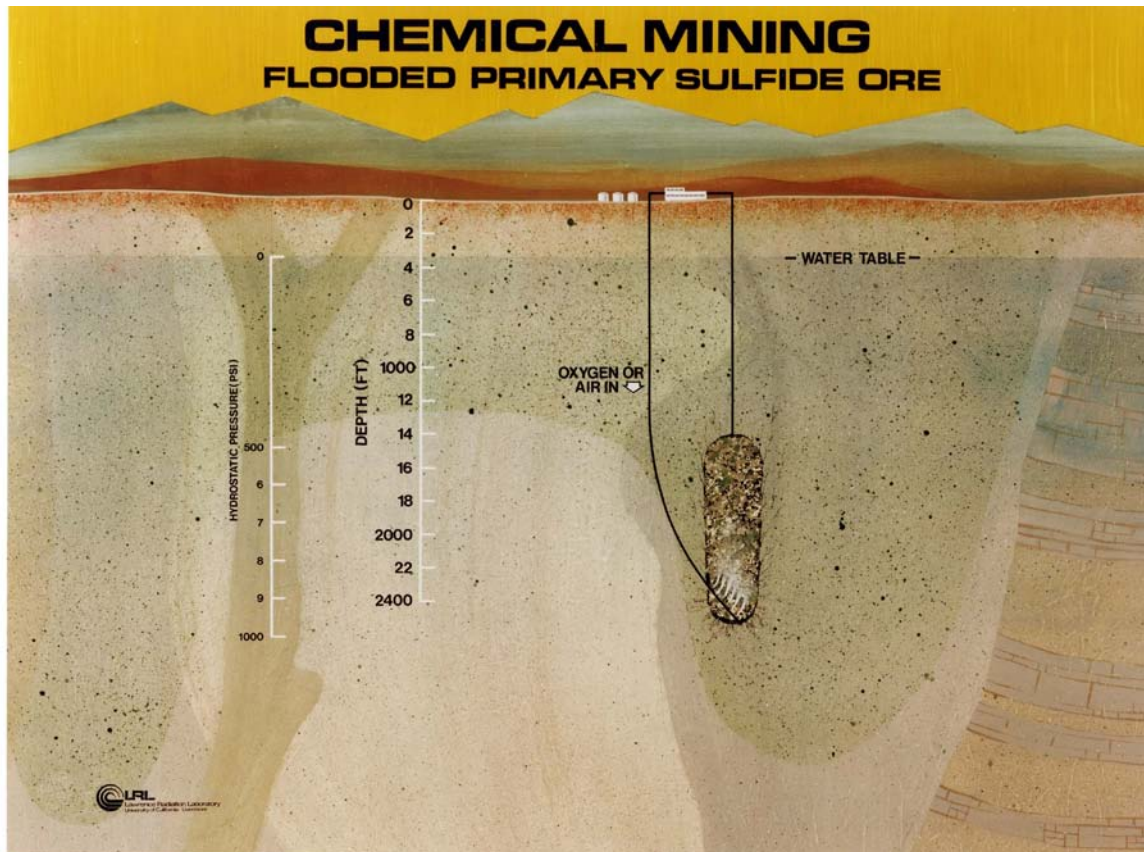


Figure 4.11-1. Illustration of chemical mining showing the use of hydrostatic pressure in a nuclear chimney to increase the solubility of oxygen (Lawrence Livermore National Laboratory n.d.).

damage were also examined. Shortly after the project concept was completed, preliminary cost estimates were provided in an August 18, 1970 Lawrence Radiation Laboratory memo, and the project was referred to as Project Newmont. The estimates were based on the cost of detonating a 100 kt nuclear explosive, 3,000 ft below the surface. The preliminary estimate for the project was approximately \$4.5 million, but did not include the costs related to copper recovery after re-entry. Preliminary costs for pumping the leached solution were also examined by Lawrence Radiation Laboratory. In a September 2, 1970 letter, the Newmont Mining Corporation expressed concerns raised by their metallurgical research group about the ability to verify the chemical mining technique developed by Lawrence Radiation Laboratory. Newmont notified the laboratory that they planned to defer submission of a proposal for a copper leach project at Copper Creek.

In January 1971, representatives from the Lawrence Radiation Laboratory met with faculty from the Mackey School of Mines at the University of Nevada, Reno, concerning the copper ore chemical mining application. Following the meeting, a list was compiled



Figure 4.11-2. States (shaded yellow) that had copper ore deposits that were proposed for a Copper Ore Chemical Mining Project (adapted from USA Relief Maps 2004).

of ten drilling projects in copper deposits in Nevada that might be suitable for a demonstration of the nuclear – chemical mining concept. By February 1971, the list had been expanded to include sixteen additional copper deposits in Idaho, Washington, Utah, New Mexico, Alaska, California, and Colorado (Table 4.11-1).

Over the next several years, laboratory experiments continued and interest grew in the mining concept. A 1971 laboratory paper on contained nuclear explosive applications included a section on chemical mining. In June 1971, Lawrence Livermore (formerly Radiation) Laboratory hosted a meeting on the chemical mining of copper with participation by various mining and mineral companies. The purpose of the meeting was to discuss recent technical developments in leaching sulfide copper ore deposits, and to elicit participation in supporting a test copper leaching project. In August 1971, in a preprint for presentation at the Symposium on the Underground Environment sponsored by the Geological Society of America on November 3, 1971, technical aspects of chemical mining of copper were discussed. In January 1972, Lawrence Livermore scientists issued a paper addressing technical aspects of nuclear chemical mining of primary copper sulfides. This paper was to be presented at the February 1972 American

Table 4.11-1. Possible Locations for a Copper Ore Chemical Mining Project (adapted from Higgins 1971)

<b>Copper Deposit</b>	<b>Location</b>
Northside Battle Mt	Humboldt County, Nevada
Coppereid	Churchill County, Nevada
Butte Valley	White Pine County, Nevada
Monte Cristo Stock, Hamilton District	White Pine County, Nevada
Jefferson Canyon, Gilh's Range	Mineral County, Nevada
4 Miles SW of Gabbs	Nye County, Nevada
Santa Fe District	Mineral County, Nevada
Southeast Pilot Mts.	Mineral County, Nevada
Crow Springs	Mineral County, Nevada
Royston	Nye and Mineral Counties, Nevada
Olanche Mine	Inyo County, California
Copper Cliff	Seven Devils Area, Western, Idaho
Big 8	Lemhi County, Idaho
Red Ledge Mine	Adams and Washington Counties, Idaho
Clipper Mine	King County, Washington
O.K. Mine	Beaver County, Utah
Glacier Peak	Chelan and Snomish Counties, Washington
Trinity Mine	Chelan and Snomish Counties, Washington
Tyrone Mine	Grant County, New Mexico
Horseshoe Bay	Latouche Island, Alaska
Ord Mountain	San Bernardino County, California
Akron Mine	Gunnisen County, Colorado
Cactus Mine	Beaver County, Utah
Lone Star	Ferry County, Washington
Rainy Mine	King County, Washington
Alder Mine	Okanogan County, Washington

Institute of Mining, Metallurgical, and Petroleum Engineers (AIME) meeting in San Francisco, and summarized information from experimental laboratory leaching studies that entailed the recovery of copper from large fragments of ore in a 1,000 gallon pressure vessel (Figures 4.11-3 and 4.11-4). Calculations from a model that used experimentally determined solubility rates were used to estimate the rate of copper recovery, and supported the conclusion that mining primary sulfides was technically feasible. Another paper, also presented at the meetings, addressed economic feasibility and safety considerations of the newly developed technique. In this paper the authors concluded that if a suitable deposit was found the procedure for solution mining primary deposits was economically competitive with other production methods.



Following the 1972 presentations at the AIME meetings, the Kennecott Copper Corporation contacted the laboratory regarding renewed interest in copper recovery (a previous interest had been with using nuclear techniques to mine oxide copper deposits-

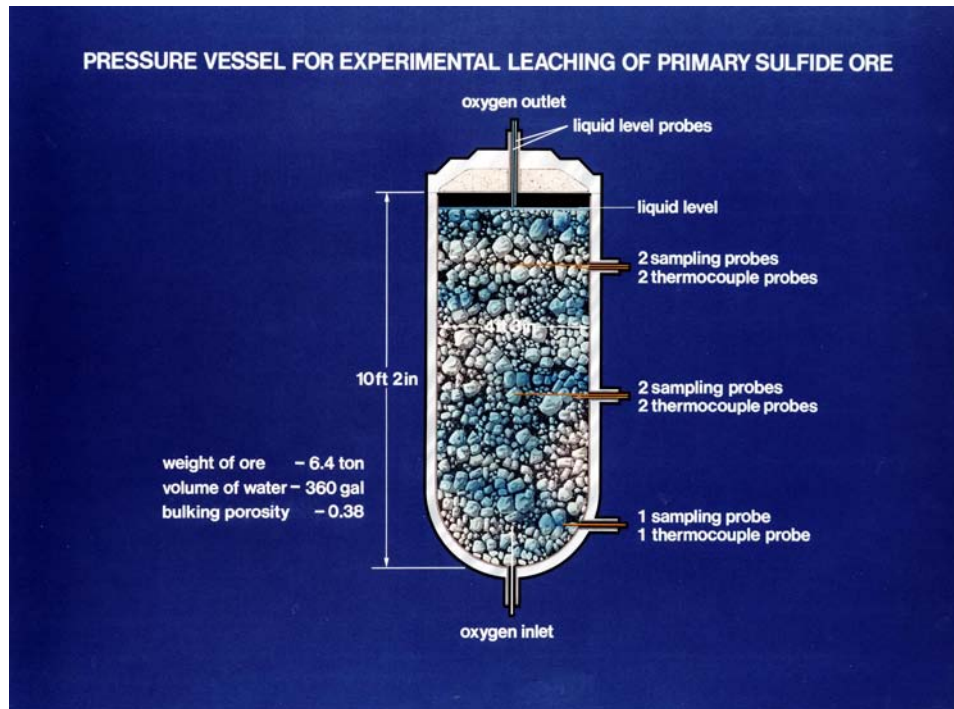


Figure 4.11-3. Diagram of a pilot pressure vessel for leaching primary sulfide ore (Lawrence Livermore National Laboratory n.d.).

see Project Sloop – Chapter 4.37, this volume) and pursued an agreement for a six month joint study between the company and the Plowshare group at Livermore. By June 1972, three areas of investigation had been identified for the joint study. These included: 1) small scale leaching studies using samples from a specific area; 2) an engineering feasibility study; and 3) a preliminary survey of possible damage and safety problems that may be associated with the project at a mining site. In August 1972, Lawrence Livermore Laboratory held a meeting with Kennecott's Ledgemont Laboratory regarding a joint program, and in the following month the U.S. Atomic Energy Commission authorized the Nevada Operations Office to negotiate an agreement for a brief feasibility study with Kennecott for a copper ore leaching project.

Work began on the joint feasibility study in February 1973 with the Ledgemont Laboratory as the principal participant for the Kennecott Copper Corporation. Fifteen potential ore bodies were identified for the project, but after analysis, seven were eliminated. The remaining eight locations were Berg, Chilito, Copper Butte, Safford, Butte Valley, Stikine, Camp Creek, and Ok Tedi. A September 1973 Battelle report presented results of preliminary environmental surveys at four locations for the project:

1) southwest Tintic Mountains near Eureka in Juab County, Utah; 2) Butte Valley near Ely in White Pine County, Nevada; 3) Courtland-Gleeson area near the south end of the Dragoon Mountains in Cochise County, Arizona; and 4) northeast of Safford in Graham County, Arizona.

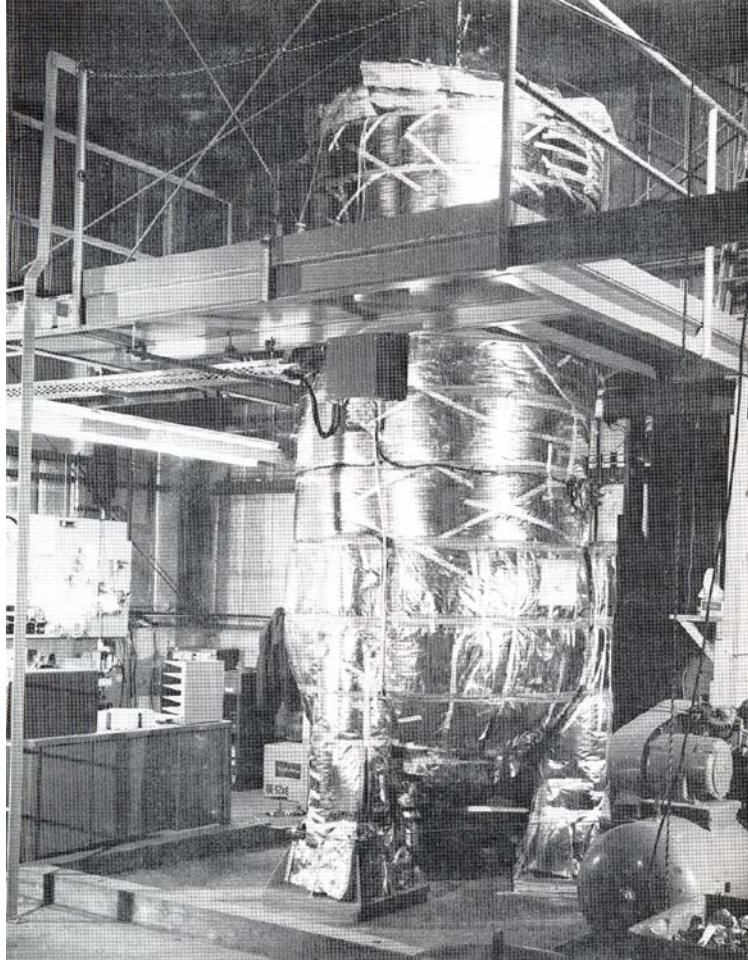


Figure 4.11-4. Photo of pilot plant pressure vessel (Lewis and Braun 1972, Figure 5).

The Anaconda Mining Company was also interested in participating in a copper ore chemical mining project. In a letter dating to May 1974, Anaconda contacted the U.S. Atomic Energy Commission regarding the work on leaching primary copper sulfides by Livermore and expressed their interest and expertise for a project. A meeting was held in Butte, Montana in July with representatives from the Anaconda Company, Lawrence Livermore Laboratory, and the U.S. Atomic Energy Commission Division of Applied Technology and Nevada Operations Office to discuss mining the deeply buried low grade copper reserve in the Butte area, referred to as the Kelly Ore. Anaconda representatives estimated that the deposit contained over 20 billion pounds of copper, most of which was not economically feasible to mine with current technologies. They expressed interest in a cooperative study to: 1) test the leaching characteristics of the Kelly Ore at the Lawrence

Livermore Laboratory; 2) conduct a rock breaking experiment at the Berkeley Pit or some other mined area; 3) conduct a small in situ leach experiment; and 4) undertake a demonstration leaching experiment in the Kelly Ore formation.

The Plowshare application of the copper recovery project relied on a concomitant development of chemical mining procedures. Laboratory-scale studies indicated that the leaching underground of primary copper sulfides was technically feasible. However, the procedure lacked relevant experimental data from actual tests. A number of technical uncertainties remained about the leaching process. Successful leaching of copper depended on a number of variables including: the size and size distribution of fractured ore in the chimney, how well oxygen mixed with the ore throughout the chimney, and the speed of the chemical reaction with oxygen that was essential for the leaching process.

Planning for a sulfide copper ore leaching demonstration project appeared to be on track at the end of 1974. In the FY 1975 budget proposal for energy and resource development concerning the peaceful use of nuclear explosives, \$200,000 was planned to continue cooperative work with Kennecott and Anaconda on copper leaching studies. The chemical leaching concept was presented at the International Atomic Meeting in January 1975. However, it appears funds were never allocated to continue with the project. While the project appeared to have potential, there is no documentation to suggest that studies for using nuclear explosives for mining copper ore continued after 1974.

Copper Ore Chemical Mining was a Level 5 activity. Activity was confined to laboratory studies, conceptual design, background research, and visual field inspections.

## **CHRONOLOGICAL BIBLIOGRAPHY**

Lewis, A. E., 1969. Chemical Mining of Primary Copper Ores by use of Nuclear Technology. Paper prepared for publication in Proceedings of the ANS Topical Meeting, Engineering with Nuclear Explosives, Las Vegas, NV, January 14-16, 1970. University of California, Lawrence Radiation Laboratory, *Preprint UCRL-72159*, December 22 Livermore, CA. On file at: Technical Reports Library, Lawrence Livermore National Laboratory, Livermore, CA.

Lawrence Radiation Laboratory, 1970. Concept of a Proposed Chemical Mining Experiment at Copper Creek, Arizona. Manuscript, Lawrence Radiation Laboratory, Livermore, CA, August 10. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-087.

Lewis, A. E., 1970. Letter from A. E. Lewis, Lawrence Radiation Laboratory, to A. H. Ewing, August 11. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-087.

- Cramer, James L., 1970. "Project Newmont, Preliminary Cost Estimate." Memo from J. L. Cramer, Lawrence Radiation Laboratory, to Art Lewis, August 18. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-087.
- Cramer, James L., 1970. "Pumping Costs for Leaching Projects." Memo from James L. Cramer, Lawrence Radiation Laboratory, to Art Lewis, August 31. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-087.
- Fulton, R. B., 1970. Letter from R. B. Fulton, Newmont Mining Corporation, New York, NY, to Anthony H. Ewing, September 2. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-087.
- Kerr, Paul F., 1970. Letter from Paul F. Kerr, Department of Geology, Columbia University in the City of New York, to Arthur E. Lewis, September 15. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-105.
- Lewis, A. E., 1970. Letter from Arthur E. Lewis, Lawrence Radiation Laboratory, to A. F. Osborne, December 16. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-087.
- Higgins, Gary H., and A. E. Lewis, 1971. "Trip Report - Mackay School of Mines, Reno." Memo from G. H. Higgins and A. E. Lewis, Lawrence Radiation Laboratory, to File, January 27. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-087.
- Higgins, Gary H., 1971. Letter with Encl. ("Copper Properties") from Gary H. Higgins, Lawrence Radiation Laboratory, to Herbert E. Grier, February 17. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-087.
- Werth, Glenn C., 1971. Status of Contained Nuclear Explosive Applications. University of California, Lawrence Radiation Laboratory, *Report UCRL-51074*, June 21. Livermore, CA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-103.
- McGarr, H. J., 1971. Letter with encls. (letter from H. J. McGarr to Glen Clark, June 17 and List of Firms) from H. J. McGarr, Holmes & Narver, to G. H. Higgins, June 22. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-087.

- Higgins, Gary H., 1971. Letter with encl. ("Chemical Mining of Copper, Agenda for July 8 Meeting at LLL") from Gary H. Higgins, Lawrence Radiation Laboratory, to Harold F. Perla, June 25. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-087.
- Ewing, Anthony H., 1971. "Meeting with H. J. McGarr, Holmes and Narver." Memo from Anthony H. Ewing, Atomic Energy Commission, to Files, July 20. On file at: Archives and Research Center, Lawrence Livermore National Laboratories, Livermore, CA, File PLO-087.
- Lewis, A. E., 1971. Nuclear Chimneys: Underground Containers for Chemical and Metallurgical Processing. Paper for presentation at the Symposium on the Underground Environment, Geological Society of America, Washington, D.C., November 3, 1971. University of California, Lawrence Radiation Laboratory, *Preprint UCRL-73130*, August 26. Livermore, CA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-087.
- Lewis, A. E., and, Robert L. Braun, 1972. Nuclear Chemical Mining of Primary Copper Sulfides. Paper prepared for AIME 1972 Meeting, San Francisco, CA. University of California, Lawrence Radiation Laboratory, *Preprint UCRL-73284*, January 27. Livermore, CA.
- Holzer, Fred, 1972. "Du Pont, in cooperation with Ranchers Mining Company..." Telex from Fred Holzer, Lawrence Livermore Laboratory, to E. M. Douthett, January 28. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-087.
- Haxby, Ronald L., 1972. Letter from Ronald L. Haxby, Occidental Minerals Corporation, to Art Lewis, February 29.
- Swan, David, 1972. Letter from David Swan, Kennecott Copper Corporation, to J. R. Schlesinger, March 20. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-087.
- Kahn, J. S., 1972. "Visit to Bureau of Mines, Washington, D.C., March 23, 1972." Memo from J. S. Kahn, Lawrence Livermore Laboratory, to Fred Holzer and Glenn Werth, March 30. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-087.
- Kelly, John S., 1972. Letter from John S. Kelly, U.S. Atomic Energy Commission, to David Swan, April 10. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-087.

- Braun, R. L., 1972. "Report of Visit to the Mining, Metallurgical, and Fuels Engineering Department of the University of Utah." Memo from R. Braun, Lawrence Livermore Laboratory, to J. Kahn, April 17. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-087.
- Holzer, Fred, 1972, Letter from Fred Holzer, Lawrence Livermore Laboratory, to Hollis Dole, May 30. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-087.
- Davy, Keith J., 1972. "Kennecott Copper Corporation Proposal." Memo with encl. (letter from D. Swan to John Kelly, June 1) from J. Keith Davy, U.S. Atomic Energy Commission, to Richard Pastore and Alfred Holzer, June 12. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-087.
- Kelly, John S., 1972. Letter from John S. Kelly, U.S. Atomic Energy Commission, to David Swan, June 18. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-087.
- Lewis, A. E., 1972. "Kennecott Proposal for Engineering Feasibility Study of Nuclear Chemical Mining of Copper Ore. Reference Letter from D. Swan to J. Kelly - June 1, 1972." Memo from A. E. Lewis, Lawrence Livermore Laboratory, to F. Holzer, June 30. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-087.
- Hard, R. A., 1972. "Planning for Joint Program with Lawrence Livermore Laboratory on Nuclear Rubbilization - July 19, 1972." Memo from R. A. Hard, Ledgemont Laboratory, to J. C. Agarwal, August 7. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA. File PLO-087.
- Johnson, Gerald W., 1972. Letter from Gerald W. Johnson, U.S. Atomic Energy Commission, to David Swan, September 21. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-087.
- Johnson, Gerald W., 1972. "Negotiation of Feasibility Study Agreement with Kennecott Copper Corporation." Letter from Gerald W. Johnson, U.S. Atomic Energy Commission, to Brigadier General Mahlon E. Gates, September 21. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-087.
- U.S. Atomic Energy Commission. Nevada Operations Office, 1972. Contract Between The United States of America, Represented by The United States Atomic Energy Commission, and Kennecott Copper Corporation. Draft, October 18. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-087.

- Higgins, Gary H., 1972. Economics and Safety of Nuclear Chemical Copper Mining. Paper prepared for presentation at the AIME, 1972 Meeting, San Francisco, CA. University of California, Lawrence Radiation Laboratory, *Preprint UCRL-73611*. Livermore, CA.
- Petrovic, Louis J., 1973. Letter with encl. ("Visit to Atomic Energy Commission, Lawrence Livermore Laboratory, Livermore, California, February 22, 1973," memo from F. A. Hard, P. Huska, and L. J. Petrovic to J. C. Agarwal, March 9) from Louis J. Petrovic, Ledgemont Laboratory, Kennecott Copper Corporation, to Arthur Lewis, March 20. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-088.
- Pastore, Richard M., 1973. "Status of NV Plowshare Activities - April 1973." Memo from Richard M. Pastore, U.S. Atomic Energy Commission, Nevada Operations Office, to Gerald W. Johnson, May 9. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030 [OUO].
- DiBona, Bennie G., 1973. "Status of Plowshare Activities - July 1973." Memo from Bennie G. DiBona, U.S. Atomic Energy Commission, Nevada Operations Office, to Gerald W. Johnson, August 8. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030 [OUO].
- Hale, Verle Q., and R. Glen Fuller, 1973. Preliminary Environmental Characterization of Candidate Sites for an Experimental Plowshare Copper Recovery Project. Manuscript, Battelle, Columbus Laboratories, Columbus, OH, September 12. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV.
- Weed, Robert C., 1974. Letter from Robert C. Weed, The Anaconda Company, Tucson, AZ, to Dixie Lee Ray, May 3. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-088.
- Larson, C. E., 1974. Letter from C. E. Larson, U.S. Atomic Energy Commission, to Robert C. Weed, May 30. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-088.
- Batzel, Roger E., 1974. Telex from Roger E. Batzel, Lawrence Livermore Laboratory, to Senator Peter H. Dominick, June 10. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-118.
- Ewing, Anthony H., 1974. "July 11 Meeting with Anaconda." Letter with encls. ("Proposed Agenda for In-Situ Leaching Meeting with AEC & LLL" and Attendance List) from Anthony H. Ewing, U.S. Atomic Energy Commission, to Edward H. Fleming, July 16. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-088.

- Holzer, Fred, 1974. Draft Letter from Fred Holzer, Lawrence Livermore Laboratory, October 3. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.
- Braun, R. L., A. E. Lewis, R. G. Mallon, C. J. Sisemore, H. A. Tewes, R. A. Hard, I. V. Klumpar, and L. J. Petrovic, 1974. In Situ Leaching of a Nuclear Rubbilized Copper Deposit. Paper for presentation at the IAEA Conference, Vienna, Austria, January 20-24, University of California, Lawrence Livermore Laboratory, *Preprint UCRL-76281*, December 11. Livermore, CA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-037.
- Lawrence Livermore Laboratory, 1974. Energy and Resource Program Annual Report for 1974. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.
- Elkins, Lloyd E., Richard Garwin, Ted Greenwood, Claude Hocott, Henry Jacoby, Gerald W. Johnson, Richard Morse, and F. A. Long (Chairman), 1975. An Analysis of the Economic Feasibility, Technical Significance, and Time Scale for Application of Peaceful Nuclear Explosions in the U.S., with Special Reference to the GURC Report Thereon. Report to U.S. Arms Control and Disarmament Agency from The Program on Science, Technology and Society, Cornell University, Ithaca, NY, April. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-028.
- Rowen, Henry, 1976. The Economics for Peaceful Nuclear Explosions. Report to International Atomic Energy Authority from Stanford University, February. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-028.
- Ballou, L., M. Nordyke, and G. Werth, 1977. A Summary of U.S. PNE Experience. Report prepared for U.S. Energy Research & Development Administration from Lawrence Livermore Laboratory, *Report UCID-17649*, November 17. On file at: Defense Threat Reduction Information Analysis Center, Albuquerque, NM; and Technical Reports Library, Lawrence Livermore National Laboratory, Livermore, CA.
- Lawrence Livermore National Laboratory, 1982. Project Plowshare: A Brief History. *Energy and Technology Review*, pp.13 -20, September. Lawrence Livermore National Laboratory, Livermore, CA.
- Lawrence Livermore National Laboratory, n.d. "Chemical Mining Flooded Primary Sulfide Ore." Chemical mining drawing. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-0883.
- Lawrence Livermore National Laboratory, n.d. "Pressure Vessel For Experimental Leaching of Primary Sulfide Ore." Pressure vessel drawing\_05\_a. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-0883.



## 4.12 COPPER RECOVERY

### Plowshare Program

#### **Nuclear Explosives for Fracturing Copper Ore Deposits for In Situ Leaching Alaska, Arizona, California, Colorado, Idaho, Nevada, New Hampshire, New Mexico, Texas, Utah, Virginia, Washington and Wyoming**

The use of nuclear explosives to recover copper from low grade oxidized and sulfide ore deposits was a focus of inquiry in the 1960s by scientists from the Lawrence Radiation Laboratory working on the Plowshare program. Recovery of copper was based on the idea that the use of nuclear explosive mining techniques would make it possible to acquire more copper ore than through conventional methods, and would provide an important demonstration project for the program. In this application, nuclear explosives would be used to fracture a copper ore deposit to create either an underground chimney of fractured rubble or a retarc (mound) in a near-surface deposit (Figures 4.12-1 and 4.12-2). Once the ore body was fractured, the mining system would require incorporation of a leaching solution into the ore, a sub-surface collection area, sump and pumping facilities to recover the solution, and a piping system to transport the solution to a processing plant for separation. A successful project would pivot on finding a deposit with suitable requirements (i.e., appropriate size and thickness of the ore body, a form of copper that could be leached, appropriate subsurface geology for the operation of the collection scheme, and isolation of ground water supplies). Numerous copper deposits were identified as possible locations for nuclear mining methods (Figure 4.12-3), and one property, the Safford deposit, received serious study (see Project Sloop – Chapter 4.37). The remaining locations are discussed here under Copper Recovery.

In 1961, the Lawrence Radiation Laboratory produced a report on nuclear explosives in mining. The report introduced the concept of combining nuclear explosives with chemical mining to recover copper ore. The Lawrence Radiation Laboratory hired the Anaconda Company as a subcontractor to work together to study the technical and economic feasibility of using nuclear explosives in commercial mineral recovery operations. In 1963, the Anaconda Company submitted a study that evaluated the technical and economic feasibility of applying nuclear explosives to a mining situation. The Anaconda Company selected two deposits in Butte, Montana for the engineering and economic analysis: the Berkeley Pit and the Kelly Mine. Meanwhile, the Laboratory requested that the U.S. Bureau of Mines and Geological Survey compile a list of deposits in the conterminous United States that were suitable for a nuclear mining experiment. The list was distributed in May 1963, and included 105 ore deposits, 38 of which were copper.

The Hansom Project was formally identified by the Lawrence Radiation Laboratory in September 1963. The overriding purpose of the project was to demonstrate the use of nuclear explosives in rock breaking applications, and had the following technical objectives: 1) to demonstrate the capabilities of nuclear explosives in a rock breaking

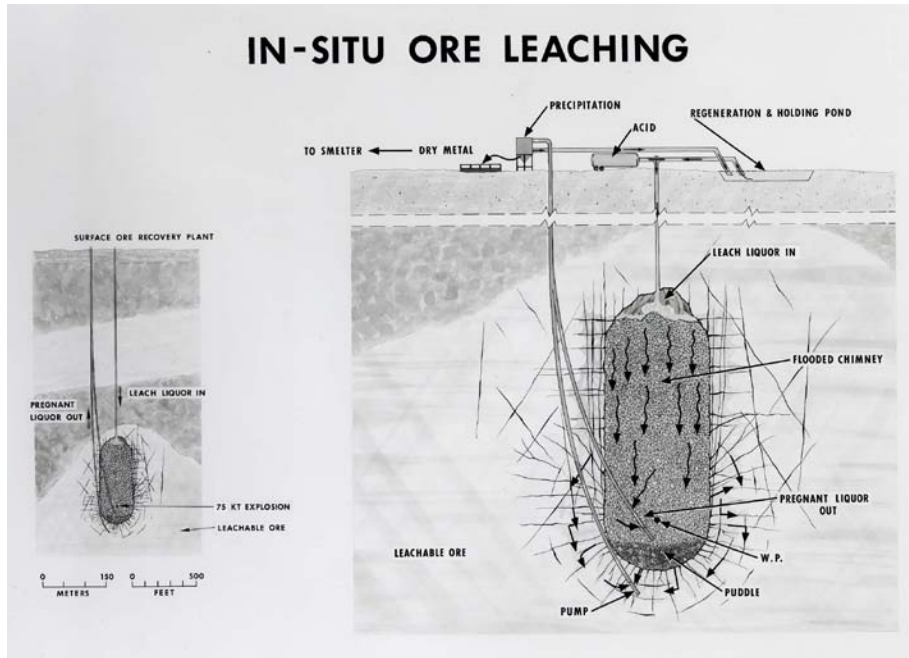


Figure 4.12-1. Conceptual diagram of in situ leaching of an ore deposit after being fractured by a contained nuclear explosion (Lawrence Livermore National Laboratory n.d.).



Figure 4.12-2. Conceptual diagram of in situ leaching of a near surface deposit after being fractured by nuclear explosives using the retarc method (Lawrence Livermore National Laboratory n.d.).

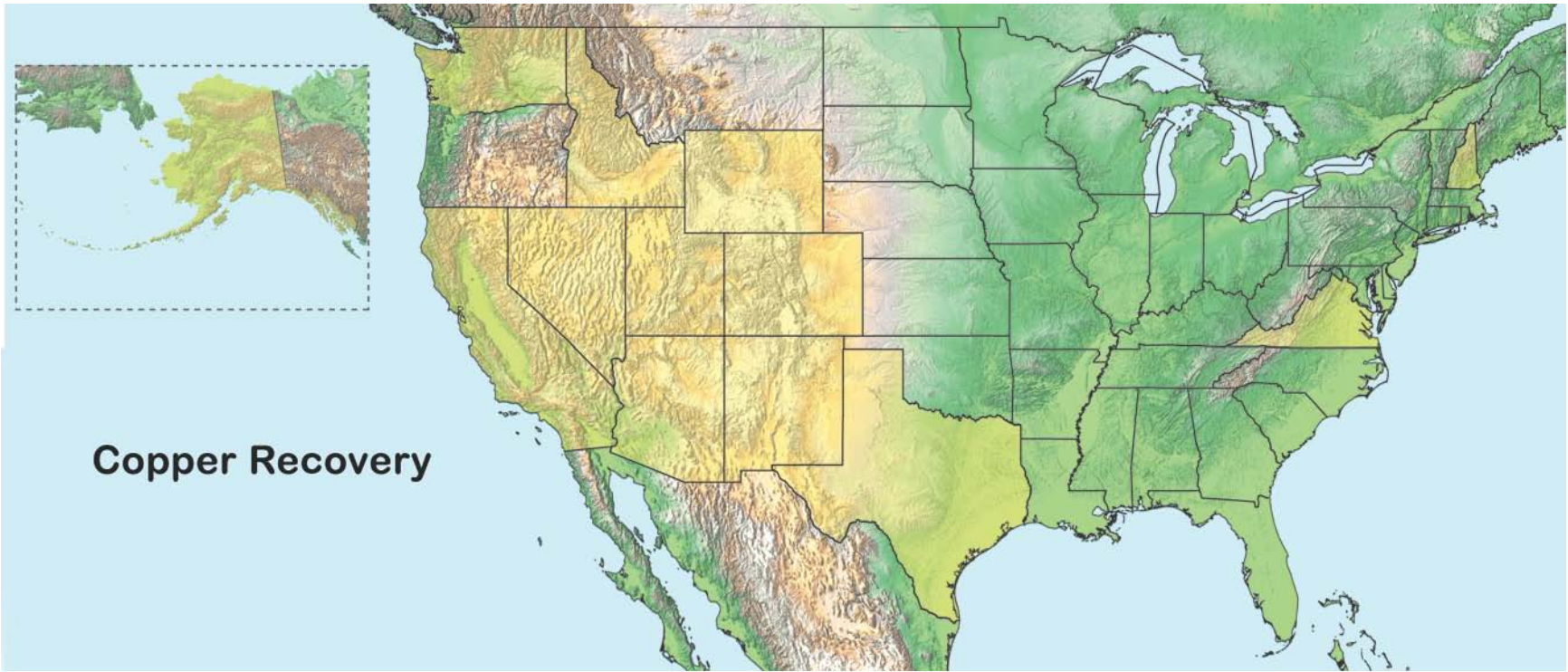


Figure 4.12-3. States with copper deposits (in yellow) that were proposed for a Copper Recovery Project (adapted from USA Relief Maps 2004).

situation of commercial interest; 2) to demonstrate the feasibility of use of the broken rock or the rock zone; and 3) to establish experience that could be used for practical economic and engineering analyses of similar projects of larger magnitude. Thus, the project focus was broad and included a wide variety of proposed industrial applications; however, Hansom Committee correspondence indicates a focus on mining applications with an emphasis on the in situ recovery of copper ore. The recovery of copper ore was likely given the most consideration because the process for leaching copper deposits had already been developed, and leaching copper ores broken by nuclear explosives was viewed as having an economic advantage over conventional techniques since mining could be accomplished at a large scale. Mining copper ore using nuclear techniques was thought to have the greatest potential for a successful demonstration and the Hansom Committee reviewed a number of locations and mining schemes for this purpose.

One of the early deposits considered by the Hansom Committee was Copper Flat in Sierra County, New Mexico. It appears that the proposal for a Plowshare mining experiment at Copper Flat was initiated by the owner, George Lotspeich. In September 1963, a representative from the San Francisco Operations Office visited the site and concluded that based on preliminary data, Copper Flat was an excellent site for a Hansom project. However, an October 1964 Lawrence Radiation Laboratory memo indicates that there may have been some problems, namely, there was question about the efficiency of leaching given the composition of the deposit, the tonnage and shape of the ore body had not been accurately determined, and the location of the water table was unfavorable for both the detonation and the leaching operation. The following December, S. M. Hansen, a member of the Hansom Committee, visited the Bear Creek Mining Company Offices in Denver, Colorado, to obtain geologic data on Copper Flat that were collected by the company during an evaluation of the property in 1958 and 1959. Assay evidence from the Bear Creek report showed that a significant amount of the total copper was contained within pyrite, and the deposit would not be productive for copper recovery.

Yet, the Lawrence Radiation Laboratory advised Mr. Lotspeich to request that the U.S. Atomic Energy Commission undertake a study of Copper Flat for a nuclear mining demonstration. In January 1965, at a Plowshare Advisory Committee Meeting, Copper Flat was included on the agenda as a possible Plowshare application. Later that month, the Lawrence Radiation Laboratory issued a report on Copper Flat based on a field examination of surface outcrops, drill cores, and data from previous geologic studies. The leaching of copper from chalcopyrite and pyrite was also investigated. The report concluded that leaching would not result in the recovery of enough of the copper contained in the Copper Flat deposit to be profitable, and did not recommend a Plowshare demonstration unless the technical uncertainties of leaching the copper sulfides could be addressed. In February, the Frederic H. Hatch Company responded to the study with a number of questions. The Laboratory maintained their position that the leaching of copper sulfides from Copper Flat was not economically feasible.

The Cactus Ore deposit also received some attention for using Plowshare techniques to fracture the ore body to prepare it for in situ leaching. The Miami Copper Company held a meeting on November 7, 1964 with representatives from the Lawrence Radiation

Laboratory's Hansom Committee, the U.S. Bureau of Mines, and the San Francisco Operations Office, to discuss the possibility of a copper leach experiment at their Cactus Ore property. The deposit is located in Gila County, Arizona, near the town of Miami. After a field visit to the site, it was agreed that a joint study should be undertaken to investigate the deposit in detail. The Miami Copper Corporation had explored and drilled the ore body and inquired if nuclear mining and leaching would be beneficial for developing the resource. The Cactus Ore deposit was a chalcocite ore (chalcocite is a copper mineral) with some oxide copper in altered schist. In a January 1964 memo, a scientist from the Lawrence Radiation Laboratory argued that a nuclear detonation in the Pinal schist would consolidate the deposit making it impervious to leaching. The Cactus Ore location was visited again in March 1964; however, the location was no longer considered for a Plowshare application.

Another location proposed for a project to recover copper was the area to be impounded by the proposed Buttes Dam. In the 1960s, the U.S. Bureau of Reclamation studied building a rock-fill dam for flood control on the Gila River, at a location about 15 miles west of the town of Florence, in Pinal County, Arizona. The dam site and the area up stream were within the Riverside mining area or the Cochran Basin and contained a low grade copper ore. Drilling operations were underway to determine the size, grade and potential depth of the deposit. According to a June 9, 1964 Hansom Committee memo, U.S. Bureau of Mine personnel were planning to propose that the area be considered for a nuclear mining experiment. In April 1965, members of the Hansom Committee visited the site and recommended that the deposit be evaluated for requirements of a copper recovery project.

Hansom Committee members met with representatives from Phelps Dodge Electronic Products Corporation in February 1964. A large percentage of copper demand was for electrical use and the corporation was interested in becoming a producer as well as a consumer of copper. To this end, Phelps Dodge expressed interest in the possibility of Plowshare applications for mining copper at a large ore body in the southwest, but did not disclose the precise location.

The effort to find a suitable deposit for a demonstration of using nuclear explosives to fracture ore deposits for in situ leaching of copper continued. In February 1964 and again in April 1964, field visits were made to copper mines and leaching operations in the southwest. Meanwhile, inquiries were made about the size and status of the copper industry in an effort to determine future demands and prospects for copper. In April 1965, five locations were reported as "alternate" sites for an oxidized copper ore leaching demonstration project. These included: 1) O.K. Mine, Beaver County, Utah; 2) Copper Standard Mine, Pinal County, Arizona; 3) Butte Reservoir Sites, Pinal County, Arizona (mentioned above); 4) Copper Prospect, Gila County, Arizona; and 5) Copper Creek District, Pinal County, Arizona. Of the five locations, Copper Prospect was rejected, and the Copper Creek District was considered the best alternative site. The locations were most likely alternates to a low grade copper deposit near Safford, Arizona, that was the subject of planning for a joint feasibility study between Kennecott Copper Corporation

and the U.S. Atomic Energy Commission for an in situ copper recovery project (later to be named Project Sloop).

In early March 1966, a Plowshare progress review meeting was held in Denver, Colorado, with representatives from the U.S. Bureau of Mines and the U.S. Atomic Energy Commission attending. At the meeting there was discussion about a cooperative study between the U.S. Atomic Energy Commission and the Kennecott Copper Corporation concerning a copper recovery project at Kennecott's Safford deposit. While work on the study was continuing, funding was not secure and the U.S. Bureau of Mines was continuing with their investigation of alternate sites for a project.

Lawrence Radiation Laboratory conducted an economic evaluation for copper recovery and summarized their findings in a March 17, 1966 memo. The study examined the use of nuclear explosives to fracture near surface deposits and the use of contained explosives to create rubble chimneys. Both rock breaking approaches in tandem with in situ recovery techniques were considered profitable given the current national shortage of copper, favorable price structure, and interest by industry, along with advances in copper leaching over the past few years. According to the evaluation, the application of nuclear fracturing and in situ leaching would increase the copper reserve by making available ore from lower grade deposits, thus, lowering the cost of copper (Figure 4.12-4).

By August 1966 the Laboratory distributed a memo that outlined the geologic conditions necessary for a copper leach application based on the grade of the ore, leachability of the copper minerals, mineralogy and size of the ore body, water conditions, and safety. Using these criteria, 32 privately owned sites were listed that were under consideration for copper recovery (Table 4.12-1). These were evaluated on a graded scale as: probable, possible, and questionable. A number of deposits required more information before a determination could be made. By 1967, focus was on a cooperative study between the Kennecott Copper Corporation and the U.S. Atomic Energy Commission for recovery of copper from Kennecott's Safford deposit named Project Sloop, and a feasibility study for this project was issued on June 1, 1967.

While feasibility and planning studies for Project Sloop were underway, the Lawrence Radiation Laboratory continued their effort to identify additional low grade copper ore deposits for nuclear mining methods. By October 1968, 60 deposits in the western United States were identified, and included 18 properties considered feasible by the U.S. Bureau of Mines, and 24 properties that were given a favorable status by David D. Rabb from the Lawrence Radiation Laboratory (Table 4.12-2). The Laboratory continued to be approached by a number of companies and individuals concerning a copper recovery project. These included inquiries from the Kaiser Aluminum and Chemical Corporation, Ranchers Exploration and Development Corporation, and others. However, by 1969 Project Sloop was being re-evaluated for economic feasibility. Concerns were raised that nuclear mining of low grade deposits may be cost prohibitive and interest in this approach lost traction in favor of a Plowshare application for mining deep, primary, copper deposits (see Copper Ore Chemical Mining – Chapter 4.11).

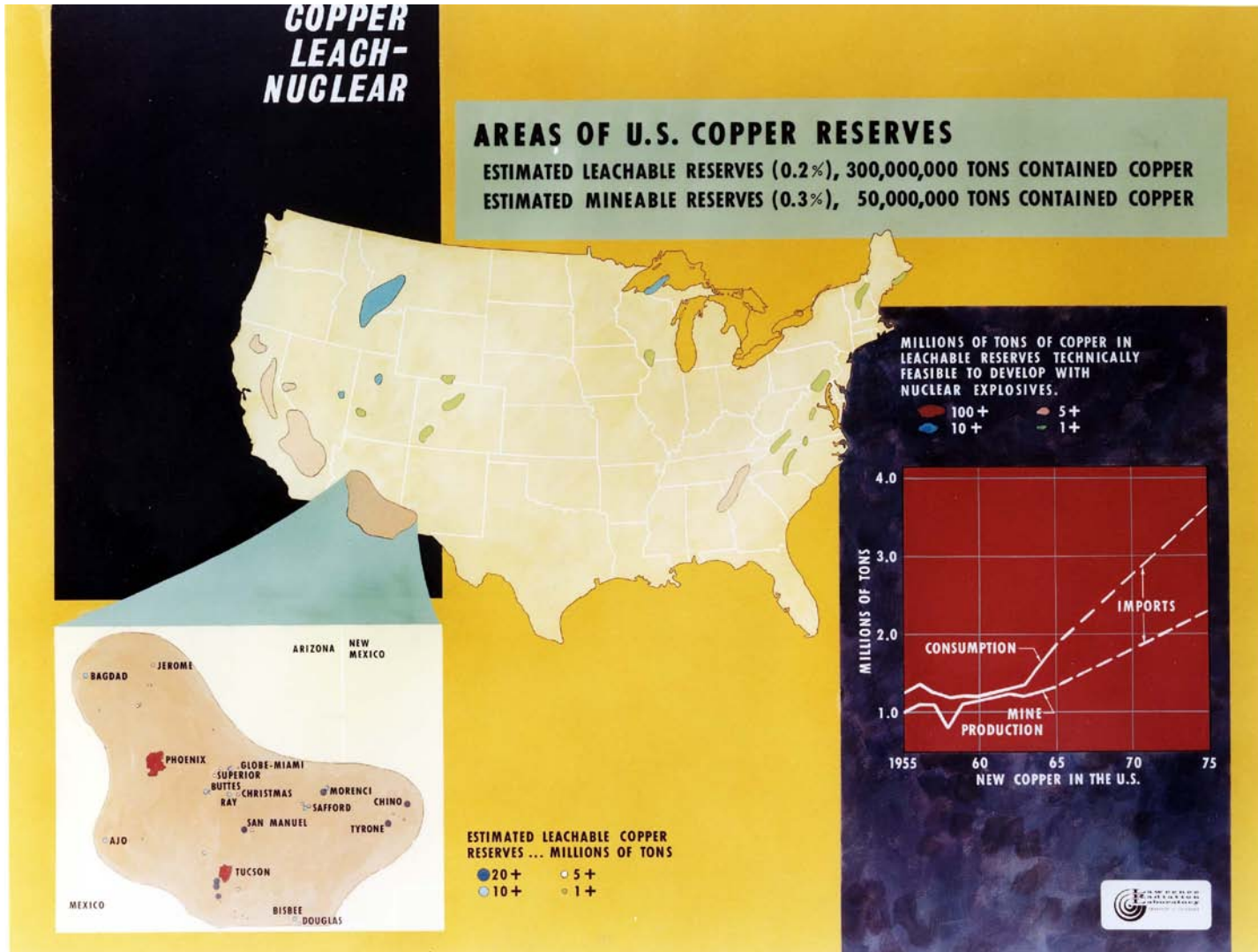


Figure 4.12-4. Schematic diagram showing estimated leachable copper reserves in the United States (Lawrence Livermore National Laboratory n.d.).

Table 4.12-1. Locations Considered for a Plowshare Copper Recovery Project in 1966 (from Hansen 1966)

<b>Site Name</b>	<b>Location</b>	<b>Evaluation</b>
Safford	Safford, Arizona	Probable
AS&R deposit	Central Arizona	Probable
Olanche Mine	Inyo County, California	Possible
Cactus	Gila County, Arizona	Possible
Copper Cliff	Seven Devils area, western Idaho	Possible
Black Mesa Breccia Pipe	Yavapai County, Arizona	Possible
Big Eight Mine	Lemhi County, Idaho	Possible
Red Ledge Mine	Adams and Washington Counties, Idaho	Possible
Copper Canyon	Lander County, New Mexico	Possible
Clipper	King County, Washington	Possible
Squaw Peak Mine	Yavapai County, Arizona	Possible
O.K. Mine	Beaver County, Utah	Questionable
Old Reliable Mine	Pinal County, Arizona	Questionable
Copper Standard	Arizona	Questionable
Bluebell	Southwest of Mayer, Arizona	Insufficient data
Copper Creek Deposits	Pinal County, Arizona	Insufficient data
Copper Basin	Yavapai County, Arizona	Insufficient data
Copper Springs	Gila County, Arizona	Insufficient data
Elephant Head Mine	Santa Cruz County, Arizona	Insufficient data
Lucky Ledge Mine	Santa Cruz County, Arizona	Insufficient data
Empire Mine	Yuma County, Arizona	Insufficient data
Glacier Peak	Chelan and Snomish Co., Washington	Insufficient data
Kerr McGee's Copper	10 miles south Miami, Arizona	Insufficient data
Metcalf Mine	Greenlee County, Arizona	Insufficient data
Mineral Hill	Near Parker, Arizona	Insufficient data
Owl Head Butte	Pinal County, Arizona	Insufficient data
Plumas	Plumas County, Arizona	Insufficient data
Red Mountain	Near Nogales, Arizona	Insufficient data
Riverside Mining District	Pinal County, Arizona	Insufficient data
Trinity Mine	Chelan County, Washington	Insufficient data
Tyrone Mine	Grant County, New Mexico	Insufficient data
Zonia	South of Prescott, Arizona	Insufficient data



Table 4.12-2. List of Low-Grade Copper Deposits for In Situ Copper Recovery, 1968 (from Rabb 1968)

<b>Deposit Name</b>	<b>Location</b>	<b>Considered Feasible by...</b>
Horseshoe Bay	60°1'N, 147°56'W, La Touche Island, Alaska	Bureau of Mines
Copper Bullion	60°20'33"N, 147°39'25"W, Knight Island, Alaska	Bureau of Mines
Orange Hill	140 miles north of Valdez, Nabesna, Alaska	Bureau of Mines
Ruby Creek	Baird Mountains, 25 miles north of Kobuk, Alaska	Bureau of Mines
Brady	58°35'N, 136°50'W, Brady Glacier, Alaska	Bureau of Mines
Carlota	Gila County, near ICC Co., Arizona	LRL
Copper King	Gila County, Arizona	possible
Red Mountain	T11S, R25E, Graham County, Arizona	LRL
San Juan	10 mine, Safford, Graham County, Arizona	possible
United Nuclear	13 miles east southeast of Safford, Graham County, Arizona	LRL and Bureau of Mines
Lone Star	12 miles east of Safford, Arizona	LRL and Bureau of Mines
Metcalf	East of Morenci, Greenlee County, Arizona	possible
Ajo Extension	3 miles south of New Cornelia, Pima County, Arizona	LRL
Copper Giant	3 miles south of New Cornelia, Pima County, Arizona	possible
San Pedro Cobre	Pima County, Arizona	possible
American	Sec 19 T1S, R14E, Pinal County, Arizona	possible
Apex	1 mile northwest of Ray, Pinal County, Arizona	LRL
Buttes	20 miles northeast of Florence, Pinal County, Arizona	possible
Red Mountain	Sec 29 T23S, R16E, Santa Cruz County, Arizona	LRL and Bureau of Mines
Copper Mountain	Sec 2 T23S, R14E, Santa Cruz County, Arizona	possible
Old Reliable	Sec 10 T8S, R18E, Pinal County, Arizona	LRL and Bureau of Mines
Red Rover	Mariposa County, California	LRL
Blue Bell	Sec 10 T11N, R1E, Yavapai County, Arizona	possible
Jackson Mule Group	Sec 14-23 T8N, R1W, Yavapai County, Arizona	LRL and Bureau of Mines
Loma Prieta	Sec 21 T13N, R3W, Yavapai County, Arizona	LRL
Victory and Zonia	Sec 14 T11N, R4W, 11 miles southeast Kirkland, Yavapai County, Arizona	LRL
Ord Mountain	San Bernardino County, California	LRL and Bureau of Mines
Olancha	Inyo County, California	possible
Akron	Sec 3 T49N, R5E, Gunnison County, Colorado	possible
IXL (Donart Group)	Sec 2,3,4,9,10 T16N, R4W, Washington	LRL and Bureau of Mines
Red Ledge	9 miles north of Cupruin, near Hell's Canyon, Snake River, Washington	LRL
Cactus Peak	Nye County, Nevada	LRL
Copper Mountain	Mineral County, Nevada	possible

Table 4.12-2. List of Low-Grade Copper Deposits for In Situ Copper Recovery, 1968  
(continued)

<b>Deposit Name</b>	<b>Location</b>	<b>Considered Feasible by...</b>
Sunrise	Donna Ana County, New Mexico	possible
Liberty Bell	Grant County, New Mexico	possible
Eighty-Five	Hidalgo County, New Mexico	LRL
Copper Cities	Sandoval County, New Mexico	possible
Hy. 60 Prospect	Socorro County, New Mexico	possible
The O.K. Mine	10 miles northwest of Milford, Beaver County, Utah	possible
Copper King	Sec 4 T27N, R14E, Taos County, New Mexico	LRL
Cactus	Beaver County, Utah	LRL and Bureau of Mines
Lone Star	Sec 1 T40N, R33E, Ferry County, Washington	LRL and Bureau of Mines
Rainy	Sec 16 T24N, R10E, King County, Washington	LRL and Bureau of Mines
Cerillos	Sec 5 T14N, R6E, Santa Fe County, New Mexico	LRL and Bureau of Mines
Copper Flat	Sierra County, New Mexico	Bureau of Mines
Alder	T33N, R22E, Okanogan County, Washington	possible
Glacier Peak	9 miles west of Holden, Snohomish County, Washington	Bureau of Mines
Copper King	Laramie County, Wyoming	possible
Terlingua – 248 Mine	Near Alpine, Texas	possible
Un-named	Dominican Republic	possible
Petaquilla and Botija	North of Nata; southwest of Balboa, Republic of Panama	possible
Sunrise Copper	T29N, R10E, Snohomish County, Washington	possible
Copper Canyon	T32N, R43W, Lander County, Nevada	LRL
Red Ledge Mine	Adams County, Idaho	LRL
Squaw Creek	Yavapai County, Arizona	possible
Three-R Mine	4 miles south of Patagonia, Santa County, Arizona	possible
Clipper, Galbrath and United Copper	T24N, R11E, King County, Virginia	possible
Black Mesa	Yavapai County, Arizona	possible
Big Eight	T25E, R15N, Lemhi County, Idaho	possible
Conway Granite	White Mountains County, New Hampshire	possible

Copper Recovery was a Level 4 activity and the level of liability is low. Locations with existing facilities, mines and drill holes, were used for data collection at a small number of the proposed locations.

## **CHRONOLOGICAL BIBLIOGRAPHY**

Flangas, W. G., and L. E. Shaffer, 1960. An Application of Nuclear Explosives to Block Caving Mining. University of California, Lawrence Radiation Laboratory, *Report UCRL-5949*, June 2. Livermore, CA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore CA, File PLO-102.

Smith, Fred L., and Thomas R. Young, 1960. Nuclear Explosives and Mining Costs. University of California, Lawrence Radiation Laboratory, *Report UCRL-5928*, July. Livermore, CA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA.

University of California. Office of Public Information, 1960. Press Release, Subject: Nuclear explosions with "block-caving" mining for recovery of ore, from University of California, September 15. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-085.

Flangas, William G., and David D. Rabb, 1961. Nuclear Explosives in Mining. University of California, Lawrence Radiation Laboratory, *Report UCRL-6636*, September 26. Livermore, CA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-102.

Lawrence Radiation Laboratory, 1963. Memo from Lawrence Radiation Laboratory, K-Division, to Distribution, January 3. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-102.

Lawrence Radiation Laboratory, 1963. "Appendix A to Purchase Order 6176305. Appendix to Purchase Order between Lawrence Radiation Laboratory and Anaconda Company, March 13. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-102.

Hasler, J. W., and A. S. Konselman, 1963. Mineral Deposits Suitable for Plowshare Mining Experiments. U.S. Department of the Interior. Geological Survey and Bureau of Mines, Technical Letter Special Projects-7, May 29. Denver, CO. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV.

Anaconda Company, 1963. "Copper Ore Body, Nuclear Feasibility Study." Report to Lawrence Radiation Laboratory from Anaconda Company, Mining Research Department, July 20. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-102.

- Lekas, Mitchell A., 1963. "Trip Report, Hillsboro, New Mexico." Memo from Mitchell A. Lekas, U.S. Atomic Energy Commission, San Francisco Operations Office, to Distribution, September 20. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-085.
- Lekas, Mitchell A., 1963. "Trip Report, Miami Copper Corporation." Memo from Mitchell A. Lekas, U.S. Atomic Energy Commission, San Francisco Operations Office, to Files, November 12. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-085 [OUO].
- Hurlbut, S. W., 1963. Letter from S. W. Hurlbut, Anaconda Company, Mining Research Department, to G. H. Higgins, December 9. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-102.
- Anaconda Company, [1963]. Nuclear Mining Feasibility Study. University of California, Lawrence Radiation Laboratory, *Report UCRL-13104*. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-102.
- Rabb, David D., 1964. "Plowshare Mining Prospect - Miami Copper Company." Memo from David D. Rabb, Lawrence Radiation Laboratory, to Hansom Committee, January 21. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-085.
- Shaffer, Lysle E., 1964. "Comments on Plowshare Mining Prospect -- Miami Mining Company." Memo with Encl. ("Barren Pinal Schist," drawing) from L. E. Shaffer, University of California, Department of Mineral Technology, to Gary H. Higgins, January 29. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-085.
- Lombard, David B., 1964. "Phelps-Dodge Interest in Plowshare." Memo from D. B. Lombard, Lawrence Radiation Laboratory, to Hansom Committee, February 10. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-085.
- Lombard, David B., 1964. "Phelps-Dodge (Phase II)." Memo from D. B. Lombard, Lawrence Radiation Laboratory, to Distribution, February 25. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-085.
- Rabb, David D., 1964. "Tour of Copper Mining Leaching-In-Place Sites." Memo from David D. Rabb, Lawrence Radiation Laboratory, to Distribution, February 25. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-085.

- Hardwick, William R., 1964. Letter from William R. Hardwick, U.S. Department of the Interior, Bureau of Mines, to Glenn Werth, April 9. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-086.
- Werth, Glenn C., 1964. Underground Applications and Industry Interest Presentation Plowshare Advisory Committee, April 14, 1964. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029 [OUO].
- Hansen, Spenst M., 1964. "Trip Report - Tour of Southwest Copper Leaching Operations." Memo from S. M. Hansen, Lawrence Radiation Laboratory, to Hansom Committee, April 15. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-086.
- Werth, Glenn C., 1964. Letter from Glenn C. Werth, Lawrence Radiation Laboratory, to William R. Hardwick, April 20. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-086.
- Rabb, David D., 1964. "The Buttes Reservoir Site." Memo from David D. Rabb, Lawrence Radiation Laboratory, to Hansom Committee, June 9. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-109 and PLO-086.
- Shaffer, Lysle E., 1964. "Copper." Memo from Lysle Shaffer, Lawrence Radiation Laboratory, to Plowshare Physics K Division, Gary H. Higgins, June 15. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, June 15.
- Rabb, David D., 1964. Memo from David D. Rabb, Lawrence Radiation Laboratory, to Hansom Group, June 17. On file at: Archives and Research, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-086.
- U.S. Atomic Energy Commission, 1964. Suggested Nuclear Excavation Projects and Possible Nuclear Excavation Projects. Manuscript, Division of Peaceful Nuclear Explosives, July. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.
- Nesbitt, L. E., 1964. Letter from L. E. Nesbitt, Duval Corporation, Carlsbad, NM, September 30, and response from David D. Rabb, Lawrence Radiation Laboratory, October 13, and Richard A. Heckman, Lawrence Radiation Laboratory, October 15.
- Evaluation of Copper Flat, 1964. "Evaluation of Copper Flat Prospect as a Potential Hansom Plowshare Application." Handwritten notes, October 16. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-086.

- Rabb, David D., 1964. "Brief on Copper Flats." Memo from David D. Rabb, Lawrence Radiation Laboratory, to Record, October 16. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-086.
- Higgins, Gary H., 1964. Letter from Gary H. Higgins, Lawrence Radiation Laboratory, to George O. Lotspeich, Jr., November 10. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-086.
- Hansen, Spent M., 1964. "Report of Trip to Bear Creek Mining Company Offices, Denver, Colorado, to Obtain Geologic Data on Copper Flat, New Mexico." Memo from S. M. Hansen, Lawrence Radiation Laboratory, to Hansom Committee, December 9. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-086.
- Higgins, Gary H., 1964. Letter from Gary H. Higgins, Lawrence Radiation Laboratory, to George O. Lotspeich, Jr., December 14. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-086.
- Lotspeich, George O. Jr., 1964. Letter from George O. Lotspeich, Jr. to Gary Higgins, December 30. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-086.
- Plowshare Advisory Committee, 1965. Plowshare Advisory Committee, Report on Thirteenth Meeting. Meeting held at Lawrence Radiation Laboratory, Livermore, CA, January 12-13. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029 [OUO].
- Hansen S. M., and D. B. Lombard, 1965. Report of Field Examination of the Copper Flat Prospect, Sierra County, New Mexico. Manuscript, University of California, Lawrence Radiation Laboratory, Livermore, CA, January 24. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-087.
- Lekas, Mitchell A., 1965. "Interest of Mountain Copper Company in Copper Flat Orebody." Memo from M.A. Lekas, U.S. Atomic Energy Commission, San Francisco Operations Office, to Files, February 8. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-087.
- Patton, Henry H., 1965. Letter from Henry H. Patton, Frederic H. Hatch & Co., Inc., to Gerald W. Johnson, February 16. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-087.
- Rabb, David D., 1965. "Photos of Subsidence Areas." Memo from David D. Rabb, Lawrence Radiation Laboratory, to Record, February 19. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-102.

- Philip, John F., 1965. Letter with Encl. (Project Sloop Status Report, February 25, 1965, manuscript and draft outline of Project Sloop study) from John F. Philip, U.S. Atomic Energy Commission, San Francisco Operations Office, to Gerald W. Johnson, February 26. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-087 [OUO].
- Johnson, Gerald W., 1965. Letter from Gerald W. Johnson, Lawrence Radiation Laboratory, to Henry H. Patton, March 5. On file at: Archives and Research, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-087.
- Wyman, R. V., 1965. Letter from R. V. Wyman to Gary H. Higgins, March 15. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-087.
- Hansen, Spent M., 1965. "Report of Field Evaluation of Alternate Sites for Oxidized Copper Ore Leaching Demonstration Experiment." Memo from S. M. Hansen, Lawrence Radiation Laboratory, to Hansom Committee, April 26. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-087.
- Howard, Hubert E., 1965. Letter from Hubert E. Howard, Jr., Shasta Mining Corporation, to Geology Section, Lawrence Radiation Laboratory, May 4. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.
- Rabb, David D., 1965. Atomic Energy for Mining; presented at the Tenth Annual Minerals Symposium, Grand Junction, Colorado, May 7-8, 1965. University of California, Lawrence Radiation Laboratory, *Report UCRL-14197-T*, May 8. Livermore, CA. On file at: Technical Reports Library, Lawrence Livermore National Laboratory, Livermore, CA.
- Copper Flat, 1965. "Copper Flat." Handwritten Note, July 30. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-085.
- Lawrence Livermore National Laboratory, 1966. Status Report, Plowshare Program. University of California, Lawrence Livermore National Laboratory, *Report UCRL-ID-126143*, February 1. Livermore, CA.
- Hansen, S. M., and D. B. Lombard, 1966. "Economic Evaluation of Nuclear Breeding and In-Situ Leaching of Large Copper Deposits." Memo from S. M. Hansen and D. B. Lombard, Lawrence Radiation Laboratory, to Glenn C. Werth, March 17. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-087.

- Rabb, David D., 1966. "USBM - USAEC Plowshare Progress Review Meeting in Denver, March 1-2; Trip Report." Memo from David D. Rabb, Lawrence Radiation Laboratory, to Distribution, March 22. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-101.
- Hansen, Spent M., 1966. "Sites for Copper Leach Application Projects." Memo from Spent Hansen, Lawrence Radiation Laboratory, to Glenn Werth, August 2. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-087.
- Rabb, David D., 1966. "Copper Production Methods." Memo from David D. Rabb, Lawrence Radiation Laboratory, to Records, August 2. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-087.
- Werth, Glenn C., 1967. Program Activities for Plowshare. University of California, Lawrence Livermore National Laboratory, *Report UCRL-124785*, February 3. Livermore, CA. On file at: Technical Reports Library, Lawrence Livermore National Laboratory, Livermore, CA.
- Werth, Glenn C., 1967. Letter with Encls. (letter from H. Clyde Davis to Glenn Werth, January 30, and letter from Glenn Werth to Clyde Davis, February 9) from Glenn C. Werth, Lawrence Radiation Laboratory, to John F. Philip, February 28. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-087.
- Tewes, H. A., 1967. "Establishment of a Leaching Task Group." Memo from H. A. Tewes, Lawrence Radiation Laboratory, to J. S. Kahn, July 31. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-087.
- Werth, Glenn C., 1968. "Plowshare Reductions." Memo from G. C. Werth, Lawrence Radiation Laboratory, to Distribution, February 15. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.
- Rabb, David D., 1968. "Selected Copper Deposits." Memo from David D. Rabb, Lawrence Radiation Laboratory, to Gary H. Higgins, October 25. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-087.
- Durek, Joseph J., 1969. Letter from Joseph J. Durek, Kaiser Aluminum and Chemical Corporation, to John Kelly, August 6. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-087.



Kelly, John S., 1969. Letter from John S. Kelly, Atomic Energy Commission, to Joseph J. Durek, August 22. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-087.

Holzer, Fred, 1969. Letter from Fred Holzer, Lawrence Radiation Laboratory, to J. Keith Davy, November 5.

Hogan, D. K., 1970. Letter from D. K. Hogan, Ranchers Exploration and Development Corporation, to A. E. Lewis, September 24. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-087.

Philip, John F., 1971. "Bureau of Mines Report on Copper Leaching Studies." Letter from John Philip, U.S. Atomic Energy Commission, San Francisco Operations Office, to Richard Hamburger, June 2. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-087.

Werth, Glenn C., [between 1966 and 1973], Handwritten notes on Plowshare program meetings from Glenn C. Werth, U.S. Atomic Energy Commission, Division of Peaceful Nuclear Explosives, 1966-1973. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-118.

Lawrence Livermore National Laboratory, n.d. "Areas of U.S. Copper Reserves." Map and drawing. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-0884.

Lawrence Livermore National Laboratory, n.d. "In-Situ Ore Leaching." In situ ore leaching drawing. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO26-1.

Lawrence Livermore National Laboratory, n.d. "Retarcs for In-Situ Leaching." Retarcs in situ leaching drawing. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-0881.

**THIS PAGE INTENTIONALLY LEFT BLANK**

## **4.13 DOGSLED**

### **Plowshare Program Nuclear Cratering Experiment in Sandstone Arizona and Utah**

Project Dogsled was originally designed as a media effects experiment to gather data on scaling and entrapment of radioactivity in either sandstone or limestone. On January 18, 1961, Lawrence Radiation Laboratory personnel conducted a reconnaissance in Area 10 at the Nevada Test Site to select a location for the Dogsled experiment. They identified a graded area near the Stagecoach and Scooter tests. This trip report mentions that the graded area would accommodate approximately 50 detonations equal in magnitude to the Dogsled shots, but no other details are available. The Project Dogsled scope evidently changed and by 1962, a conceptual model for Project Dogsled had been developed by Lawrence Radiation Laboratory. As of July 10, 1962, selection of an appropriate location for this test was underway and consideration was being given to conducting the experiment at Dugway Proving Grounds in Utah. Project Dogsled was to be a 1- to 10-kt nuclear test, tentatively planned for FY 1964, with a projected cost of 4.5 million dollars. By the time of a September 11, 1962 U.S. Atomic Energy Commission Meeting, plans for Project Dogsled had changed and the experiment was then scheduled for FY 1965 in a sandstone medium in Arizona or Utah (Figure 4.13-1). Project Dogsled would provide data on cratering in sandstone that would be comparable to data obtained in alluvium from Sedan and the data expected from hard rock by Schooner. These data would be applicable to the sandstone within the proposed Trans-Isthmian Canal Project. Another project, named Streetcar, was scheduled for a limestone medium on the Nevada Test Site. A study of the geology and hydrology in the United States found the Colorado Plateau to best meet the requirements for the experiment.

In April of 1963, the U.S. Atomic Energy Commission Nevada Operations Office requested planning authorization for Project Dogsled. By this time, the yield for the experiment had grown to 100 kt. The nuclear device was to be detonated in a 36-inch diameter hole at a depth between 400 and 600 ft. Planning included site selection, site exploration, safety hazards evaluation, a cost estimate and preparation of a comprehensive plan for the project. Previous testing indicated that sandstone was unique in regard to cratering characteristics and, therefore, this project would be extremely valuable in expanding current knowledge of sandstone's cratering characteristics, contributing to cratering theory, and facilitating more reliable predictions on cratering dimensions of future megaton explosions.

A Pre-Dogsled high explosives program was proposed as a low-yield (approximately 20 ton) cratering program to determine the shape of the burst curve in order to determine the exact design requirements for Dogsled. Pre-Dogsled was to be funded and executed by the U.S. Army Engineer, Nuclear Cratering Group. As Dogsled increased in scope from a project to an experimental program, it included planned technical programs, cratering

studies, radiological studies, air blast studies, ground shock studies, and physical effects studies.

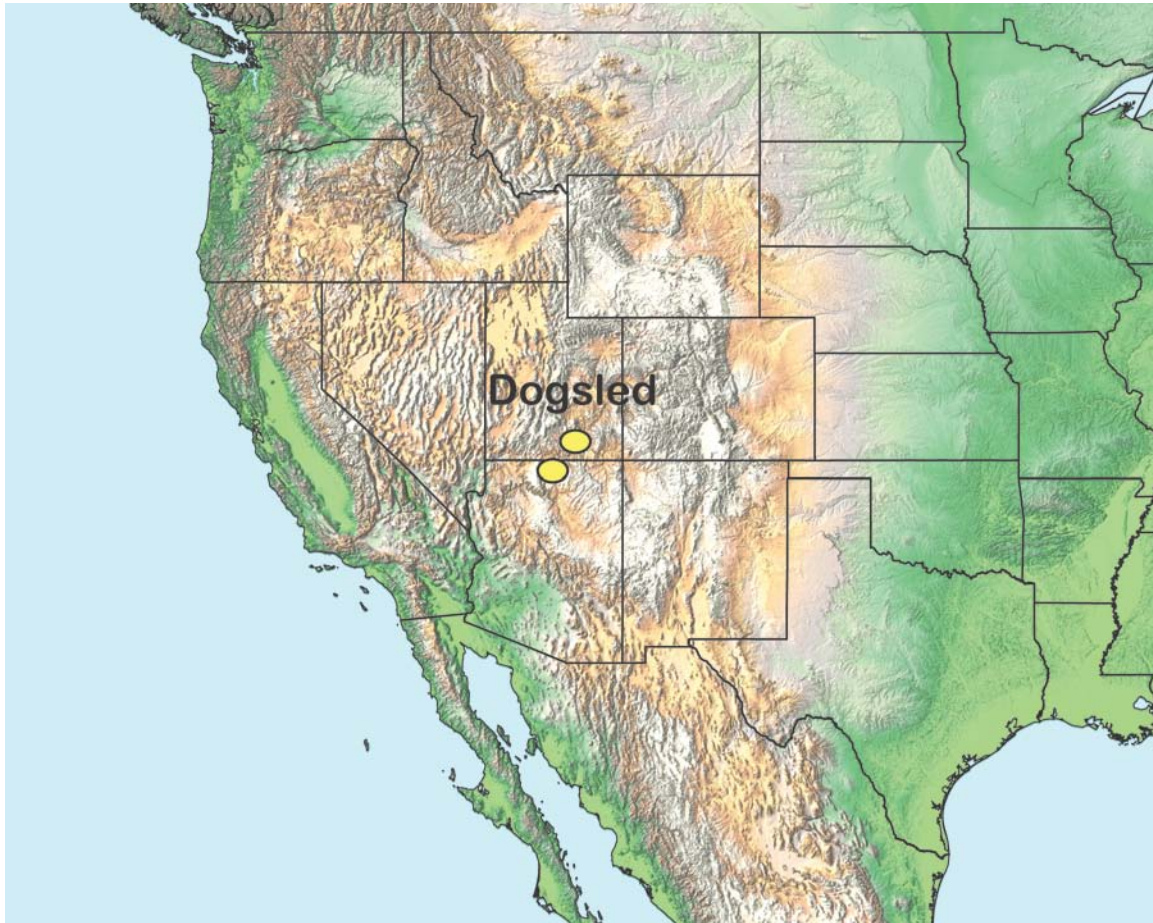


Figure 4.13-1. Location of Project Dogsled in southern Utah (top) and northern Arizona (bottom) (adapted from USA Relief Maps 2004).

The technical objectives for Dogsled were: 1) to develop theoretical and empirical models for cratering in a dry, porous rock with intermediate-yield range explosives; 2) to gather data on the nature and amounts of radioactivity released; and 3) to study other safety programs as part of the nuclear excavation program. Answering these questions for a dry, porous rock medium was considered critical to developing appropriate designs for full-scale nuclear excavation projects, particularly in regard to the Isthmian Canal Project with a potential site location in the Gatun sandstone formation.

Costs continued to be projected in the 4 to 6 million-dollar range. The preliminary design for Project Dogsled required a massive, indurated sandstone formation in an area of low relief and minimal population density. Additional characteristics of the host medium were to include sub-horizontal strata, a porosity in excess of 8 percent, a low water content

(including both bound water in minerals and water in available pore space), a minimum thickness of 500 ft, and a depth to groundwater in excess of 900 ft.

In 1963, the U.S. Geological Survey conducted a literature search to identify potential sites in the western United States that met the project criteria. A number of sandstone formations were studied that ultimately did not meet at least one of the required criteria. These included the Aztec (Nevada and California), the Casper (Wyoming), the Chuska (Arizona and New Mexico), the Coconino (Arizona, Utah, and Nevada), the Cow Springs (Arizona and Utah), the Entrada (Arizona and Utah), the Fox Hills (Colorado, Montana, North Dakota, South Dakota, and Wyoming), the Glorietta (New Mexico), the Moenave (Arizona and New Mexico), the Nugget (Idaho and Wyoming), the Santa Rosa (New Mexico), the Tensleep (Wyoming), the Timothy (Idaho), and the Weber (Colorado and Utah). Three sandstone formations (the Navajo, the Wingate, and the Cedar Mesa formations of the western Colorado Plateau) were identified as appropriate project locations with the Navajo determined best suited for Project Dogsled.

By the end of 1963, the U.S. Geological Survey identified 11 potential sites (Figure 4.13-2 and Table 4.13-1) that met the project criteria, five in northern Arizona and six in southern Utah. The proposed locations in northern Arizona were Echo Cliffs (north), Echo Cliffs (south), Kaibito Plateau, the Paris Plateau, and Tsai Skizzi Rock. In southern Utah, the locations were Cedar Mesa, Clark Bench, Early Weed Bench, Red Rock Plateau, Scorpion Flat, and Straight Cliffs (Fortymile Ridge). Some preliminary field and laboratory data were available from a previous engineering study of the Glen Canyon dam site, and additional laboratory data came from the U.S. Bureau of Reclamation. By May 1964 the site selection effort for Dogsled had received approval and area surveys for site selection were in progress by September. No Project Dogsled information later than this date has been located by this research effort.

Project Dogsled was a Level 4 activity. Activity was confined to conceptual design, background research, and site visits.

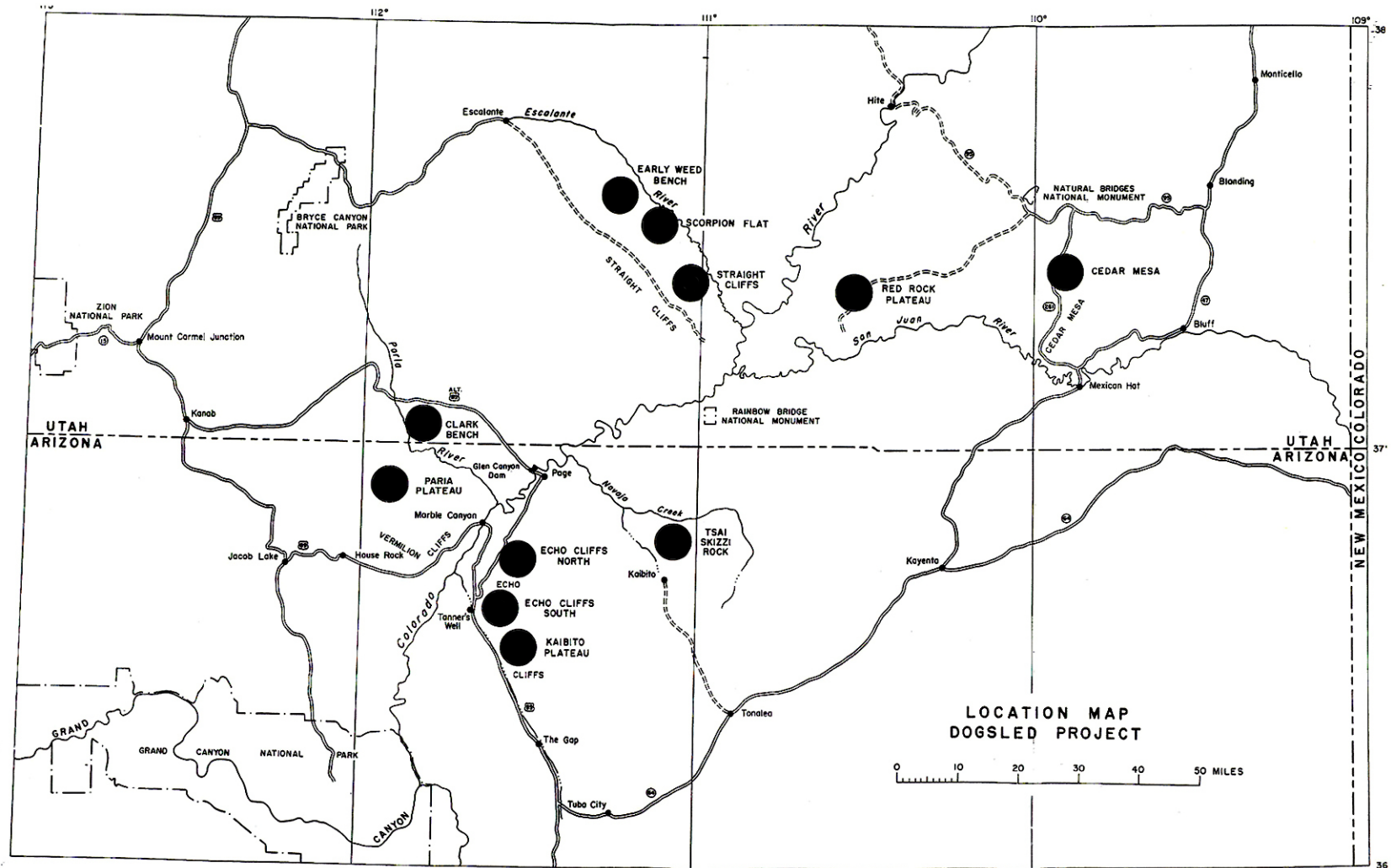


Figure 4.13-2. Map of preliminary Project Dogsled locations (adapted from Hansen and Parker 1963).

Table 4.13-1. Preliminary Dogsled Locations (after Hansen and Parker 1963)

Site	Location	Access
Paria Plateau, Arizona	Sec. 36, T41N R4E, about half way from Jacob Lake, Arizona to Page; about 17 miles N. 77°W. of Marble Canyon. Bureau of Land Management.	Dirt roads N. up House Rock Valley from House Rock, Arizona on alt. U.S. 89, and south past the Cockscomb in Utah via U.S. 89. Air connections at Page, Arizona.
Echo Cliffs, south Arizona	About 4 mi. E. of Echo Cliffs escarpment 5 mi. ESE. of junction of U.S. 89 and Alt. U.S. 89, 14 mi. S. of Marble Canyon (Navajo) Bridge and about 23 airline miles SSW. Of Page, Arizona. Navajo Indian Reservation.	Easily reached from U.S. 89 via short jeep trail. Air connections at Page, Arizona.
Echo Cliffs, north Arizona	About 5 mi. E. of Echo Cliffs escarpment, 4 mi. E. of U.S. 89, 12 mi. S. 10° W. of Page, Arizona in extreme NE. Cor. Tanner Wash 15' quadrangle, about 14 mi. S. of Glen Canyon dam. Navajo Indian Reservation.	Easily reached from U.S. 89 via short jeep trail. Air connections at Page, Arizona.
Kaibito Plateau, Arizona	Intersection 111°30'W. and 36°30'. About 4-1/2 mi. E. of U.S. 89, 29 mi. S. 3 W. of Page. Would be in Secs. 14 and 23, T36N R8E. if surveyed. Navajo Indian Reservation.	Reached via dirt road from Cedar Ridge on U.S. 89, about 8 mi. Air connections at Page, Arizona.
Straight Cliffs, Utah (Fortymile ridge)	Sec. 27, T39S R8E, 40 mi. S. 50° E. of Escalante, Utah on Fortymile ridge between Escalante River and Kaiparowits Plateau. Bureau of Land Management..	Dirt road from Escalante, about 45 mi.
Tsai Skizzi Rock, Arizona	Gray Mesa 25 mi. ESE of Page, Arizona near SE corner Navajo Creek 15' quad on Navajo Reservation. Ground zero is about 3 mi. SE of Tsai Skizzi Rock. (Sec. 24, T39N R12E, unsurveyed).Navajo Indian Reservation	Reached from Kaibito, about 25 mi. by dirt roads. Kaibito is about 25 mi. by dirt roads from Tonalea, 21 mi. NE of Tuba City on Arizona Highway 64.

Table 4.13-1. Preliminary Dogsled Locations (continued)

Site	Location	Access
Early Weed Bench, Utah	Sec. 3 or 9, T38S R6E, NE of Kaiparowits Plateau, 25 mi. SE. of Escalante, Utah. Bureau of Land Management.	Good dirt road to within 4 to 5 mi. of site.
Cedar Mesa, Utah	Sec. 2, T39S R18E, almost due north 20 mi. from Mexican Hat, Utah. Bureau of Land Management.	Reached from Utah 261 north about 25 mi. from Mexican Hat.
Clark Bench, Utah	Sec. 20, T43S R1E, 21 airline mi. N. 63° W. of Page, Arizona. Bureau of Land Management.	Reached via dirt road 3-1/2 mi. from Utah U.S. 89, 25 mi. from Glen Canyon dam. Air connections at Page, Arizona.
Scorpion Flat, Utah	Sec. 3, T38S R7E, 30 mi. S. 58° E. of Escalante Utah, between Escalante River on NE., Twentyfive Mile Gulch on NW., and Coyote Gulch on south. Bureau of Land Management.	Very difficult; no existing roads within about 10 mi.
Red Rock Plateau, Utah	Sec. 24, T39S R12E, about 40 mi. N. 67° W. of Mexican Hat, Utah at bend of dirt road west of VABM 5150 near center, east border of Lake Canyon 15' quad., Utah. Bureau of Land Management.	Dirt road leads into area from Natural Bridges Nat'l. Monument 35 mi. to NE. Natural Bridges are reached from Mexican Hat or Blanding, a distance of about 40 mi.



## CHRONOLOGICAL BIBLIOGRAPHY

- Bacigalupi, C. M., 1961. "Trip Report on Visit to NTS, 17 January through 20 January, 1961." Memo with encl. ("Proposed Dogsled Area," drawing, January 18) from C. M. Bacigalupi, Lawrence Radiation Laboratory, to Distribution, January 23. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-066.
- McCool, W. B., 1962. "Atomic Energy Commission, Plowshare Excavation Program." Note with encl. (Plowshare Program, Nuclear Excavation Application, manuscript) from W. B. McCool, U.S. Atomic Energy Commission, Report 811/105, July 10. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0075573.
- U.S. Atomic Energy Commission, 1962. U.S. Atomic Energy Commission Meeting 1872: Tuesday, September 11, 1962. Minutes from U.S. Atomic Energy Commission, November 9. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0032480.
- U.S. Atomic Energy Commission, 1963. Plowshare Program. In *Annual Report to Congress of the Atomic Energy Commission*, pp. 224 -252, January. Government Printing Office, Washington, D. C.
- Science News, 1963. Dig Ditches with Atoms. *Science News Letter*, February 9. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.
- U.S. Atomic Energy Commission, 1963. Long Range Plan, 1964-1973, Peaceful Uses of Nuclear Explosives Program (Plowshare). Report from U.S. Atomic Energy Commission, March 20. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV.
- Miller, Robert E., 1963. "Project Dogsled." Memo from Robert E. Miller, U.S. Atomic Energy Commission, Nevada Operations Office, to List, April 30. On file at: Nevada Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0018528 [OUO].
- Defense Atomic Support Agency, 1963. Peaceful Uses of Nuclear Explosives: Project Plowshare. Report from Defense Atomic Support Agency, Sandia Base, Albuquerque, NM, September 1. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV [OUO].

- Graves, Ernest, 1963. "Program and Budget Justification, Nuclear Explosives Studies." Letter with encl. ("FY 1964 Program") from Ernest Graves, Lawrence Radiation Laboratory, U.S. Army Engineer Nuclear Cratering Group, to Chief of Engineers, Department of the Army, September 20. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029 [OUO].
- Hansen, W. R., and G. G. Parker, 1963. Technical Letter: Dogsled-1, Potential Sites, Project Dogsled. Report for the U.S. Atomic Energy Commission from U.S. Department of the Interior, Geological Survey, November 22, Denver, CO.
- Johnson, Walter, 1963. Project Plowshare - Opportunity for the Drilling Industry. University of California, Lawrence Radiation Laboratory, *Report UCRL-7615*, December 6. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV.
- Lawrence Livermore National Laboratory, 1964. Status of Plowshare Field Programs. Report from Lawrence Livermore National Laboratory, May 6. On file at: Technical Reports Library, Lawrence Livermore National Laboratory, Livermore, CA.
- Defense Atomic Support Agency, 1964. Peaceful Uses of Nuclear Explosives: Project Plowshare. Report From Defense Atomic Support Agency, Sandia Base, Albuquerque, NM, September 1. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV [OUO].
- Shafer, David S., William C. Beck, Dwight Treadwell, and Stephen A. Mellington, 1995. Inventory of Potential Environmental Restoration Liabilities Associated with Plowshare and Vela Uniform Program Sites. Manuscript, U.S. Department of Energy, Office of Environmental Restoration. On file at: Desert Research Institute, Las Vegas, NV.
- U.S. Department of Energy. Nevada Operations Office, 1997. Plowshare Program Executive Summary. Report from U.S. Department of Energy, December 22.
- U.S. Department of Energy. Nevada Operations Office, n.d. The Plowshare Program (Draft). Report from U.S. Department of Energy.

## **4.14 GALLEY**

### **Plowshare Program Row Charge Nuclear Cratering Experiment Idaho**

Lawrence Radiation Laboratory proposed projects Buggy and Galley because a row charge of nuclear explosives had never been detonated simultaneously and data were needed to understand the variables in such an event. Project Buggy, in an alluvial media, would study the dimensions of elongated craters in terms of how such dimensions related to yield, depth and spacing of charges. Project Galley in hard rock would look at the effect of uneven terrain on crater size, slope stability, and the effect of cratering in different media. The plan was to use data from Buggy for the design of Galley. Conceptually, Galley would be a row charge experiment with geometrical complexities in varying terrain or geology. Galley also was designed to acquire basic data on radioactivity distribution, ground shock, and air blast. By 1963, Project Galley was in the planning stages.

The U.S. Atomic Energy Commission's Long Range Plan for the Plowshare Program presented the courses of action for Objective 1, the Excavation Program. The Excavation Program was experimental and scheduled to be completed by the end of FY 1967, consisting of at least eight nuclear detonations with two detonations planned per year, to study the characteristics of craters produced in various earth media in relationship to depth of burial and yield. Galley was part of this series. In 1964, yields of the charges to be used in Galley were estimated to range between 2 and 20 kt each; the yield of the charges probably would vary. By FY 1966, Project Galley was planned for a location in southern Idaho (Figures 4.14-1 and 4.14-2). Proposed dates for project construction were April 1967 through October 1967 with the detonation planned for November 1967, but it is not clear if these dates were for the execution of Galley in Idaho or elsewhere.

During FY 1966, the Plowshare excavation experimental objectives were revised due to changing priorities driven by a need to meet the information requirements on excavation technology for the Atlantic-Pacific Interoceanic Canal Study Commission and this affected the execution of Galley. Subsequently, Project Galley was presented to the Bureau of the Budget for funding in FY 1968 as a high yield row charge, but given changing priorities; a series of 100-kt point charge projects was given a higher priority. Lawrence Radiation Laboratory's recommendation at the time was to delay or replace the Galley project.

A 1968 tentative schedule for the Plowshare Program presented two alternate schedules for the execution of projects. Under Alternate #1, the fabrication of Galley was to begin in the third quarter of FY 1969 with the test in the third quarter of FY 1970. The test would consist of five 40 kt devices in a row and would be conducted at the Nevada Test Site. Alternate #2 showed the Galley pre-fabrication beginning in the third quarter of FY

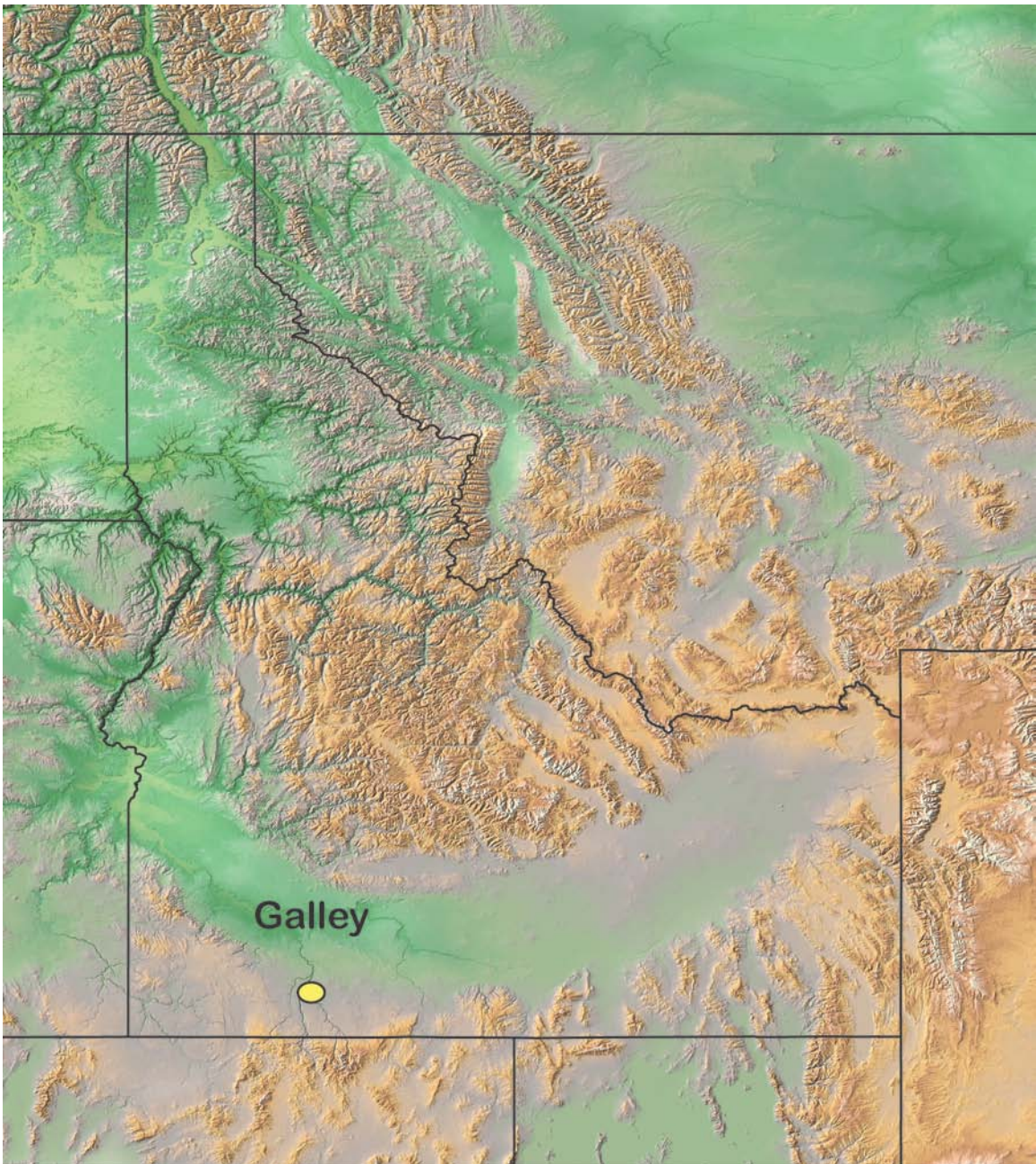


Figure 4.14-1. Area proposed for Project Galley in southern Idaho (adapted from USA Relief Maps 2004).

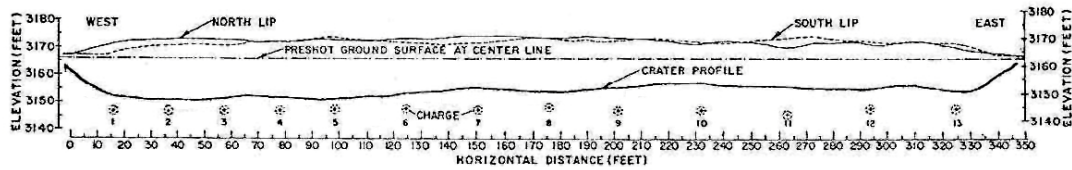


Figure 4.14-2. Proposed row charge profile for Project Galley (Lawrence Radiation Laboratory 1965, no figure number).

1968, the Galley fabrication beginning in the second quarter of FY 1970, and the test in the second quarter of FY 1971. Under this alternative, Galley would consist of seven 40-250 kt devices and was slated for the Nevada Test Site. On December 10, 1968, the U.S. Atomic Energy Commission established budget and reporting account numbers for Sturtevant, Galley, Gondola, and Yawl. Less than three weeks later, on December 27<sup>th</sup>, Representative Craig Hosmer, in a letter to President Johnson, proposed that the nuclear excavation project for the Cape Keraudren harbor in Western Australia be substituted for the Galley experiment. The results of this letter are not known, but Lawrence Radiation Laboratory's funding for Galley continued during FY 1969. A year later, in December of 1969, the U.S. Atomic Energy Commission contacted the Lawrence Radiation Laboratory regarding putting the Galley and Yawl projects in an indefinite deferred status. The laboratory responded with a recommendation of no further activity on the Galley Project in FY 1970.

In response to a query regarding the importance of nuclear excavation experiments, Lawrence Radiation Laboratory sent a letter dated January 13, 1970, to the manager of the U.S. Atomic Energy Commission, Nevada Operations Office, defending nuclear excavation experiments. This letter stated that Galley would remain on the schedule and that Lawrence Radiation Laboratory considered the Galley Project to be one of three key nuclear excavation experiments, along with Sturtevant and Yawl, because these experiments would provide data needed to adequately assess two critical aspects of nuclear excavation. At that time, researchers envisioned Galley as involving five or more 100 to 300 kt charges detonated simultaneously in a row configuration, producing a long ditch. The experiment would be needed to resolve the probable differences in both cratering mechanisms and radioactivity distribution between small, essentially experimental 1-kt blasts and useful 1,000-kt explosions with practical applications. The continuing promotion of Galley was also related to the notion that these types of large-scale experiments were needed to demonstrate to the private sector that useful excavations would result from nuclear detonations. There was increasing concern that without such successful demonstrations, few potential users would consider nuclear excavation as an alternative to more costly, but proven, conventional techniques. Despite this plea, there is no indication that Project Galley continued after this letter.

Project Galley was a Level 5 activity because there were no field activities.

## CHRONOLOGICAL BIBLIOGRAPHY

- U.S. Atomic Energy Commission, 1963. Plowshare Program. In *Annual Report to Congress of the Atomic Energy Commission*, pp. 2241-252, January. Government Printing Office, Washington, D. C.
- Science News, 1963. Dig Ditches with Atoms. *Science News Letter*, February 9. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.
- U.S. Atomic Energy Commission, 1963. Long Range Plan, 1964-1973, Peaceful Uses of Nuclear Explosives Program (Plowshare). Report from U.S. Atomic Energy Commission, March 20. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV.
- Defense Atomic Support Agency, 1963. Peaceful Uses of Nuclear Explosives: Project Plowshare. Report from Defense Atomic Support Agency, Sandia Base, Albuquerque, NM, September 1. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV [OUO].
- Graves, Ernest, 1963. "Program and Budget Justification, Nuclear Explosives Studies." Letter with encl. ("FY 1964 Program") from Ernest Graves, Lawrence Radiation Laboratory, U.S. Army Engineer Nuclear Cratering Group, to Chief of Engineers, Department of the Army, September 20. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029 [OUO].
- Johnson, Walter, 1963. Project Plowshare - Opportunity for the Drilling Industry. University of California, Lawrence Radiation Laboratory, *Report UCRL-7615*, December 6. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV.
- U.S. Atomic Energy Commission, 1964. Plowshare Program. In *Annual Report to Congress of the Atomic Energy Commission for 1963*, pp. 207-228, January. U.S. Government Printing Office, Washington D.C.
- Lawrence Livermore National Laboratory, 1964. Status of Plowshare Field Programs. Report from Lawrence Livermore National Laboratory, May 6. On file at: Technical Reports Library, Lawrence Livermore National Laboratory, Livermore, CA.
- Defense Atomic Support Agency, 1964. Peaceful Uses of Nuclear Explosives: Project Plowshare. Report From Defense Atomic Support Agency, Sandia Base, Albuquerque, NM, September 1. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV [OUO].

- Lawrence Radiation Laboratory, 1965. Nuclear Cratering: Experience, Problems, Programs. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0184661.
- U.S. Atomic Energy Commission, 1966. Reprogramming Activities in Plowshare Program FY 1966 and FY 1967. Manuscript, U.S. Atomic Energy Commission, Peaceful Nuclear Explosives, AEC 111/136, January 24. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0075653.
- Lawrence Livermore National Laboratory, 1966. Status Report, Plowshare Program. University of California, Lawrence Livermore National Laboratory, *Report UCRL-ID-126143*, February 1. Livermore, CA.
- U.S. Atomic Energy Commission. Nevada Operations Office, 1966. Briefing Material for the Plowshare Program. Manuscript, U.S. Atomic Energy Commission, April. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV.
- Lawrence Radiation Laboratory. U.S. Army Engineer Nuclear Cratering Group, 1967. Summary of Long Range Programming for Nuclear Excavation Research and Development. Manuscript, April 5. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.
- Kelly, John S., 1968. Letter with Encl. ("U.S. Atomic Energy Commission Plowshare Program Projections – Estimated Cost in Thousands and Number of Nuclear Detonations") from John S. Kelly, U.S. Atomic Energy Commission, Division of Peaceful Nuclear Explosives, to Charles C. Noble, April. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-065.
- Werth, Glenn C., 1968. "Alternate #1, Tentative Schedule – Plowshare Program – LRL Related." Schedule from Lawrence Radiation Laboratory, September 10. On file at: Archives and Records Office, Lawrence Berkeley National Laboratory, Berkeley, CA, File 434-900205, 28/48.
- Werth, Glenn C., 1968. "Alternate #2, Tentative Schedule - Plowshare Program - LRL Related." Schedule from Lawrence Radiation Laboratory, September 10. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-118.
- Ide, Roger H., 1968. Letter from Roger H. Ide, Lawrence Radiation Laboratory, to W. R. Cooper, November 25. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession Nos. NV0308620 and NV0309997.

- Kelly, John S., 1968. Telex from John S. Kelly, Lawrence Radiation Laboratory, to Multiple Recipients, December 10. On file at: Archives and Records Office, Lawrence Berkeley National Laboratory, Berkeley, CA, File 434-900205, 28/48.
- Connell, Richard P., 1968. Letter with encl. ("U.S. Atomic Energy Commission, Fiscal Year 1969 Midyear Review, Schedule A, Plowshare Program") from Richard P. Connell, Lawrence Radiation Laboratory, to John S. Kelly, December 19. On file at: Lawrence Berkeley National Laboratory, University of California, Berkeley, CA, File 434-900205, 28/48.
- Hosmer, Craig, 1968. Letter from Craig Hosmer, Member of U.S. Congress, Representative of California, to President Lyndon B. Johnson, December 27. On file at: Archives and Records Office, Lawrence Berkeley National Laboratory, Berkeley, CA, File 434-90025 47/48.
- U.S. Atomic Energy Commission, 1969. "United States Atomic Energy Commission, Plowshare Program Statement, JCAE FY 1970 Authorization Hearings." Statement from U.S. Atomic Energy Commission, April 18. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-028.
- Kelly, John S., 1969. "Approve the Update Concept for Project Yawl." Telex with encl. ("Analysis of FY 1969 Plowshare Program Financial Plans") from John S. Kelly, Lawrence Radiation Laboratory, to Glenn C. Werth, August 28. On file at: Archives and Records Office, Lawrence Berkeley National Laboratory, Berkeley, CA, File 434-900205, 28/48; and Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-072.
- Werth, Glenn C., 1969. "Actions Related to Placing the Yawl and Galley Projects in an Indefinite Deferred Status." Telex with encl. ("Analysis of FY 1970 Plowshare Program Financial Plans") from Glenn C. Werth, Lawrence Radiation Laboratory, to John S. Kelly, December 30. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-072.
- Higgins, Gary H., 1970. Nuclear Excavation (Letter to R. E. Miller, Atomic Energy Commission). University of California, Lawrence Livermore National Laboratory, *Report UCRL-124784*, January 13. Livermore, CA. On file at: Nuclear Testing Archives, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0330819.
- Connell, Richard P., 1970. "Request for FY70 Plowshare Financial Plan Change." Telex from Richard P. Connell, Lawrence Radiation Laboratory, to John S. Kelly, May 27. On file at: Archives and Records Office, Lawrence Berkeley National Laboratory, Berkeley, CA, File Director's Office, Budget, A&GS, Plowshare Program, DC 1968, File 434-900205, 28/48.



Shafer, David S., William. C. Beck, Dwight Treadwell, and Stephen. A. Mellington, 1995. Inventory of Potential Environmental Restoration Liabilities Associated with Plowshare And Vela Uniform Program Sites. Manuscript, U.S. Department of Energy, Office of Environmental Restoration. On file at: Desert Research Institute, Las Vegas, NV.

U.S. Department of Energy. Nevada Operations Office, 1997. Plowshare Program Executive Summary. Report from U.S. Department of Energy, December 22.

U.S. Department of Energy. Nevada Operations Office, n.d, The Plowshare Program (Draft). Report from U.S. Department of Energy.

**THIS PAGE INTENTIONALLY LEFT BLANK**

## 4.15 GEOTHERMAL POWER PLANT

### Plowshare Program Nuclear Explosives for Geothermal Power Western States

The idea of applying the Plowshare nuclear program to stimulate geothermal generated electrical power was discussed when the program was initiated in 1957. This concept gained attention in 1959 at the Second Plowshare Symposium. Roland Carlson from Sandia National Laboratory made a presentation in which he discussed successful geothermal projects in California and other parts of the world done with conventional methods. He outlined two different approaches using nuclear explosives for geothermal energy. The first one addressed the issue that geothermal projects sometimes do not have enough groundwater to make the amount of steam needed for long-term operation. This occurs when the underground zone is impermeable or there are no subsurface cracks to channel the water to the hot underground area. Carlson proposed that nuclear explosives could create a permeable zone. The explosion would create a chimney of broken material that would allow underground water to descend continually to the underlying heat source. In his second proposal, he strongly supported using nuclear explosives to take advantage of geothermal steam, citing the demonstrated longevity of naturally occurring steam sources shown by successful projects in Italy and New Zealand. He encouraged using nuclear explosives to produce a large underground cavity with extensive boundary surfaces. By creating a cavity that covered a substantial area, concerns regarding the difficulty in determining the pattern of the cracks in the rock through which the steam moves would be minimized because the cavity would intersect many cracks and probably would be filled continuously with high-temperature, high-pressure steam. This energy would be processed through a geothermal power plant (Figure 4.15-1). Carlson buttressed his argument for this approach by doing a cost comparison of a conventional geothermal power plant versus a geothermal field developed with nuclear explosives. He acknowledged that actual costs depend on the geographic location and that nuclear explosives are more economical for very large projects. He compared the costs for a proposed geothermal project in Southern California. His analysis showed that conventional methods would cost about 25 million dollars and the nuclear explosive method would be about 13.5 million dollars (including the cost of the nuclear devices), a savings of 11.5 million dollars.

At the Third Plowshare Symposium in 1964, University of California, Los Angeles Professor George Kennedy presented a concept for an entire geothermal energy system which involved using a nuclear device to create a large underground cavity of broken rock in a dry hot rock area. Surface or well water introduced into the cavity would produce high pressure, high temperature, superheated steam that could power a turbine generator (Figure 4.15-2). The steam would then be re-condensed and returned to the cavity to begin the process again, making the whole process essentially a closed system. The closed cycle meant minimal release of vapors to the environment during operation. In addition, deep detonation prevented venting of radioactivity with most of the fission

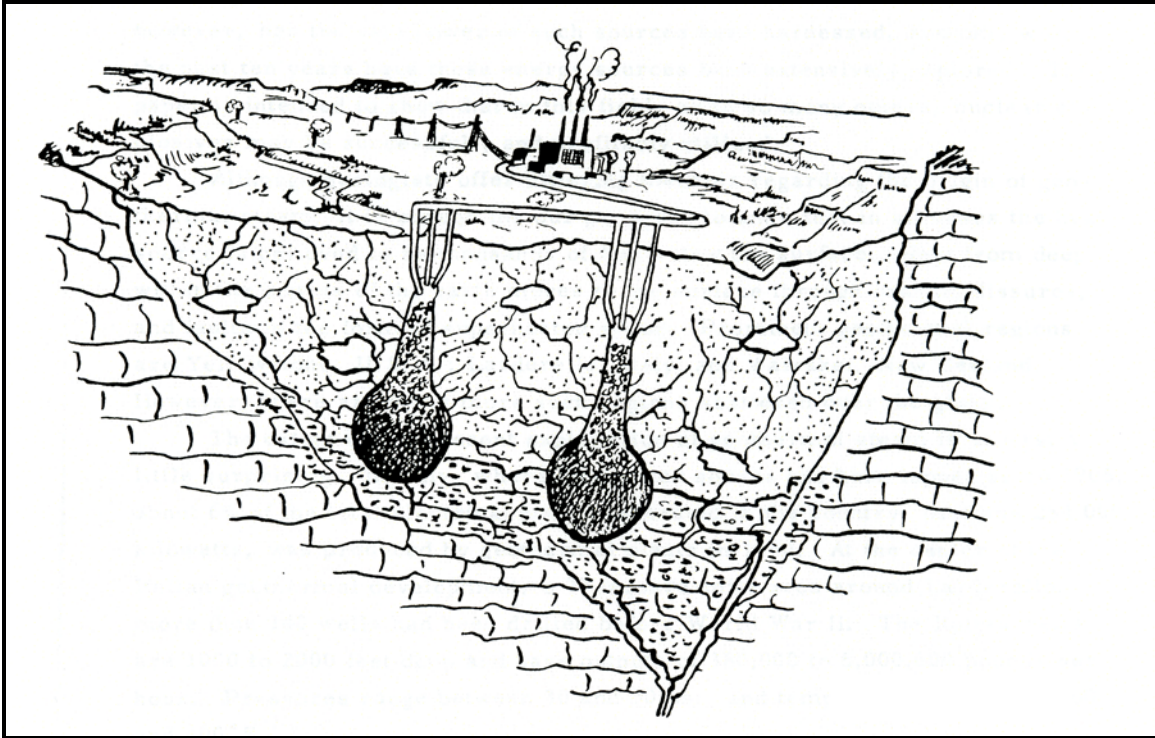


Figure 4.15-1. Nuclear cavity and processing plant for geothermal energy (Carlson 1959, Figure 8.1b).

products frozen in the molten rock of the cavity wall. This process would eliminate the need for naturally occurring geothermal steam sites, a rare commodity. The principal advantage of using nuclear augmented geothermal power plants would be their reliance on hot rock rather than natural steam from hot water.

A few months later, Sun Oil Company met with Keith Davy and Richard Hamburger of the Division of Peaceful Nuclear Explosions on October 8, 1964 to discuss the company's interest in geothermal heat. As a result of their drilling program, the company had encountered many areas with hyperthermal subsurface temperatures on about 17,000 acres of land on which they held two to three year options but the locations were not specified. The company representatives were briefed on the Plowshare Program and provided relevant documents. They indicated that they would review the materials and other available literature. Although the company was provided with contacts at Lawrence Radiation Laboratory, the U.S. Atomic Energy Commission Nevada Operations Office and the U.S. Atomic Energy Commission San Francisco Office, there is no indication that they pursued further discussions with Plowshare participants.

In January 1970, Battelle Memorial Institute's Pacific Northwest Laboratory presented a paper on the economics of Plowshare geothermal power at a Plowshare symposium in Las Vegas. This was a preliminary analysis of the concept for producing geothermal energy by way of a subsurface nuclear explosion. Battelle was studying the economics of various shot patterns for a multiple-cavity geothermal power plant for an unidentified

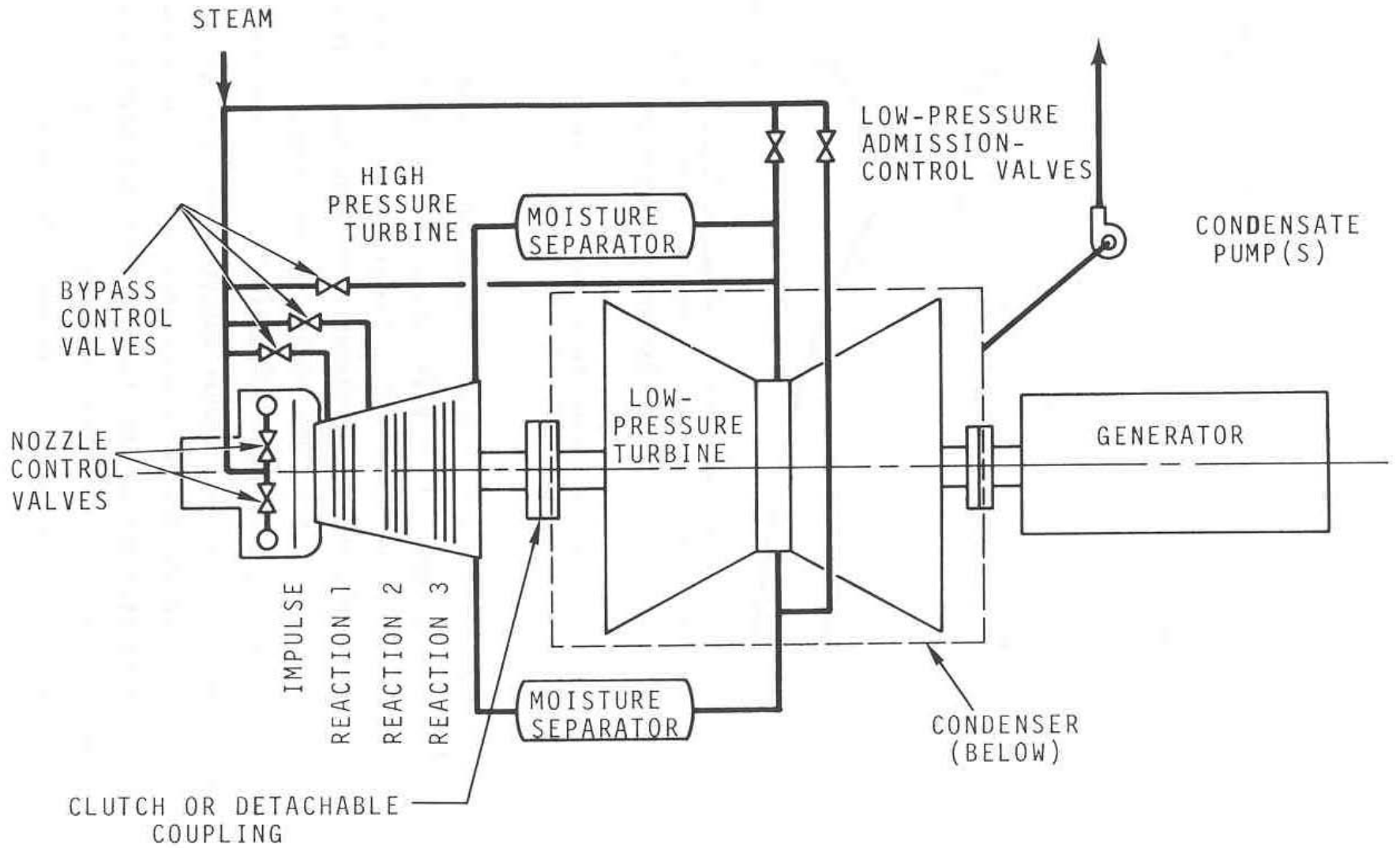


Figure 4.15-2. Turbine generator (Chapin et al. 1971, Figure 6.2).

private sponsor. During the 1960s, Battelle investigated the potential of Plowshare enhanced geothermal power production and identified the key criteria for appropriate project sites. These included: 1) rock temperatures in excess of 600°F at depths between 6,000 and 10,000 ft.; 2) large quantities of surface or well water for extracting the heat from the fractured rock and cooling the steam condenser; 3) an area away from large population centers; and 4) proximity to major electrical transmission lines. Many known geothermal areas in Oregon, Nevada, Idaho, Utah, Washington, Montana, and California met these criteria. By 1970, Battelle-Northwest had concluded that the concept was feasible and advocated a more in-depth study and a demonstration experiment using nuclear explosives to verify the technique's practical application.

Following this symposium, in May 1970, the U.S. Atomic Energy Commission signed a joint-study agreement with the American Oil Shale Corporation. American Oil Shale Corporation was responsible for procuring assistance from Battelle Memorial Institute's Pacific Northwest Laboratory and the Westinghouse Electric Corporation with the U.S. Atomic Energy Commission responsible for the Lawrence Radiation Laboratory and the U.S. Atomic Energy Commission Nevada Operations Office. These organizations coordinated their work on the feasibility study for Plowshare geothermal power plants for production of electricity. A 1970 memo on Plowshare project schedules mentions that a potential site for this project might be identified at the conclusion of the feasibility study in 1971, but actual detonation was five to six years away. Of note, an August 1970 Lawrence Radiation Laboratory document on the applicability of underground nuclear explosions to geothermal power production clearly states that at that time, the Plowshare geothermal program was focused on using nuclear explosives for fracturing large quantities of rock in a geothermal area and was no longer exploring augmenting natural steam fields.

The feasibility study was completed in April of 1971 and concluded that nuclear augmented geothermal power plants were technically and economically feasible, although more detailed studies were needed. The report specifies site location criteria as well as providing various conceptual models for actual plant construction. The study evaluated three different power plant designs, each reflecting various methods of coping with seismic motion from the nuclear detonations. The first plant design assumed full development of the geothermal field prior to construction, eliminating the need for special seismic reinforcement (Figure 4.15-3). The second design required a hardened plant capable of withstanding subsequent detonations at intervals (every 10 years) throughout the field's production life. The third design relied on a mobile plant mounted on skids, railroad cars, or a barge that could be moved away during the detonation and later reconnected to steam and transmission lines. Most United States locations appropriate for Plowshare geothermal heat extraction projects were determined to be west of the Continental Divide. The study indicated that valuable or potentially valuable geothermal resources occurred on both public and private land. Over one million acres of federal land were identified as valuable for geothermal development in California, Idaho, Montana, Nevada, and New Mexico. Almost 300,000 acres of federal land deemed potentially valuable were identified in Alaska, California, Idaho, Nevada, Oregon, Utah, and Washington. States listed that had non-federal land with geothermal potential were

Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming. No specific locations were identified (Figure 4.15-4). The most suitable sites would be seismically stable and have rock temperatures exceeding 600°F at a depth between 5,000 and 10,000 ft. Large quantities of surface or well water would be needed for injection into the cavity and cooling the steam condenser. Also, the site should be located away from large population centers, but near power transmission lines. Cost estimates for the various methods of nuclear augmented geothermal power production compared favorably and actually had economic advantages over conventional methods. The report also recommended additional laboratory experiments and field tests were needed to solve some technical issues and refine geothermal exploration techniques.

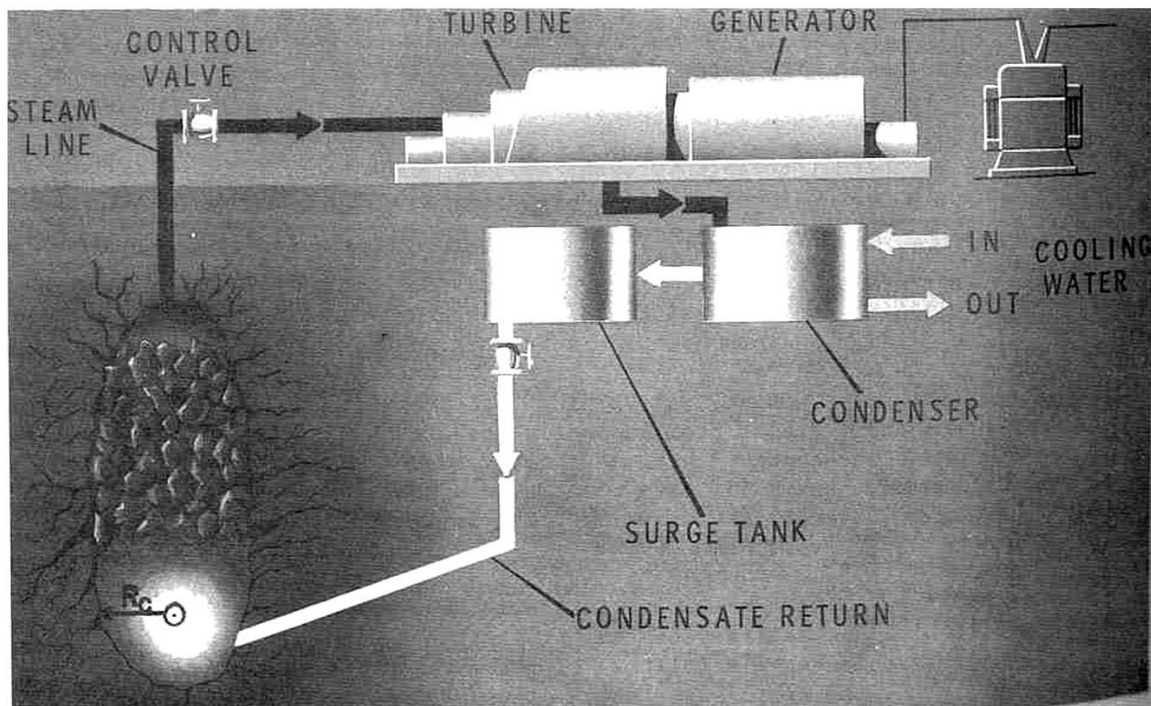


Figure 4.15-3. Conceptual design of a geothermal power plant (Burnham and Stewart 1970, Figure 2).

Lawrence Radiation Laboratory scientists continued to work on pertinent aspects of nuclear geothermal research including topics, such as published research in 1972 by Oscar Krikorian on corrosion and scaling by steam in nuclear geothermal power plants and A.E Sherwood's report on the explosive stimulation of a geothermal steam reservoir. What is interesting about Sherwood's report is that he mentions nuclear explosives and their potential but also states that new conventional explosives might work. Conventional explosives had long been considered impractical, due to the heat in a geothermal area. The report's discussion of explosive stimulation is not specific to the type of explosive.

Research efforts focused more and more on the power plant as funding decreased. A June 8, 1973 Lawrence Radiation Laboratory memorandum discusses the funding situation for

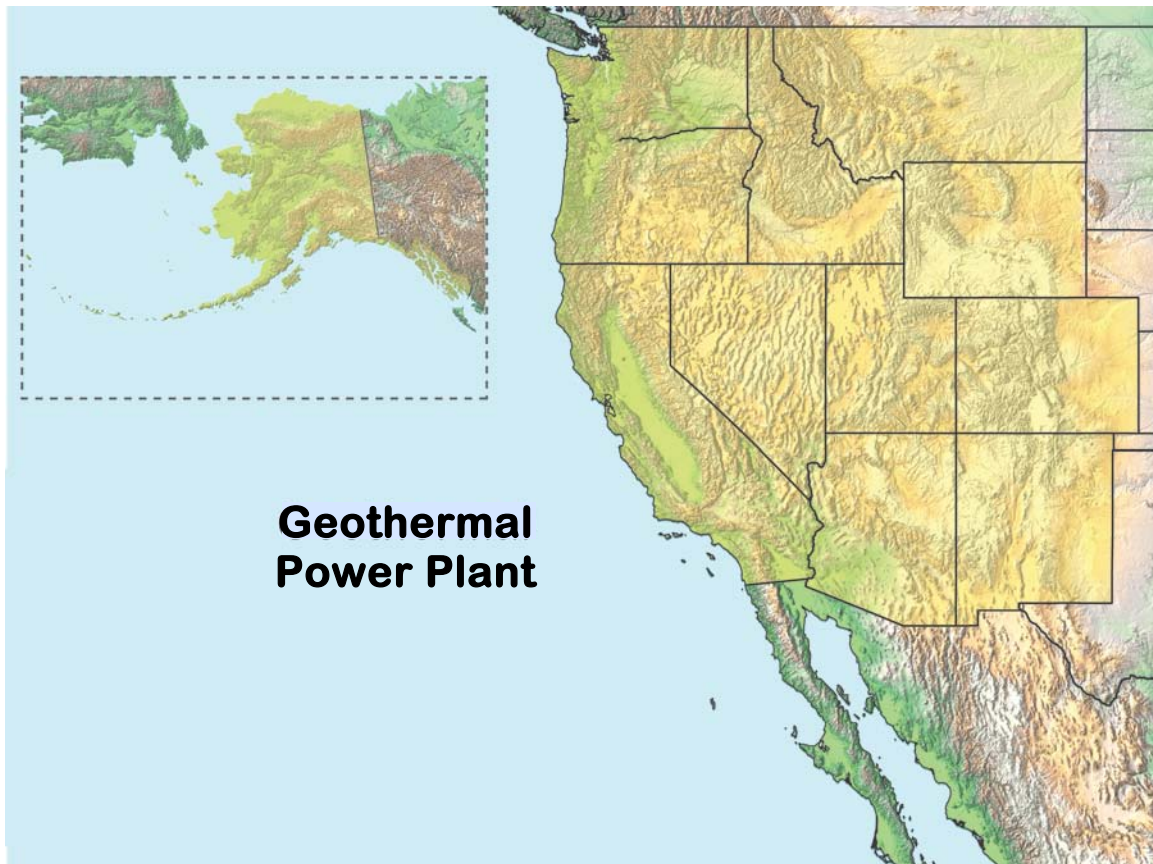


Figure 4.15-4. Proposed areas for the Geothermal Power Plant in the western United States (adapted from USA Relief Maps 2004).

geothermal energy. In May, the U.S. Atomic Energy Commission Geothermal Advisory Committee met and at this meeting stated that there still was no U.S. Atomic Energy Commission money for geothermal research programs. The best that the geothermal researchers could hope for would be funding in October of 1974. The memo also discusses visits to geothermal plants by Lawrence Radiation Laboratory personnel. Along with the work on how to develop geothermal energy, there was a focus on identifying or developing an efficient turbine for the process. In addition, they were reviewing patents and patent applications. In a July 17, 1973 letter from Lawrence Radiation Laboratory to Phillips Petroleum Company, the laboratory was negotiating access to one of Phillips' geothermal wells to conduct preliminary testing of possible materials for a total-flow turbine.

By July 20, 1973, the laboratory had prepared four budget proposals for the Geothermal Program: 1) 80 million dollars for a 10 year project that would involve a 100 MW pilot plant; 2) 15 million dollars for a five year program for a 10 MW field experimental facility; 3) same proposal as #2 except with a higher budget for the first two years; and 4) 80 million dollars for a 10 year project that would include a 10 MW field experimental facility and 100 MW pilot plant. These budgets were being developed for the Atomic



Energy Commission Geothermal Advisory Board Committee meeting on August 7<sup>th</sup> and 8<sup>th</sup> in Idaho Falls, Idaho.

On December 6, 1973, the U.S. Atomic Energy Commission, San Francisco Office filed an application with the U.S. Bureau of Land Management for the temporary withdrawal for two years of 88,160 acres of public land in Buffalo Valley, Kyle Hot Spring and Leach Hot Springs, Nevada. The purpose of the withdrawal was to obtain a suitable location of high heat flow where a small geothermal experimental facility could be built for Lawrence Berkeley Laboratory to conduct a comprehensive study of geothermal potential. After selection of the site, the other land would be released from the withdrawal. At that time no industrial partners had been identified for this study. The proposed research effort was to focus on locations with existing natural geothermal sources.

The Energy Research and Development Administration assumed the U.S. Atomic Energy Commission's responsibilities in January of 1975. On March 7, 1975, the Energy Research and Development Administration announced that it was notifying the U.S. Bureau of Land Management that land in Buffalo Valley was required. As of the date of the memo, no decision had been made on the parcels requested for withdrawal. This project appears to be unrelated to the Plowshare Program as it focuses on research on existing geothermal energy and does not mention the use of explosive technology. It is apparent that by this time, the research had moved towards applying new geothermal power plant technology to traditional geothermal extraction methods.

On October 7, 1977, the U.S. Department of Energy (succeeding the Energy Research and Development Administration), Nevada Operations Office awarded six contracts to bore new holes and wells, along with testing of existing drill holes for geothermal reservoir data on two known geothermal resources areas in southwestern Utah.

Union Geothermal Division of Union Oil Company of California received the contract for the Cove Fort-Sulphurdale area. Thermal Power Company of San Francisco, California, Geothermal Power Company of Novato, California, University of Denver, Getty Oil Company of Bakersfield, California and Seismic Exploration, Inc. of Salt Lake City received the contracts for the Roosevelt Hot Springs region. This activity may or may not be Plowshare related. The press release includes a handwritten list that reads, "Nevada and Utah, Yellow, Plowshare."

In 1978, the U.S. Department of Energy assumed responsibility for the East Mesa Geothermal Test Facility in southeastern California. This facility was built in 1968 by the Bureau of Reclamation for the development of geothermal resources in the area. Geothermal research activities at the 82-acre site were discontinued in 1987 as commercial-scale geothermal power developed in the region. Currently, some areas at the site are being cleaned up through the U.S. Department of Energy Environmental Restoration Program. When this work is completed, the facility will be turned over to the Bureau of Land Management.

On May 2, 1980, the U.S. Department of Energy awarded a contract to the Eaton Operating Co., Inc. of Houston, Texas to obtain data from four geothermal test wells in the Gulf Coast Area. This project does not appear to be Plowshare related. In fact, after 1974, there is no indication that Plowshare technology was being considered to augment geothermal energy production anywhere in the United States.

The Geothermal Power Plant Project activity category was a Level 5 with work based on existing data.

## **CHRONOLOGICAL BIBLIOGRAPHY**

Carlson, Roland H., 1959. Utilizing Nuclear Explosives in the Construction of Geothermal Power Plants. In Proceedings of the Second Plowshare Symposium, Part III, pp. 78 -87. University of California, Lawrence Radiation Laboratory, *Report UCRL-5677*, May 14. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA.

Van Hoosear, Burr S., 1963. "Peaceful Uses of Atomic Energy." Letter from Burr S. Van Hoosear to John S. Foster, January 28. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.

Tracy, James F., 1963. Letter from James F. Tracy, Lawrence Radiation Laboratory, to Burr S. Van Hoosear, March 5. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.

Kennedy, George C., 1964. A Proposal for a Nuclear Power Program. In *Engineering with Nuclear Explosives, Proceedings of the Third Plowshare Symposium*, April 21-23, University of California, Lawrence Radiation Laboratory, Report TID 7695, pp. 305-308. Livermore, CA.

Davy, Keith J., 1964. "Contact with Sun Oil Company." Memo from Keith J. Davy, U.S. Atomic Energy Commission, Division of Peaceful Nuclear Explosions, to Files, October 8. On file at: Archives and Research Center, Lawrence Livermore National Laboratories, Livermore, CA, File PLO-030.

Werth, Glenn C., [between 1966 and 1973]. Handwritten notes on Plowshare program meetings from Glenn C. Werth, U.S. Atomic Energy Commission, Division of Peaceful Nuclear Explosions, 1966-1973. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-118.

U.S. Atomic Energy Commission, 1967. Letter from Chairman, U.S. Atomic Energy Commission, to Bruce Graham, February 9. On file at: National Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0075871.

- Perlman, David, 1969. An A-Blast Key to Volcanic Energy. *San Francisco Chronicle*, December 3. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.
- Burnham, J .B., and D H. Stewart, 1970. The Economics of Plowshare Geothermal Power. In *Symposium on Engineering with Nuclear Explosives: Proceedings*, Report CONF-700101, Vol. 2, pp. 1376 -1383, May. American Nuclear Society, Hinsdale, IL.
- Evans, Roy B., and David E. Bernhardt, 1970. "Probable Scheduling of Plowshare Events." Memo from Roy B. Evans and David E. Bernhardt, U.S. Department of Health, Education, and Welfare, Southwestern Radiological Health Laboratory, to Francis N. Buck, May 8. On file at Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0173142 [OUO].
- Regnier. John E., 1970. "Telephone Call From Paul Smith, 5/25/70." Memo from John E. Regnier, U.S. Department of Health, Education, and Welfare, Southwestern Radiological Health Laboratory, to ODC:JER, May 25. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0173138.
- Chapin, Clair E., 1970. Letter from Clair Chapin, Lawrence Radiation Laboratory, to E. O. Dahle, July 20. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-098.
- Chapin, Clair E., 1970. "Applicability of Underground Nuclear Explosions to Geothermal Power Production." Memo from Clair E. Chapin, Lawrence Radiation Laboratory, to Distribution, August 28. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-098.
- U.S. Atomic Energy Commission, 1971. Chapter 9 - Peaceful Nuclear Explosives. In *Annual Report to Congress of the Atomic Energy Commission for 1970*, pp. 195-202, January. U.S. Government Printing Office, Washington D.C.
- Chapin, Clair E., D. W. Sherwood, W. H. Comtois, P. T. Walton, D. H. Stewart, and J. B. Burnham., 1971. A Feasibility Study of a Plowshare Geothermal Power Plant. U.S. Atomic Energy Commission, Report PNE 1550, April. Oakridge, TN. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV.
- Ingram, Frank L., 1971. Press Release, Subject: Summary: Geothermal Power Plant, from U.S. Atomic Energy Commission, June 7. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0032604 and NV0147143.

- Nuclear News, 1971. Report on a Plowshare Geothermal Power Plant. *Nuclear News*, July, p. 33 . On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0052036.
- U.S. Atomic Energy Commission, 1972. Plowshare Program. In *Annual Report to Congress of the Atomic Energy Commission for 1971*, pp. 139-142, January. U.S. Government Printing Office, Washington D.C.
- Krikorian, Oscar H., 1972. Corrosion and Scaling by Steam in Nuclear Geothermal Power Plants. University of California, Lawrence Livermore National Laboratory, Report UCRL-73686, February 4. Livermore, CA. On file at: Technical Reports Library, Lawrence Livermore National Laboratory, Livermore, CA.
- Coffer, Henry F., 1972. Letter with encl. ("Geothermal Program Schedule 18th Annual Meeting of the American Nuclear Society, Civil Explosion Application Division, June 18 - 21, 1972") from Henry F. Coffer, CER Geonuclear Corporation, May 12. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-098.
- Whan, Glenn, A., 1972. Letter from Glenn A. Whan, University of New Mexico, Nuclear Engineering Department, to Melvin W. Carter, May 30. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0173193.
- Krikorian, Oscar H., 1972. Corrosion and Scaling by Steam in Nuclear Geothermal Power Plants. University of California, Lawrence Livermore National Laboratory, Report UCRL-73939 Rev. I, July 26. Livermore, CA. On file at: Technical Reports Library, Lawrence Livermore National Laboratory, Livermore, CA.
- Sherwood, A. E., 1972. Explosive Stimulation of a Geothermal Steam Reservoir. University of California, Lawrence Livermore National Laboratory, Report UCRL-51303, November. Livermore, CA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-036.
- Howard, John H., 1972. "Highlights of the Geothermal Symposium of the 42nd Annual International Meeting of the Society of Exploration Geophysicists." Memo from J. Howard, Lawrence Livermore Laboratory, to A. L. Austin, December 7. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-098.
- Howard, John H., 1973. "United Nations Seminar on Development and Use of Geothermal Energy." Memo from J. Howard, Lawrence Livermore National Laboratory, to Distribution, January 15. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-098.

- Howard, John H., 1973. "Scope and Validity of Patents 3,258,069 and 3,330,356 on Geopressure Energy Resource." Memo from J. H. Howard, Lawrence Livermore Laboratory, to F. A. Robertson, January 22. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-098.
- Robertson, F. A., 1973. "U.S. Patents 3,258,069 and 3,330,356." Letter from F. A. Robertson, U.S. Atomic Energy Commission, San Francisco Office, to John H. Howard, February 2. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-098.
- Howard, John H., 1973. Letter from J. H. Howard, Lawrence Livermore Laboratory, to Roland A. Anderson, February 12. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-098.
- Howard, John H., 1973. "Brief Statement of Developments Regarding the Geothermal Research Program." Memo from J. Howard, Lawrence Livermore Laboratory, to Jack Kahn, June 8. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-098.
- Howard, John H., 1973. Letter from J. H. Howard, Lawrence Livermore Laboratory, to Fred Terry, July 17. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-098.
- Howard, John H., 1973. "Geothermal Research Project, June 9, 1973, to July 18, 1973." Memo from J. Howard, Lawrence Livermore Laboratory, to Jack Kahn, July 20. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-098.
- North Atlantic Treaty Organization, 1973. "Meeting of Experts to Consider Proposals for International Cooperation in the Field of Geothermal Resources Development (California/Mexico October 1-5, 1973) Chairman's Report." On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-098.
- U.S. Atomic Energy Commission. Nevada Operations Office, 1973. Press Release, Subject: land withdrawal for geothermal investigations, from U.S. Atomic Energy Commission, December 11. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0326105.
- Neitzel, J. W., 1975. Cooling Methods Study for the Proposed Raft River Geothermal Power Plant. Aero Jet Nuclear Company, Idaho National Engineering Laboratory, Report ANCR-1203. Idaho Falls, ID. On file at: Technical Reports Library, Lawrence Livermore National Laboratory, Livermore, CA.

- Energy Research Development Administration, 1975. Press Release, Subject: Temporary withdrawal of Public land in northern Nevada for geothermal study, from Nevada Operations Office, NV-75-12, March 7. On file at: Nuclear Testing Archives, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0332818.
- Green, Michael A., and Howard S. Pines, 1975. Calculation of Geothermal Power Plant Cycles Using Program GEOTHM. University of California, Lawrence Berkeley Laboratory, Report No. LBL-3238, May. Berkeley, CA. On file at: Technical Reports Library, Lawrence Livermore National Laboratory, Livermore, CA.
- Walter, R. A., C. M. Bloomster, and S. E. Wise, 1975. Thermodynamic Modeling of Geothermal Power Plants. Battelle Pacific Northwest Laboratories, Report No. BNWL-1911, May. Richland, Washington. On file at: Technical Reports Library, Lawrence Livermore National Laboratory, Livermore, CA.
- Eno, Eugene, 1975. Optimization of Thermodynamic Efficiency in Binary-Type Geothermal Electric Power Generating Plants. University of California, Lawrence Berkeley Laboratory, Report No. LBL-4404, September. Berkeley, CA. On file at: Technical Reports Library, Lawrence Livermore National Laboratory, Livermore, CA.
- Bechtel Corporation, 1976. Conceptual Design of Commercial 50 Mwe (Net) Geothermal Power Plants at Heber and Niland, California. Bechtel Corporation, Report SAN-1124-1, October. San Francisco, CA. On file at: Technical Reports Library, Lawrence Livermore National Laboratory, Livermore, CA.
- Wilson, S. W., and R. A. Walter, 1976. An Optimization Technique for Geothermal Power Plants Using a Binary Fluid Cycle. Battelle Pacific Northwest Laboratories, Report No. BNWL-2155, October. Richland, Washington. On file at: Technical Reports Library, Lawrence Livermore National Laboratory, Livermore, CA.
- Shaffer, C. J., 1976. Geothermal Steam Plant Modeling and Power Tradeoff Studies. Idaho National Engineering Laboratory, Aerojet Nuclear Company, Report No. ANCR-1295, December. Idaho Falls, ID. On file at: Technical Reports Library, Lawrence Livermore National Laboratory, Livermore, CA.
- Eskeen, J. H., 1977. Study of Practical Cycles for Geothermal Power Plants. Corporate Research and Development, General Electric Company, Report No. COO-2619-1, April. Schenectady, NY. On file at: Technical Reports Library, Lawrence Livermore National Laboratory, Livermore, CA.
- Ingvarsson, I. J., and S. E. Turner, 1977. Working Fluid and Cycle Selection Criteria for Binary Geothermal Power Plants with Resource Temperatures in the Range of 220° F and 400° F. Idaho National Engineering Laboratory, *EG&G Idaho Inc., Report*, No. TREE-1108, April. Idaho Falls, ID. On file at: Technical Reports Library, Lawrence Livermore National Laboratory, Livermore, CA.

- City of Burbank, 1977. Site-Specific Analysis of Hybrid Geothermal/Fossil Power Plants. U.S. Energy Research and Development Administration, Division of Geothermal Energy, Report TID-27926, June. On file at: Technical Reports Library, Lawrence Livermore National Laboratory, Livermore, CA.
- Shaffer, C. J., 1977. Floating Power Optimization Studies for the Cooling System of a Geothermal Power Plant,. Idaho National Engineering Laboratory, EG&G Idaho, Inc., Report No.TREE-1164, August. Idaho Falls, ID. On file at: Technical Reports Library, Lawrence Livermore National Laboratory, Livermore, CA.
- Schulte, S. C., 1977. Capital Cost Models for Geothermal Power Plants and Fluid Transmission Systems. Battelle Pacific Northwest Laboratories, Report No. PNL-2307, September. Richland, WA. On file at: Technical Reports Library, Lawrence Livermore National Laboratory, Livermore, CA.
- U.S. Department of Energy News. Nevada Operations Office, 1977. Press Release, Subject: Six Geothermal contracts awarded, from U.S. Department of Energy News, Doc. No. NV-77-67, October 7. On file at: Atomic Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0333191.
- Burns & Roe Industrial Services Corporation, 1977. Economic Assessment of Polymer Concrete Usage in Geothermal Power Plants. Process Sciences Division, Department of Energy & Environment, Brookhaven National Laboratory, Report No. BNL 50777, November. Upton, New York. On file at: Technical Reports Library, Lawrence Livermore National Laboratory, Livermore, CA.
- DiPippo, Ronald, 1978. An Historical Note on a Forerunner of a Hybrid Fossil-Geothermal Power Plant. Brown University, Division of Engineering, Report No. COO-4051-13, January. Providence, RI. On file at: Technical Reports Library, Lawrence Livermore National Laboratory, Livermore, CA
- DiPippo, Ronald, 1978. Geothermal Power Plants of Japan: A Technical Survey of Existing and Planned Installations. *Brown University, Division of Engineering, Report*, No. COO-4051-16, March. Providence, RI. On file at: Technical Reports Library, Lawrence Livermore National Laboratory, Livermore, CA.
- DiPippo, Ronald, H. Ezzat Khalifa, Robert J. Correia, and Joseph Kestin, 1978. Fossil Superheating in Geothermal Steam Power Plants. Brown University, Division of Engineering, Report No. COO-4051-18, March. Providence, RI. On file at: Technical Reports Library, Lawrence Livermore National Laboratory, Livermore, CA.
- Khalifa, H. Ezzat, Ronald DiPippo, and Joseph Kestin, 1978. Geothermal Preheating in Fossil-Fired Steam Power Plants. Brown University, Division of Engineering, Report COO-4051-19, March. Providence. RI. On file at: Technical Reports Library, Lawrence Livermore National Laboratory, Livermore, CA.

- DiPippo, Ronald, 1978. Geothermal Power Plants of the United States: A Technical Survey of Existing and Planned Installations. Brown University, Division of Engineering, Report No. COO-4051-20, April. Providence, RI. On file at: Technical Reports Library, Lawrence Livermore National Laboratory, Livermore, CA.
- DiPippo, Ronald, 1978. Geothermal Power Plants of Mexico and Central America: A Technical Survey of Existing and Planned Installations. Brown University, Division of Engineering, Report No. COO-4051-26, July. Providence, RI. On file at: Technical Reports Library, Lawrence Livermore National Laboratory, Livermore, CA.
- DiPippo, Ronald, 1978. A Summary of the Technical Specifications of the Geothermal Power Plants in the World: Revision 1. *Brown University, Division of Engineering, Report*, No. COO-4051-27, July. Providence, RI. On file at: Technical Reports Library, Lawrence Livermore National Laboratory, Livermore, CA.
- Miller, L. G., S. M. Prestwich, and J. L. Griffith, 1978. INEL/Snake River Plain Geothermal Drilling and Testing Plan, INEL-1 Well, Butte County, Idaho. U.S. Department of Energy, Idaho Operations Office, Report No. IDO-10077, December. Idaho Falls, ID. On file at: Technical Reports Library, Lawrence Livermore National Laboratory, Livermore, CA.
- Iszler, John, Dan D. Carda, Dale Skillman, W. L. Reuter, and G. F. Dunham, 1979. Western South Dakota Usage of Geothermal Energy from the Madison Formation, Final Report, January 1, 1978 through January 31, 1979. U.S. Department of Energy, Geothermal Energy, Report DOE/ID/01707-14, January. On file at: Technical Reports Library, Lawrence Livermore National Laboratory, Livermore, CA.
- DiPippo, Ronald, and Eileen M. Avelar, 1979. Compound Hybrid Geothermal-Fossil Power Plants. Brown University, Division of Engineering, Report No. COO-4051-44, June. Providence, RI. On file at: Technical Reports Library, Lawrence Livermore National Laboratory, Livermore, CA.
- Fluor Engineers and Constructors, Inc., 1979. Heber Geothermal Demonstration Power Plant. Fluor Engineers and Constructors, Inc., *Report ER-1099*, Research Project 580-2, June. Irvine, CA. On file at: Technical Reports Library, Lawrence Livermore National Laboratory, Livermore, CA.
- U.S. Department of Energy. Nevada Operations Office, 1980. Press Release, Subject: DOE awards contract for testing four geopressured geothermal wells, from U.S. Department of Energy, May 2. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Las Vegas, NV, Accession No. NV0335248.
- Fenix & Scisson, Inc., 1981. "GLCE Geothermal Logging Calibration Facility - Air-Water Jet System Assembly." Drawing No. M3269-04-01, Fenix & Scisson, Mercury, NV. On file at: Engineering Records Library, Nevada Test Site, Mercury, NV, Index No. 174170.



- Shafer, David S., William. C. Beck, Dwight Treadwell, and Stephen. A. Mellington, 1995. Inventory of Potential Environmental Restoration Liabilities Associated with Plowshare And Vela Uniform Program Sites. Manuscript, U.S. Department of Energy, Office of Environmental Restoration. On file at: Desert Research Institute, Las Vegas, NV.
- U.S. Department of Energy. Nevada Operations Office, 1997. P lowshare Program Executive Summary. Report from U.S. Department of Energy, December 22.
- U.S. Department of Energy. Office of Environmental Management, 2002. Geothermal Test Facility <<http://www.em.doe.gov/ca/ca-gtf.html>>, last accessed on September 29, 2002.
- Holmes & Narver, Inc., n.d. Geothermal Well, Old Maid Flats Site Well No. 7A - Grading and Plot Plan." Drawing No. JS-095-094-C2. On file at: Engineering Records Library, Nevada Test Site, Mercury, NV, Index No. 036200.
- Mt. Hood Geothermal, n.d. "Mt. Hood Geothermal OMF #7A." Drawing, no date. On file at: Engineering Records Library, Nevada Test Site, Mercury, NV, Index No. 171075.
- U.S. Department of Energy. Nevada Operations Office, n.d. The Plowshare Program (Draft). Report from U.S. Department of Energy.

**THIS PAGE INTENTIONALLY LEFT BLANK**

## 4.16 GOLD LEACHING

### **Nuclear Explosives to Fracture Ore for In Situ Leaching of Gold Plowshare Program Alaska and Wyoming**

By 1966, the Lawrence Radiation Laboratory began investigating new techniques for recovering gold from low-grade ores in hard rock deposits (versus placer deposits). The project concept was to use nuclear explosives to fracture gold-bearing ore deposits followed by in situ leaching to recover the gold. If successful, in situ gold leaching would permit the recovery of gold from very large reserves of low-grade domestic ore. In 1967, scientists from the Lawrence Radiation Laboratory met with Dow Chemical Company personnel to discuss stabilizing agents that could be used in the gold leach process and by January 1968, during a visit to Lawrence Radiation Laboratory, the Dow Chemical Company expressed interest in possible participation in the development of in situ gold leaching. On February 16, 1968, the *New York Times* carried an article titled "A-Blasts Studied as Way to Expand U.S. Gold Output," reporting on a speech presented by Congressman Craig Hosmer on the floor of the House of Representatives in support of a Plowshare gold leaching project. Shortly thereafter, the U.S. Atomic Energy Commission directed Lawrence Radiation Laboratory to coordinate work on gold leaching with the Bureau of Land Management, and in situ gold leaching seemed well on the way to being the focus of a Plowshare application.

The in situ leaching of gold was analogous to the in situ recovery of copper (see Copper Recovery - Chapter 4.12). Nuclear explosives would be used to create a rubble chimney in a low-grade gold deposit. Leaching fluids in contact with the gold ore minerals would dissolve the gold and move it downward to a collection zone. The leach solution would then be pumped to the surface for extraction of the gold. During 1967 and 1968, experiments were conducted at Oak Ridge National Laboratory and Lawrence Radiation Laboratory to evaluate the application of an acid leach process to the in situ recovery of gold. The results of the experiments were published in a University of California, Lawrence Radiation Laboratory report issued on February 28, 1968. The report outlined two basic problems for the development of an in situ leach process. First, the gold in the ore deposit needed to be oxidized from a metallic to a soluble state. Second, the gold would need to be held in solution until it was extracted. The goals of the laboratory experiments were to address these problems. Specifically, the experiments were designed to determine a suitable oxidant, test the effectiveness of stabilizing agents, study the in situ leach process with laboratory-scale columns, and obtain information relevant for experiments concerning radioactivity of the leach solution. According to the study a modified chlorination process with a strong stabilizing agent would be technically feasible for the leaching process; however, the authors noted that the study did not examine if the leaching and refining process could be conducted economically to produce radioactive free gold. The report recommended studies to characterize the mineralogy of ore deposits, additional laboratory studies of the chemistry of oxidation of gold and gold

stabilizing agents, and experimental tests to assess processing problems related to radionuclides. Site evaluations and economic analyses were also suggested.

In April 1968, a Lawrence Radiation Laboratory memo was distributed reporting on a meeting with the U.S. Department of Interior. The memo raised doubts about the technical feasibility of leaching gold. Problems were noted in three major areas: 1) the chemistry of the leach process and the ability to extract gold from a leach solution, 2) the geometry of gold ore deposits, and 3) the size of rubble created by nuclear explosions (the host rock would need to be fine-grained to leach the gold versus the coarse size produced by explosives).

In May 1968, a meeting was held with representatives from the U.S. Geological Survey, the Bureau of Mines, Lawrence Radiation Laboratory and the U.S. Atomic Energy Commission's San Francisco Operations Office to discuss the technical status of in situ leaching of gold. The minutes from the meeting were reviewed and a revised edition was submitted during August 1968. The review reiterated many of the uncertainties about the gold leach process discussed in the Lawrence Radiation Laboratory memo, and these concerns were highlighted in the revised minutes. Questions remained about the optimum leach solution and its efficiency in a rubble chimney. Another concern was the fact that a nuclear blast would produce rock fragments that were generally too coarse-grained for a gold leach operation and the penetrability of the leach solution into micro-fractures in the rubble material was not well understood. Also, additional study was needed concerning the chemistry of gold leaching and stabilizing agents. In particular, information was lacking about the relationship of the leach process to different geologic environments and the process of extracting gold from solution.

The minutes indicate that during the meeting, the U.S. Geological Survey and the Bureau of Mines presented a brief evaluation of six locations for a gold leaching project, but of these, only two were considered possibly suitable for a Plowshare experimental project. The overriding problem was one of geometry. For the most part gold bearing deposits were relatively thin and occurred near the surface and did not conform to the geometry of nuclear chimney collapse structures. The two possible locations mentioned for a gold leach experiment were an area in the vicinity of Juneau, Alaska, and in northwest Wyoming, east of the Teton Range (Figure 4.16-1). At the Alaskan location, deposits contained gold in quartz veins in slate, schist and volcanic rock, with zones of up to 200 ft in depth and 500 ft in thickness. Northwest Wyoming contained gold in an area of approximately 200 sq miles up to 10,000 feet thick. However, additional site characterization studies were needed before either location could be further evaluated as suitable for a leaching project.

Given the technical problems of leaching and extracting gold, as well as the geographical problem of finding gold ore deposits suitable for nuclear fracturing, interest in the project concept diminished. By the end of 1968 in situ leaching of gold was no longer studied for a Plowshare application.



Figure 4.16-1. Locations that the Bureau of Mines and the U.S. Geological Survey proposed as possibly suitable for a Gold Leaching Project. A precise location for a Gold Leach experiment was never selected (adapted from USA Relief Maps 2004).

Gold Leaching was a Level 5 activity. Activity for the project was limited to conceptual design, background studies, and laboratory research.

## **CHRONOLOGICAL BIBLIOGRAPHY**

Hansen, Spent M., 1966. "Potential Application of Nuclear In-Situ Leach Techniques to Gold Ores." Memo from Spent M. Hansen, Lawrence Radiation Laboratory, to Gary H. Higgins, August 29. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-098.

Hague, Richard S., 1966. "Informal Discussion on In Situ Gold Leaching with LRL." Memo from Richard S. Hague, U.S. Atomic Energy Commission, San Francisco Operations Office, to John F. Philip, October 11. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-098.

Hansen, Spent, and Dave Snoeberger, 1967. "Gold Leach Development Project." Memo from Spent Hansen and Dave Snoeberger, Lawrence Radiation Laboratory, to Gary Higgins, February 20. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-098 [OUO].

- Snoeberger, D. F., 1967. "Visit to the Dow Research Laboratory, Walnut Creek, re Gold Complexing." Memo from D. F. Snoeberger, Lawrence Radiation Laboratory, to Distribution, August 8. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-098.
- Snoeberger, D. F., 1968. "Meeting with Dow Chemical Company Personnel re Gold Leaching." Memo from D. F. Snoeberger, Lawrence Radiation Laboratory, to Distribution, January 30. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-098.
- Werth, Glenn C., 1968. "Plowshare Reductions." Memo from G. C. Werth, Lawrence Radiation Laboratory, to Distribution, February 15. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.
- Hosmer, Craig, 1968. Remarks of Congressman Craig Hosmer (R-Calif.) During Debate on H.R. 14743 (to Eliminate the Reserve Requirements for Fed. Res. Notes Etc.), February 21. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-098.
- Kelly, John S., 1968. "Work on Gold Leaching Should be Immediately Coordinated with the Bureau of Mines." Telex from John S. Kelly, U.S. Atomic Energy Commission, to Michael May, February 26. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-098.
- New York Times, 1968. A-Blasts Studied as Way to Expand U.S. Gold Output. *New York Times*, February 26.
- Harris, John A., 1968. "Congressman Hosmer, in House Last Week, Disclosed Some Details of LRL Study of Gold Leaching Technology." Telex from John A. Harris, U.S. Atomic Energy Commission, to H. G. Vermillion, February 27. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-098.
- Hansen, Spenst M., David F. Snoeberger, and Chandler Kay, 1968. Evaluation of Experiments to Investigate the In-Situ Leach Recovery of Gold from Nuclear Chimneys. University of California, Lawrence Radiation Laboratory, *Report UCID-15253*, February 28. Livermore, CA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-098.
- Werth, Glenn C., 1968. "Gold Leaching." Memo from Glenn Werth, Lawrence Radiation Laboratory, to File, February 29. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-098.

- May, Michael M., 1968. Letter with encls. ("Disclosure of LRL Activity Relative to Gold Leaching," memo from David D. Rabb to File, February 28, and "Gold Leaching," memo from G. Werth to File, February 29) from Michael M. May, Lawrence Radiation Laboratory, to John S. Kelly, March 4. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-098.
- Werth, Glenn C., 1968. "The Following Information Concerning Gold Leaching Studies at LRL." Telex from Glenn C. Werth, Lawrence Radiation Laboratory, to John S. Kelly, March 7. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-098.
- May, Michael M., 1968. Letter with encl. ("Note on Gold Deposits," from Gary Higgins) from Michael M. May, Lawrence Radiation Laboratory, to Glenn T. Seaborg, March 15. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-098.
- Rabb, David D., and D. Snoeberger, 1968. "Gold Leaching." Memo from D. D. Rabb and D. Snoeberger, Lawrence Radiation Laboratory, to Record, April 1. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-098.
- English, S. G., 1968. Letter with encl. ("Discussions with the Department of the Interior on Gold Leaching," memo from John S. Kelly to Chairman Seaborg, et al.) from S. G. English, U.S. Atomic Energy Commission, to Michael M. May, April 5. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-098.
- Rabb, David D., and D. Snoeberger, 1968. "Visit by Dow Chemical Company Personnel." Memo from D. Rabb and D. Snoeberger, Lawrence Radiation Laboratory, to Distribution, April 9. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-098.
- Caldwell, Blake A., 1968. Letter from A. Blake Caldwell, Engineering and Mining Journal, to Lawrence Radiation Laboratory, April 22. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-098.
- Metals Week, 1968. Plowshare Gold Mining Tests Look Good. *Metals Week*, April 22. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-098.
- Higgins, Gary H., 1968. Letter from Gary H. Higgins, Lawrence Radiation Laboratory, to John S. Kelly, May 9. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-098.

- Fankhauser, C. L., 1968. Letter from C. L. Fankhauser, Lawrence Radiation Laboratory, to A. Blake Caldwell, May 22. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-098.
- Industrial Research, 1968. Preoccupied with Gold. *Industrial Research*, June. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-098.
- Higgins, Gary H., 1968. Letter from Gary H. Higgins, Lawrence Radiation Laboratory, to Harold L. James, June 10. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-098.
- Kahn, J. S., 1968. "Minutes from Gold Meeting." Memo with encl. (Informal Gold Chemistry Meeting, Minutes, May 14) from J. S. Kahn, Lawrence Radiation Laboratory, to Distribution, June 11. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-098.
- Commonwealth, 1968. "Operation Plowshare, The Gold Dilemma & Earth Shaking Power," by Hon. Craig Hosmer. Announcement, *Commonwealth*, Vol. 62, No. 27, July 1. San Francisco, CA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-098.
- James, Harold L., 1968. Letter from Harold L. James, U.S. Department of the Interior, Geological Survey, to Gary H. Higgins, July 2. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-098.
- Hamburger, Richard, 1968. Letter from Richard Hamburger, U.S. Atomic Energy Commission, to Gary Higgins, July 3. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-098.
- Hosmer, Craig, 1968, Remarks by Rep. Craig Hosmer (R-Calif.) to the Commonwealth Club of California, July 5. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-098.
- San Francisco Chronicle, 1968. The Nuclear Gold Rush. *San Francisco Chronicle*, July 6. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-098.
- James, Harold L., 1968. Letter with encl. (remarks concerning minutes of May 14 Gold Chemistry Meeting by Frank S. Grimaldi, July 2) from Harold L. James, U.S. Department of the Interior Geological Society, to Gary H. Higgins, July 9. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-098.



Higgins, Gary H., 1968. "Telephone Conversation with Paul Russell, US BuMines, Regarding Gold Meeting Notes: This Date." Memo from Gary H. Higgins, Lawrence Radiation Laboratory, to Record, July 15. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-098.

Gold Chemistry Meeting, 1968. Informal Gold Chemistry Meeting, May 14, 1968, Lawrence Radiation Laboratory, Livermore, CA. Agenda and Revised Minutes, August 7. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-098.

Higgins, Gary H., 1968. Letter from Gary H. Higgins, Lawrence Radiation Laboratory, to Richard Hamburger, August 20. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-098.

Larson, Max, 1969. Letter from Max Larson to D. F. Snoeberger and J. S. Kahn, December 9. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-098.

Nordyke, Milo D., 1969. Letter from Milo D. Nordyke, Lawrence Radiation Laboratory, to Max Larson, December 18. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-098.

**THIS PAGE INTENTIONALLY LEFT BLANK**

## **4.17 GONDOLA**

### **Plowshare Program Nuclear Cratering Experiment South Dakota, Montana, and Nevada**

Project Gondola was a proposed nuclear cratering project in wet clay shale. Planning for Gondola began in 1963 with the expectation that associated small-scale experiments would occur in April to November of 1965 with the project being executed in March of 1966. However, the project was put on hold for several years. In the meantime, Project Pre-Gondola was undertaken by the U.S. Army Engineer Nuclear Cratering Group. Pre-Gondola was a series of chemical high explosives experiments in wet clay shale, conducted between June 1966 and October 1969 on the edge of the Fort Peck Reservoir in northeastern Montana (see Pre-Gondola).

The Gondola project was planned as a series of several nuclear experiments, designed to study cratering in weak rock types with high water content. The first in the series was Gondola I, a 20 to 200 kt nuclear cratering experiment in a wet, weak clay shale formation that could be either one detonation or a row charge of five 40 kt explosives. Subsequent Gondola experiments under discussion included cratering tests with a wide range of emplacement depths and possibly row charge detonations. The information from these experiments could be applied to the Interoceanic Canal and other programs that involved massive excavations, such as waterway, harbor and reservoir construction.

The first meeting of the Gondola Site Selection Committee was on October 8, 1968. This committee consisted of members from the U.S. Atomic Energy Commission Nevada Operations Office, the Lawrence Radiation Laboratory, Sandia Corporation, the U.S. Army Corps of Engineers Nuclear Cratering Group, and the U. S. Geological Survey. The meeting had two general purposes. The first was to evaluate and rate potential sites for Gondola. The sites under consideration had been identified during the Nuclear Cratering Group's initial studies for site selection of Pre-Gondola. The second goal was to discuss whether or not it was advisable to conduct additional research to determine if there were other suitable sites, not identified on the Pre-Gondola list. While the objective was to select a site for Gondola I, the committee preferred that the chosen site be appropriate for the other Gondola experiments as well.

The sites were rated in terms of their technical acceptability. Technical requirements included 1) a site in a weak, wet shale that contained more than 25% clay minerals and extended 1,000 ft below at least one of the prospective ground zero locations; 2) site should be a contiguous 2 miles square with a Control Point location at least 2 miles away upwind; 3) there should be an essentially unoccupied 90 degree sector for at least 25 miles in the predominant downwind direction from September to June; and 4) the site had to be available for construction by July 1969. Other considerations were: 1) to avoid downwind areas with grazing, farming, recreation or similar purposes; 2) be located so that a debris trajectory would stay within the boundaries of the United States for 50 hours

(Limited Test Ban Treaty); and 3) for seismic and air blast effects, the ground zero had to be at minimum distances from different types of structures. Due to time constraints on the project, government-owned lands were preferred but a large, private tract of land with one or two owners was acceptable. It was mentioned that public acceptance of this project in the states of New Mexico, Nevada, Idaho, Arizona, and possibly Colorado probably would be better than states where there had not been concerted public relations efforts by the U.S. Atomic Energy Commission.

Following a discussion with the Nuclear Cratering Group and the U.S. Geological Survey regarding the list of potential Gondola I sites, each site was rated as preferred, conditionally acceptable, or least desirable. Ten locations in six states were considered preferred sites. There were two sites in Colorado, two in Montana, one in New Mexico, one in North Dakota, and four in South Dakota. The remaining sites on the list were eliminated from further study. The Nuclear Cratering Group and the U.S. Geological Survey agreed that there were other potential sites that could be investigated, and the U.S. Geological Survey was asked to search for other places and to refine the locations at the 10 potential Gondola sites.

The proposed Gondola schedule was based on a readiness commitment for the third quarter of FY 1970 (October–December). Schedules for activities were determined by working backward from this date. The need to conduct preliminary shallow drilling at potential sites was a new requirement and some discussion ensued about when to issue a press release on the project in order to announce this preliminary effort.

The committee met again on October 24, 1968 and reduced the potential site locations from 10 to six. These sites were in Utah, Colorado, Montana, and South Dakota. The two locations in Utah were later taken off the list due to technical and operational concerns. Plans called for 100 ft core holes to be drilled at the proposed sites in Colorado, Montana and South Dakota to determine the depth of overburden, depth to the water saturated medium, and to take samples for rock analyses (Phase 1). If these data showed sites to be acceptable, beginning in January 1969, 1,500 ft core holes would be drilled at those locations (Phase 2). At the committee meeting in November 22, 1968, the Gondola potential site list was reduced to four potential locations, two in southeastern Montana, one in northwestern South Dakota, and one in northern Nevada (Figure 4.17-1). In South Dakota, the potential location was directly north of the community of Newell and adjacent to Hoover in Butte County. The two locations in Montana were in Carter County. The first was between Albion and Capitol just west of the Little Missouri River. The other straddled Box Elder Creek near Ridgeway, halfway between the towns of Ekalaka and Alzada. The proposed Nevada site was in the Black Rock Desert, west of Winnemucca on the Humboldt-Pershing county lines.

The shallow drilling would commence when the public announcement for this effort was authorized. However, a delay occurred due to a lack of authority to make the announcement. Also, funding for the Gondola site selection was \$250,000 which was \$83,000 less than anticipated, impacting the activity schedule. The authority to issue the public announcement on the Gondola shallow drilling effort was granted on January 6,

1969 and it was issued on January 30, 1969. Between the date of authorization and the date of the issuance of the press release, representatives from the Nevada Operations Office and the U.S. Atomic Energy Commission Division of Peaceful Nuclear Explosives met with the governors of Montana, Nevada, and South Dakota, briefing them on the scope of the preliminary Gondola investigations. This was followed by discussions with the local news media and area residents. The January 30<sup>th</sup> press release stated that an exploratory drilling effort to determine the geological characteristics of the sites in all four locations was scheduled to begin within the next few days. To begin this program, the U.S. Atomic Energy Commission personnel and/or its contractor planned to contact landowners to make arrangements to drill shallow test holes to obtain core samples for further evaluation. Shortly after the announcement, officials with the South Dakota Department of Health and U.S. Public Health Service personnel began making tentative plans for a radiological monitoring program. Even at this early stage, it was believed that the monitoring program would need to be extended to surrounding states, because it was likely that radioactivity associated with the project might exceed the boundaries of the state due to the project's scale and tentative location.

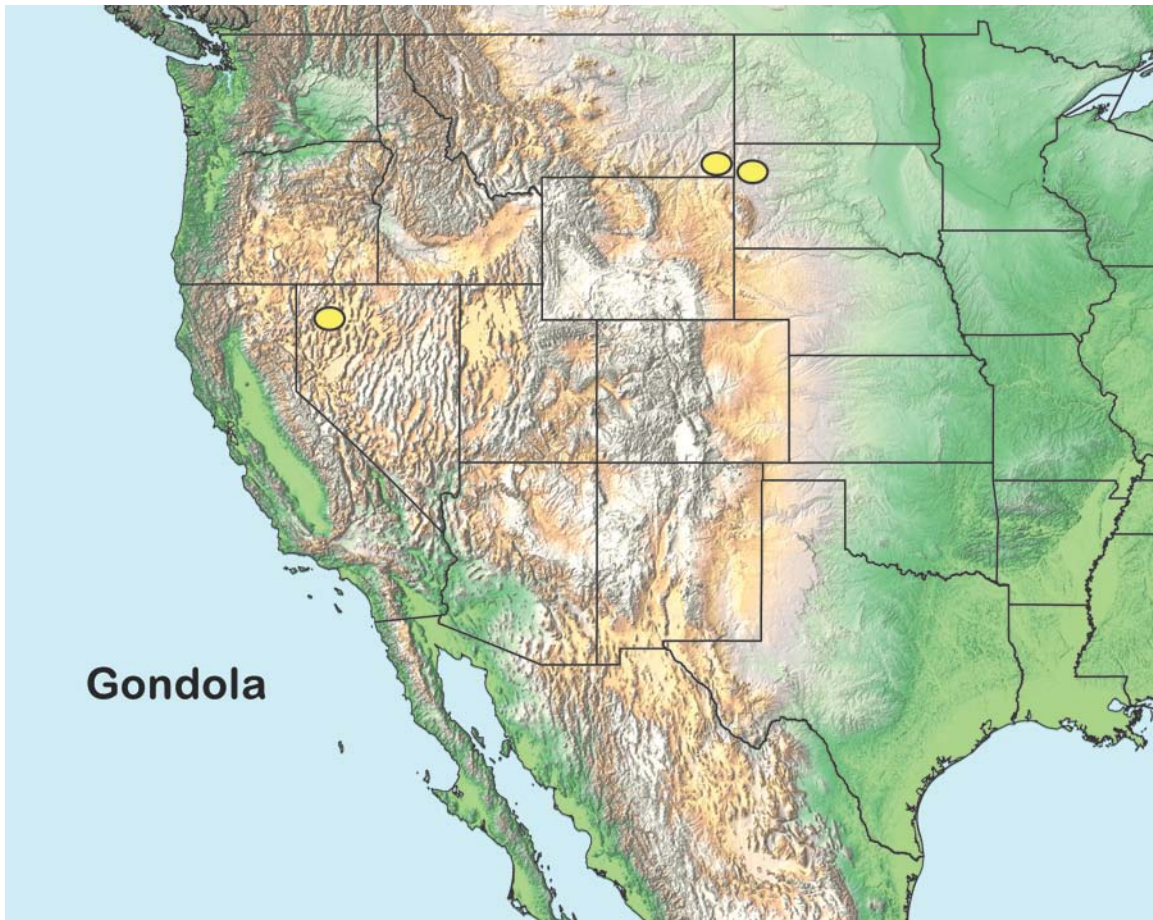


Figure 4.17-1. Proposed Gondola locations in South Dakota, Montana, and Nevada (adapted from USA Relief Maps 2004).

The access and drilling permits for the shallow drill holes at the locations in Montana and South Dakota were approved in late February 1969, with drilling scheduled to begin in early March. The planning called for safety contractors from the Nevada Operations Office to conduct site inspections in late February or early March and detailed real estate and surface investigations that would be initiated around March 10<sup>th</sup>. The work effort for the Black Rock Desert in Nevada was delayed until mid-April or so in order to wait until the desert was dry enough to support vehicles with equipment. This meant that data from the core analyses there would not be available until late May.

Sometime in February 1969, the Nevada Operations Office was informed that the overall U.S. Atomic Energy Commission FY 1969 expenditure freeze would result in a suspension of the Gondola site selection activities until at least July 1, 1969. On March 28<sup>th</sup>, the project participants were notified that Gondola site selection activities were on hold until FY 1970. It was expected that the site selection work would resume in early FY 1970, so that results of the drilling and field surveys would be ready by late August or early September 1969. Following the receipt of the termination notification, the January 30, 1969 press release was revised to include the suspension of field activities. This press release, however, went further and stated that pending a completion of the reassessment of the project and given FY 1970 fiscal constraints, the Nevada Operations Office did not anticipate any further effort for Gondola. In April 1969, during FY 1970 authorization hearings by the Joint Commission on Atomic Energy, the Plowshare authorization request included a statement that Gondola was one of five tests needed to provide the data required to determine the feasibility of nuclear excavation for construction of a sea-level canal in Panama or Colombia. At that time, Gondola had been rescheduled for FY 1971.

A February 20, 1970 U.S. Atomic Energy Commission memo requested that the Nevada Operations Office, due to a lack of Gondola funding, create a record file for the Site Selection Committee records, provide a brief summary statement of the Committee's activities, and officially terminate the Committee. The official language included the statement that site selection activities for Gondola were indefinitely deferred. As a result of this memo, the Nevada Operation Office of Public Affairs worked with Headquarters to notify the Governors and Congressional Delegations of Montana, South Dakota, and Nevada of this decision and developed a public announcement regarding the deferral of the Gondola site selection effort. This action effectively ended the Gondola project.

Gondola was a Level 5 activity with site selection data based on existing information.

## **CHRONOLOGICAL BIBLIOGRAPHY**

Graves, Ernest, 1963. "Program and Budget Justification, Nuclear Explosives Studies." Letter with encl. ("FY 1964 Program") from Ernest Graves, Lawrence Radiation Laboratory, U.S. Army Engineer Nuclear Cratering Group, to Chief of Engineers, Department of the Army, September 20. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029 [OUO].

- Lawrence Radiation Laboratory. U.S. Army Engineer Nuclear Cratering Group, 1967. Summary of Long Range Programming for Nuclear Excavation Research and Development. Manuscript, April 5. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.
- Carter, Melvin W., 1968. Letter from Melvin W. Carter Public Health Service, Southwest Radiological Health Laboratory, to Donald G. Kurvink, April 8. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0162453.
- Kelly, John S., 1968. Letter with Encl. ("U.S. Atomic Energy Commission Plowshare Program Projections – Estimated Cost in Thousands and Number of Nuclear Detonations") from John S. Kelly, U.S. Atomic Energy Commission, Division of Peaceful Nuclear Explosives, to Charles C. Noble, April. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-065.
- Werth, Glenn C., 1968. "Alternate #1, Tentative Schedule – Plowshare Program – LRL Related." Schedule from Lawrence Radiation Laboratory, September 10. On file at: Archives and Records Office, Lawrence Berkeley National Laboratory, Berkeley, CA, File 434-900205, 28/48.
- Werth, Glenn C., 1968. "Alternate #2, Tentative Schedule - Plowshare Program - LRL Related." Schedule from Lawrence Radiation Laboratory, September 10. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-118.
- Lewis, A. E., 1968. Letter with encls. (Membership Gondola Site Selection Committee, Gondola Proposed Assignments, List of Potential Gondola Sites, and Gondola - Site Selection Schedule) from A. E. Lewis, Lawrence Radiation Laboratory, to Thomas H. Blankenship, October 11. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0038202.
- Reeves, James E., 1968. "Summary Minutes of Gondola Site Selection Committee Meeting." Memo with encls (Summary Minutes - Gondola Site Selection Committee Meeting of October 8, 1968 and Gondola Site Selection Committee Meeting Attendees, October 8, 1968) from James E. Reeves, U.S. Atomic Energy Commission, Nevada Operations Office, to John S. Kelly, November 5. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0038201.

- Reeves, James E., 1968. "Planning directive for Gondola Site Selection, PL-2-11-68." Memo from James E. Reeves, U.S. Atomic Energy Commission, Nevada Operations Office, to List, November 14. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0038200.
- Kelly, John S., 1968. Telex from John S. Kelly, Lawrence Radiation Laboratory, to Multiple Recipients, December 10. On file at: Archives and Records Office, Lawrence Berkeley National Laboratory, Berkeley, CA, File 434-900205, 28/48.
- Connell, Richard P., 1968. Letter with encl. ("U.S. Atomic Energy Commission, Fiscal Year 1969 Midyear Review, Schedule A, Plowshare Program") from Richard P. Connell, Lawrence Radiation Laboratory, to John S. Kelly, December 19. On file at: Lawrence Berkeley National Laboratory, University of California, Berkeley, CA, File 434-900205, 28/48.
- Miller, Robert E., 1968. Reorganization - Nevada Operations Office Effects Safety Program. Draft Manuscript, U.S. Atomic Energy Commission, December 31. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0133972.
- Project Gondola, [1968], "Project Gondola Potential Sites in the Western United States." Map. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0186947.
- Smith, Allan E., 1969. "Gondola Site Selection." Memo with encls. (map; letter from Donald E. Edwards to Melvin W. Carter, January 11; and Project Gondola, manuscript) from Allan E. Smith, Staff Officer, Southwest Radiological Health Laboratory, to Melvin W. Carter, January 17. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0038199.
- U.S. Atomic Energy Commission. Nevada Operations Office, 1969. Press Release, Subject: The AEC has identified areas in Montana, South Dakota, and Nevada suitable for an earth moving experiment using nuclear explosives, from U.S. Atomic Energy Commission, January 30. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession NV 0325590.
- U.S. Department of Energy. Nevada Operations Office, 1969. Press Release, Subject: Possible earth moving experiment using a nuclear explosive, from U.S. Atomic Energy Commission, January 30. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0325590.



- Ingram, Frank L., 1969. Letter from Frank L. Ingram, U.S. Atomic Energy Commission, Division of Public Information, to Donald Kurvink, February 6. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0164632.
- Williamson, M. W., 1969. Letter from M. W. Williamson, U.S. Atomic Energy Commission, Division of Peaceful Nuclear Explosives, to D. Kurvink, April 8. On file at: Nuclear Testing Archive, Nevada Site Office, National Security Administration, Las Vegas, NV, Accession No. NV0164637.
- U.S. Atomic Energy Commission, 1969. "United States Atomic Energy Commission, Plowshare Program Statement, JCAE FY 1970 Authorization Hearings." Statement from U.S. Atomic Energy Commission, April 18. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-028.
- Kurvink, Donald G., 1969. Letter from Donald G. Kurvink, South Dakota Department of Health, Pierre, to G.A. Jacobson, April 24. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0164636.
- Jacobson, G. A., 1969. "Plowshare Surveillance - South Dakota." Memo from G. A. Jacobson, Department of Health, Education, and Welfare, to Director Southwest Radiological Health Laboratory, April 28. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0164635.
- Carter, Melvin W., 1969. Letter from Melvin W. Carter, Public Health Service, Southwest Radiological Health Laboratory, to G. A. Jacobson, May 16. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0164640.
- Kelly, John S., 1969. "Approve the Update Concept for Project Yawl." Telex with encl. ("Analysis of FY 1969 Plowshare Program Financial Plans") from John S. Kelly, Lawrence Radiation Laboratory, to Glenn C. Werth, August 28. On file at: Archives and Records Office, Lawrence Berkeley National Laboratory, Berkeley, CA, File 434-900205, 28/48; and Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-072.
- Miller, Robert E., 1970. "Termination of Gondola Site Selection Committee and the Manager's Review Group." Memo with encl. (Gondola Site Selection Committee Summary of Activities, manuscript) from Robert E. Miller, U.S. Atomic Energy Commission, Nevada Operations Office, to List, February 20. On file at Nevada Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0038196.

**THIS PAGE INTENTIONALLY LEFT BLANK**

## **4.18 GROUNDHOG**

### **Vela Uniform Program High Explosive Seismic Monitoring Experiment California, Louisiana, Michigan, Mississippi, Montana, Nevada and New Mexico**

Groundhog was a planned experimental test series within the high explosive portion of the Vela Uniform seismic detection program. The project proposal called for a series of 14 high explosive tests in different geologic mediums. The project was conceived by the U.S. Air Force Technical Applications Center to supplement data from the Shade and Dribble explosive programs for seismic detection and recognition of underground nuclear explosions. The U.S. Department of Defense had overall responsibility for the Vela Uniform Program. The primary overseer of the program was the Advanced Research Projects Agency which delegated the portion of the program involving a series of chemical high explosives to the Defense Atomic Support Agency.

A project formulation meeting for Groundhog was held on December 22, 1960, and six objectives for the study were identified that involved investigation of coupled (tamped) emplacements. In a coupled emplacement, the explosive charge is fired in as small a shot chamber as possible in contrast to a decoupled emplacement where the explosive charge is set apart from the surrounding earth in a chamber or cavity. The specific objectives included: 1) comparison of coupling in various media; 2) determination of the effect of depth in a single medium; 3) comparison of wave forms produced by the explosions with those from earthquakes in the same region; 4) investigation of the spectrum and amplitude of first motion at distances of several hundred kilometers from a decoupled explosion of a few kilometers; 5) determination of the accuracy of the epicenter location; and 6) examination of the nuclear to high explosive equivalence.

The Defense Atomic Support Agency at Sandia Base was instructed to carry out preliminary planning and site selection. The project scope comprised four shot groups (A-D) in different mediums and in different locations throughout the U.S (Figure 4.18-1). Shot Group A was a planned single 100-ton shot in a salt formation at the Dribble site and was to address objectives #4 and #6. Shot Group B was to include three 30-ton shots at various depths in hard rock in a mine in northern Michigan and would address objectives #2 and #4. The mine location was as yet not determined. Shot Group C, addressing objectives #3, #4, and #5, called for three 100-ton shots in rock near Hollister, California and three shots in rock at either Fallon, Nevada or West Yellowstone, Montana. Eleven 1/2-ton coupling shots were planned for Shot Group D to address objective #1. One was planned in rock at the Coyote Test Field near Albuquerque; two in tuff in Area 12 and two in granite in Area 15 at the Nevada Test Site; and two in halite, two in sandstone, and two in limestone at Winnfield, Louisiana.

For the larger explosions, 30 to 100 ton detonations, the explosive material would be composed of stacked blocks of Composition B reclaimed from high explosive bombs. It

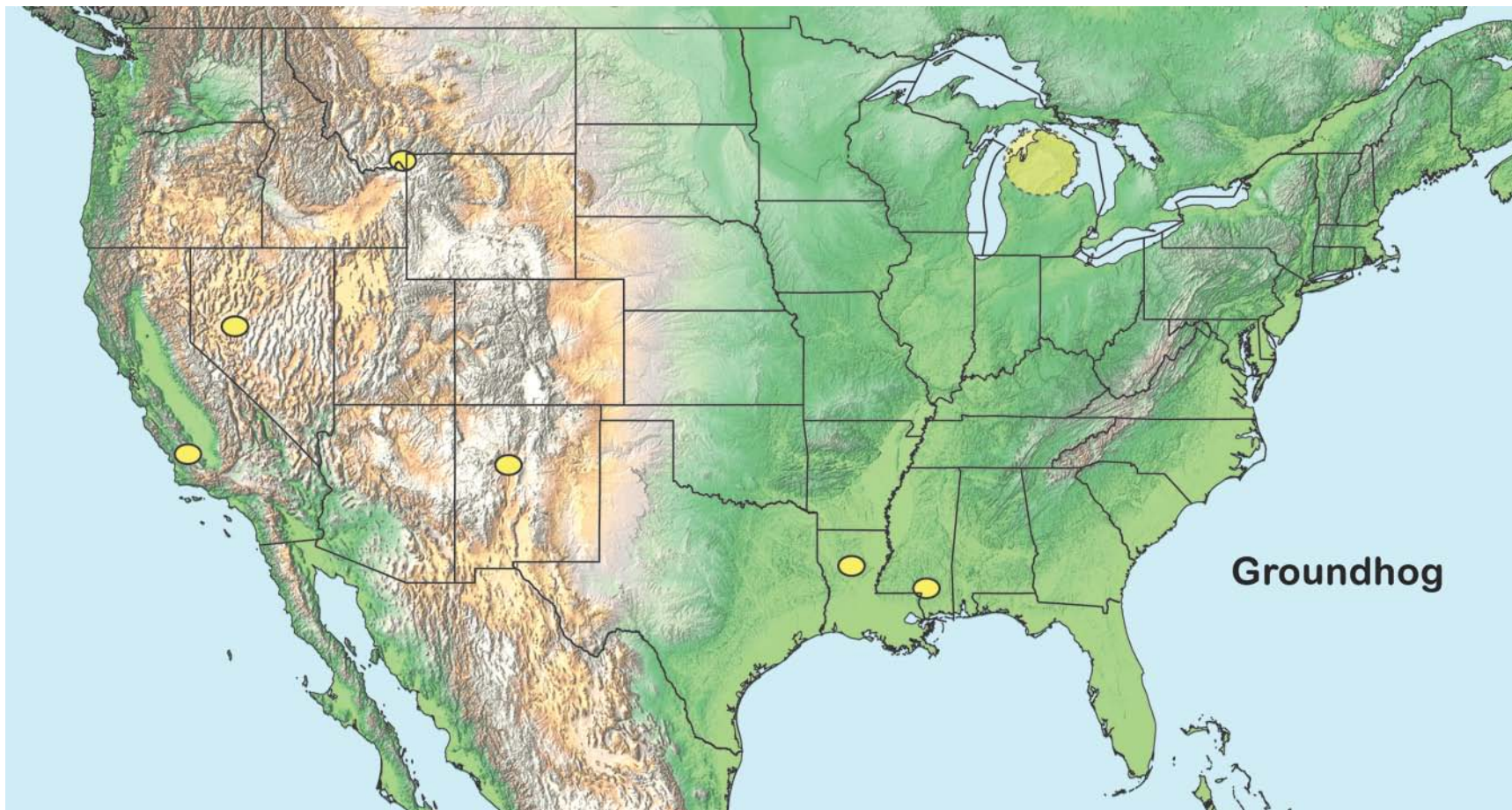


Figure 4.18-1. Locations of proposed high explosive tests for Groundhog (adapted from USA Relief Maps 2004).

was to be purchased from the U.S. Army Ordnance Ammunition Command or from commercial companies. Produced by the Iowa Ordnance Plant at Burlington, Iowa, this material had already been used in the Linen Event of Project Shade. For the smaller 1/2 ton shots, nitromethane purchased from commercial companies was to be used and emplaced according to the methods developed by Sandia Corporation and Lawrence Radiation Laboratory.

Sandia Corporation planned on making the close-in measurements for the various tests, including motion, stress, and strain observations, while the agencies involved in the Shade and Dribble projects would be used for the measurements further away. These latter measurements ranged from distances of several kilometers to several hundred kilometers from the tests. Site preparation (i.e., vehicles, communications, utilities, emplacements, construction, housing, etc.) was mostly to be provided by local contractors if available. Timing and firing systems, as well as radio and other communication equipment, were to be provided by Edgerton, Germeshausen and Grier, Inc., who would also maintain equipment on the different sites. Architect and engineering support and contracts were to be performed by the U.S. Atomic Energy Commission, Albuquerque Operations, Office of Test Operations.

Project Groundhog was scheduled to start in June 1961 and finish by August 1963. However, the Groundhog high explosive seismic monitoring experiment was never carried out. A memo dating to October 1961, four months after the Groundhog proposal was issued, states that the Defense Atomic Support Agency had been advised that the U.S. Department of Defense no longer required a 100 ton Groundhog test at the Dribble site. Documentation is lacking that discusses the timing and reasons for suspension of activities for Groundhog.

Groundhog was a Level 5 activity. Project activity was limited to conceptual design.

## **CHRONOLOGICAL BIBLIOGRAPHY**

Reeves, James E., 1961. "Glossary of Seismic Projects, Plowshare Program, and Reactor Programs." Memo from James E. Reeves, U.S. Atomic Energy Commission, Albuquerque Office, to List, March 17. On file at Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV [OUO].

Sandia Corporation, 1961. Project Proposal: Vela Uniform, Project Groundhog. Report to U.S. Atomic Energy Commission from Sandia Corporation, Albuquerque, NM, June 6. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV.

Reeves, James E., 1961. "Planning Directive (VU10-10-61) AEC Vela Uniform." Memo from James E. Reeves, U.S. Atomic Energy Commission, to List, October 23. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV.

Romney, C. F., 1985. VELA Overview: The Early Years of the Seismic Research Program. In *The VELA Program: A Twenty-Five Year Review of Basic Research*, Ann U. Kerr, editor, pp. 38 -66. Defense Advanced Research Project Agency, Arlington, VA.

## 4.19 HEBGEN LAKE EARTHQUAKE

### Vela Uniform Program Earthquake Seismic Data Montana

Goals of the Vela Uniform program for detection and verification of underground nuclear detonations included: lowering the detection threshold for seismic events, developing seismic identification criteria, and improving on-site verification and seismic location accuracy. One of the major components of the program was to develop improved seismic detection and analysis systems. In 1961, the Long Range Seismic Measurements Experiment, under Vela Uniform Project 8.4, established forty mobile systems with magnetic tape recording capability. The mobile systems were positioned across the United States to record seismic data that would improve understanding of long range seismic effects of underground nuclear explosions, especially those seismic data anticipated as part of the planned explosive program for Vela Uniform.

On February 25, 1962, a low magnitude earthquake occurred near Hebgen Lake, Montana. The U.S. Coast and Geodetic Survey placed the location at 45.2°N latitude, 111.2°W longitude, approximately 25 km deep, 17:17:38.9 Greenwich Mean Time (Figure 4.19-1). Seismic activity from the earthquake provided an opportunity to gather data for comparison to seismic signatures from other natural and manmade sources. The Hebgen Lake Earthquake project involved compiling seismic data from 36 mobile Long Range Seismic Measurement stations and data from the Wichita Mountains Seismological Observatory (Figure 4.19-2).

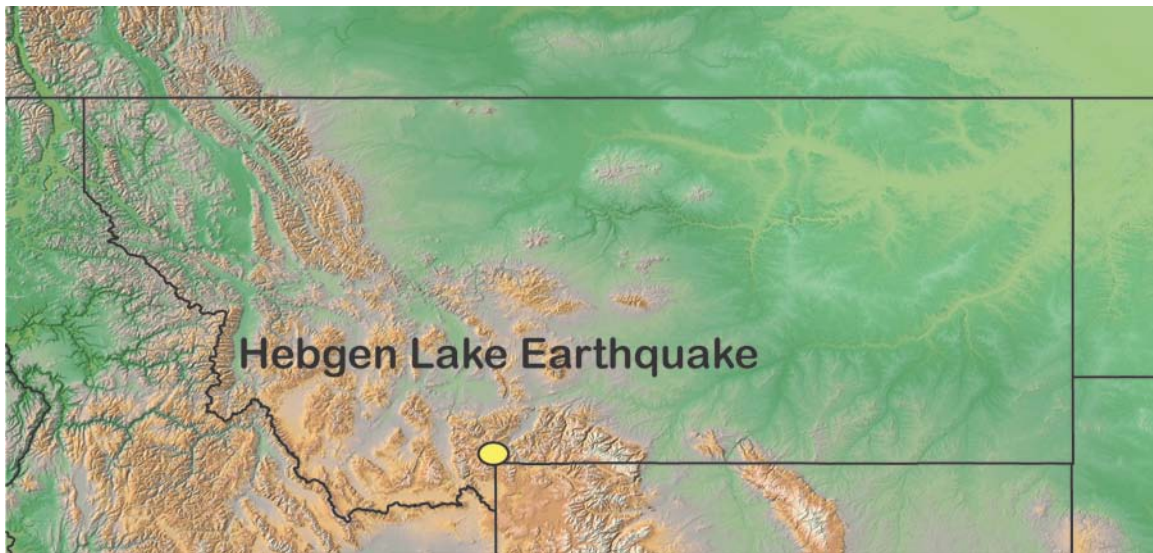


Figure 4.19-1. Location of Hebgen Lake Earthquake in Montana (adapted from USA Relief Maps 2004).

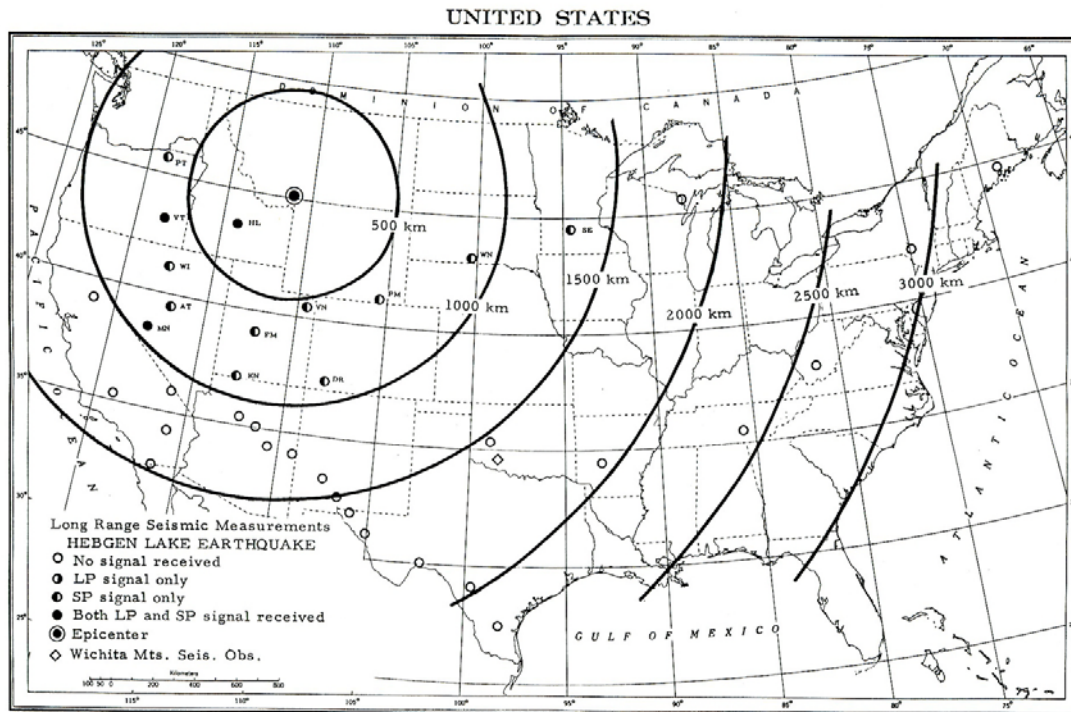


Figure 4.19-2. Approximate location of stations receiving a signal from Hebgen Lake Earthquake (Geotechnical Corporation 1962, Figure 1).

The data were presented in a report prepared for the U.S. Air Force Technical Applications Center dating to November 1, 1962. Recognizable signals from the earthquake were recorded at thirteen of the 37 stations. Of these, only one station in Sleepy Eye, Minnesota, recorded a signal beyond 950 km from the epicenter. The report concluded that the data from the earthquake at Hebgen Lake did not warrant further study since there were no distinctive features to discriminate between the seismic signature of this earthquake and an underground nuclear explosion.

Project Hebgen Lake was a Level 4 activity. Field activity for the project was based on using existing facilities for recording seismic data.

## CHRONOLOGICAL BIBLIOGRAPHY

Geotechnical Corporation, 1962. Hebgen Lake Earthquake: Long Range Seismic Measurements, Project 8.4. Report to Air Force Technical Applications Center, HW USAF (AFTAC), Washington, D.C., from Geotechnical Corporation, Garland, Texas, November 1. On file at: Technical Reports Library, Lawrence Livermore National Laboratory, Livermore, CA.

Kerr, Ann U. (editor), 1985. *The VELA Program: A Twenty-Five Year Review of Basic Research*. Defense Advanced Research Projects Agency. Arlington, VA.



## 4.20 KATALLA HARBOR

### Plowshare Program Nuclear Construction of a Deep-Water Harbor Alaska

In July 1958, members from the U.S. Atomic Energy Commission and Lawrence Radiation Laboratory, headed by Dr. Edward Teller, traveled to Alaska to discuss a number of excavation projects that could be accomplished with nuclear explosives in the soon to be new state of Alaska. A conference was held in Fairbanks and several large scale civil works projects were proposed. These ideas included the nuclear excavation of a protected shipping basin on the Gulf of Alaska near Katalla Bay (Figure 4.20-1), a place where establishment of a breakwater and other developments in the early 1900s did not survive.



Figure 4.20-1. Location of proposed Katalla Harbor (adapted from USA Relief Maps 2004).

Following the conference, a consulting engineering company in Alaska, Exploration Services, Inc., was subcontracted by Lawrence Radiation Laboratory to prepare a report on the economic feasibility of a deep water harbor at Katalla. The report was delivered in September 1958, emphasizing the economic need for a harbor to help with the development of coal deposits in the Bering River area. Reconnaissance mapping and prospecting in the early 1900s had revealed vast coal deposits of excellent grade and coking quality, 20 to 30 miles north of the abandoned town of Katalla (Figure 4.20-2).

Coal resources could be transported to a harbor at Katalla along a fairly level route at low elevation. Petroleum fields in the area were also available for development. The report noted that Japan provided a ready coal market and the harbor would reduce the shipping costs for coal and petroleum.

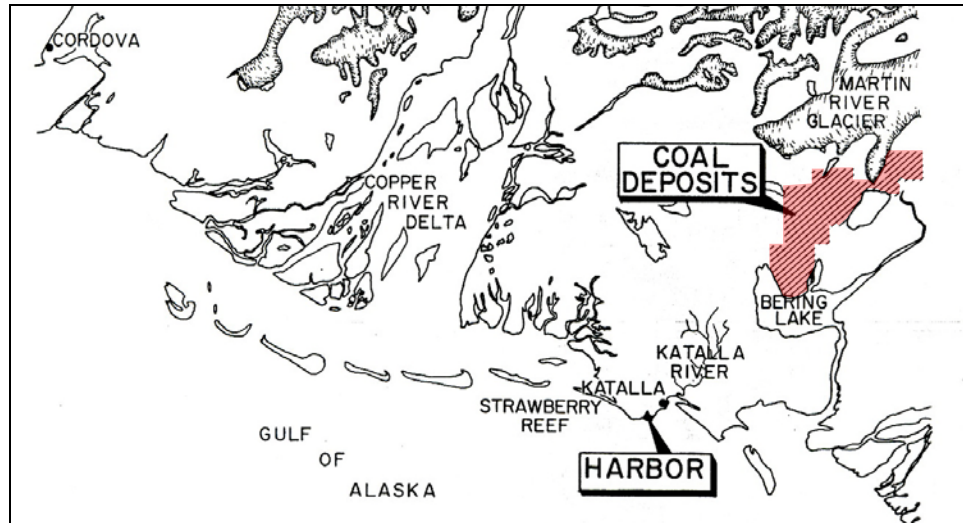


Figure 4.20-2. Location of Bering River coal deposits in relation to the harbor proposed near Katalla (adapted from Teller 1963, Figure 2).

The Operational Concept for Katalla Harbor was distributed by the Lawrence Radiation Laboratory in December 1958. The conceptual design was based on constructing an inland harbor with a channel entrance (Figure 4.20-3). The proposed harbor location was on the western shoreline of Katalla Bay, southwest of the abandoned village of Katalla in an area that overlapped with the northeastern side of Lake Kahuntla, with a channel entrance north of Palm Point (Figure 4.20-4). The design concept for the completed harbor indicated that the basin would be 1,800 ft long by 1,000 ft wide with a minimum depth of 30 ft. The associated entrance channel would be 450 ft wide by 30 ft deep and extend from the harbor to the 30 foot depth contour at sea. This would allow access for ships of up to 500 ft in length with a 30 ft draft. (Figure 4.20-5). Two phases of fieldwork were planned for the project. During the first phase topographic, hydrographic and geological data would be collected, the second phase would consist of emplacement and detonation. The Operational Concept included plans for construction of six ground zero sites, probably as a row charge series. After nuclear excavation, a dredging operation would be undertaken to clear the entrance channel.

A report concerning the proposed harbor was prepared for a P lowshare Advisory Committee briefing held November 12-13, 1959. At the time, the Jewel Ridge Coal Company of Tazwell, Virginia, was undertaking an exploratory drilling program to determine if the coal veins were sufficient for underground mining in the Bering River area. Concurrently, the Richfield Oil Company was carrying out geophysical explorations

for oil between Katalla and Icy Bay and had begun drilling an exploratory hole. If either of these ventures proved economically feasible a deep-water harbor constructed by early 1962 would provide an opportunity to export oil and/or coal from the region. According to the report a project at Cape Thompson (Project Chariot) would be initiated first to demonstrate technological capability and develop nuclear excavation technology, hopefully in early 1961, with nuclear excavation of a harbor at Katalla to begin a year later.

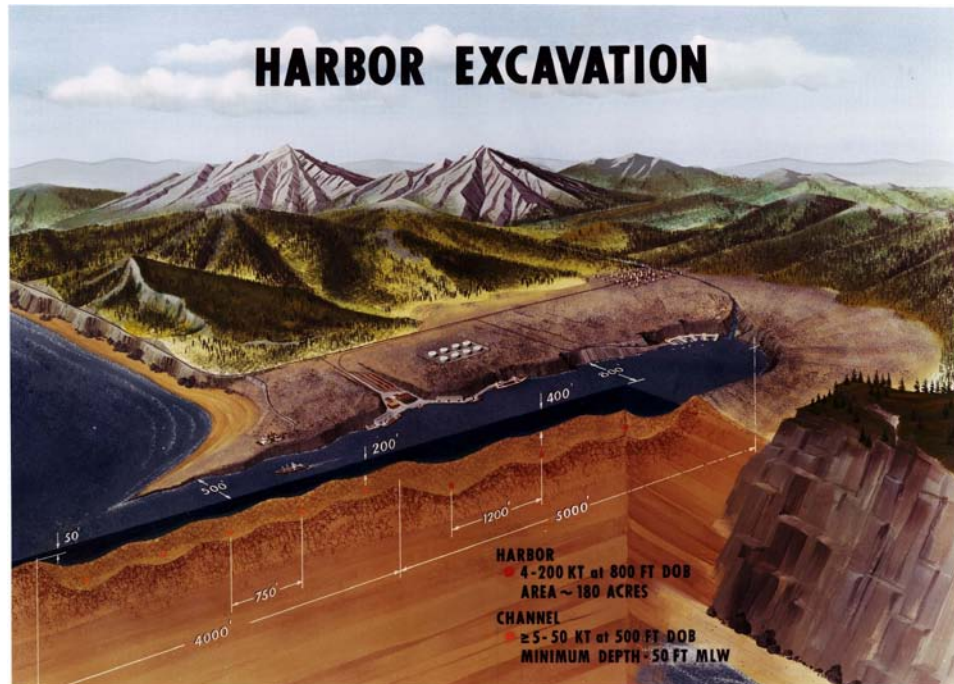


Figure 4.20-3. Schematic design for an inland harbor. The design includes size dimensions for a harbor at Cape Thompson, a proposed harbor project to be completed prior to Katalla Harbor (Lawrence Livermore National Laboratory n.d., Negative No. GLC-6610-9007).

No documentation mentioning the Katalla project was found for the period from December 1959 until early 1963. This may reflect the Laboratory's preoccupation with the environmental studies and preliminary engineering designs for Project Chariot which eventually stalled. The next documents that mention a harbor at Katalla are a February 1963 Lawrence Radiation Laboratory publication, *Report UCRL-7222*, and a March 1963 publication of *Nuclear News*, both by Teller. Here, nuclear excavation of a harbor at Katalla is mentioned as being under consideration, although it had not yet been established if it was feasible to mine the Bering River coal fields. Finally, a March 1964 document from the U.S. Atomic Energy Commission, Division of Peaceful Nuclear Explosives, lists a harbor at Katalla as a suggested nuclear excavation project.

Katalla Harbor was a Level 5 activity. The proposed harbor was a location where activity was confined to conceptual design and background research.

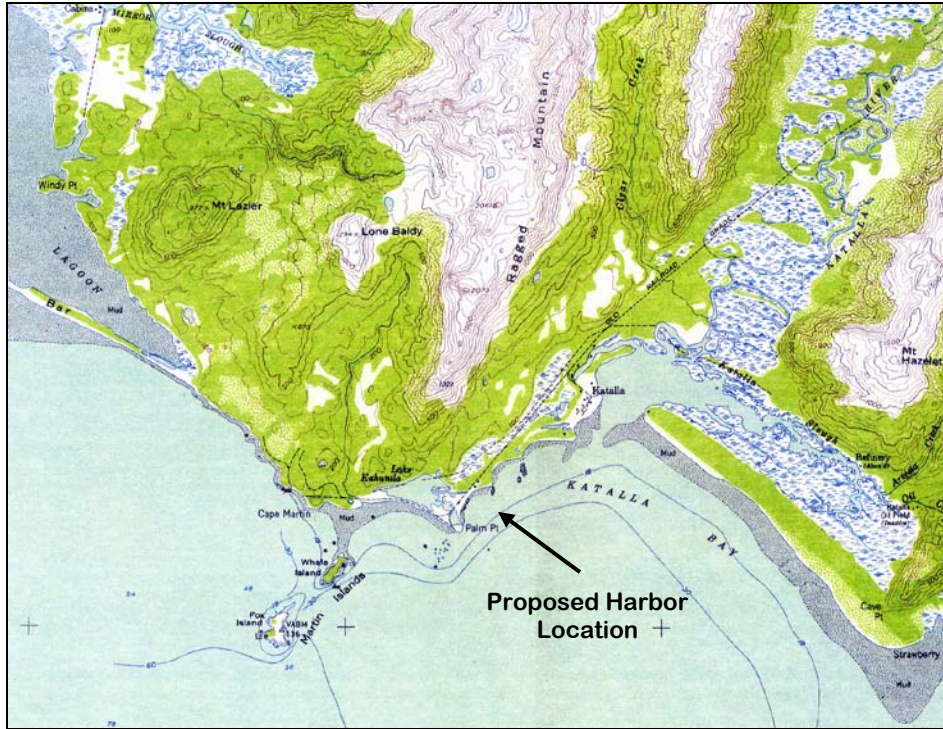


Figure 4.20-4. Proposed location for a harbor in Katalla Bay showing Lake Kahuntla and Palm Point (adapted from U.S. Geological Survey 1953, Cordova A-2).

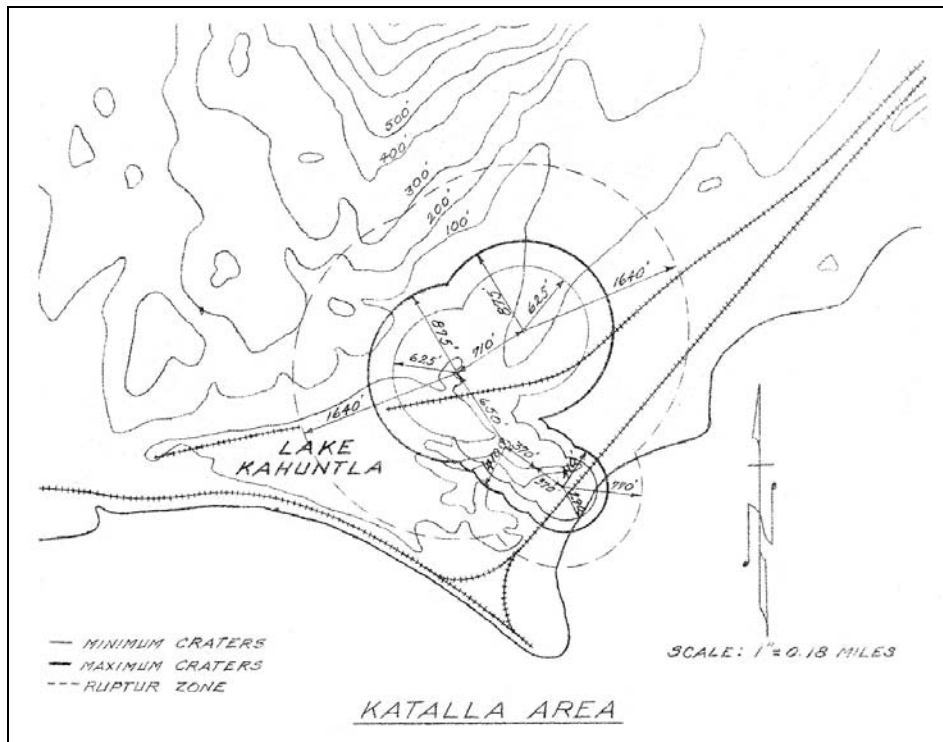


Figure 4.20-5. Pre-blast and post-blast schematic for Katalla Harbor (Bacigalupi 1958).

## CHRONOLOGICAL BIBLIOGRAPHY

- U.S. Coast and Geodetic Survey, 1913. *South Coast of Alaska, Controller Bay Map*. Washington, D.C. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-074.
- U.S. Geological Survey, 1948. *Cordova, Alaska, Quadrangle Map*. Washington, D.C. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-074.
- U.S. Geological Survey, 1953. *Cordova (A-1), (A-2), (B-1), and (B-2), Alaska, Quadrangle Maps*, 1:63 360 series, Washington, D.C. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-074.
- Daily News Miner, 1958, Physicists Here For Discussion: Dam at Rampart, Harbors Along Arctic Coast Possible. *Daily News Miner*, Vol. 36, July 16. Fairbanks, AK. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.
- Daily News Miner, 1958, Alaska Can Have Massive Nuclear Engineering Job. *Daily News Miner*, July 17. Fairbanks, AK. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.
- Jessen's Weekly, 1958, Alaska Given First Chance on Nuclear Construction for Economic Development. *Jessen's Weekly*, Vol. 17, No. 29, July 17. Fairbanks, AK. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.
- Blue, C. L., 1958, "Project Plowshare." Memo from C. L. Blue, Lawrence Radiation Laboratory, to W. B. Reynolds, September 24. On file at: Archives and Records Office, Lawrence Berkeley National Laboratory, Berkeley, CA, File 434-900157, 2/18.
- Mathews, Ted C., 1958. Letter with encl (The Feasibility of a Harbor at Katalla, Alaska. Report to Lawrence Radiation Laboratory from Exploration Services) from Ted C. Mathews, Exploration Services Inc., Anchorage, AK, to Gerald W. Johnson, September 30.
- Bacigalupi, C. M., 1958. "Transmittal of the Operational Concept for Katalla." Memo with encl. (Operational Concept of the Technical Director for Katalla Harbor, manuscript) from C. M. Bacigalupi, Lawrence Radiation Laboratory, December 24. On file at: Archives and Records Office, Lawrence Berkeley National Laboratory, Berkeley, CA, File 434-900157, 2/19 [OUO].

- Lawrence Radiation Laboratory, 1958. Operational Concept of the Technical Director for Katalla Harbor. Manuscript, Lawrence Radiation Laboratory, December 24. On file at: Technical, Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV and Lawrence Berkeley National Laboratory, Berkeley, CA, file 434-900157, 2/18 [OUO].
- Plowshare Advisory Committee, 1959. Katalla Harbor. Report prepared for Plowshare Advisory Committee Briefing, November 12-13, October 30. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.
- Plowshare Advisory Committee, 1959. Plowshare Advisory Committee Briefing, November 12-13, 1959, agenda. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.
- Teller, Edward, 1963. Plowshare. University of California, Lawrence Radiation Laboratory *Report UCRL-7222*, February 4. Livermore, CA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.
- Teller, Edward, 1963, Plowshare. *Nuclear News*, Vol. 6, No. 3, pp. 4-12, March. American Nuclear Society.
- U.S. Atomic Energy Commission, 1964. Suggested Nuclear Excavation Projects and Possible Nuclear Excavation Projects. Manuscript, Division of Peaceful Nuclear Explosives, July. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.
- U.S. Department of Energy. Nevada Operations Office, 1997. Plowshare Program Executive Summary. Report from U.S. Department of Energy, December 22.
- U.S. Department of Energy. Nevada Operations Office, n.d. The Plowshare Program (Draft). Report from U.S. Department of Energy.
- Lawrence Livermore National Laboratory, n.d. "Harbor Excavation." Excavation drawing, harbor-a. Negative No. GLC-6610-9007. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA.

## **4.21 KAUNAKAKAI HARBOR**

### **Plowshare Program Nuclear Harbor Excavation Experiment Molokai, Hawaii**

Beginning in 1962, the U.S. Atomic Energy Commission and the U.S. Army Corps of Engineers engaged in joint research efforts as part of the Commission's Plowshare Program – a development initiative for the peaceful use of nuclear explosives. Charged with investigating practical applications for nuclear excavation technology, the U.S. Army Engineer Nuclear Cratering Group tasked the Honolulu Engineer District with identifying civil works projects within its administrative purview that might be appropriate study subjects. Two letters (63-100 and 63-108) from the Nuclear Cratering Group to the Honolulu Engineer District, each dated May 06, 1963, authorized the initial funding and designated a location on the island of Molokai, Hawaii for a potential harbor construction project (Figure 4.21-1). The Nuclear Cratering Group proposed using a nuclear explosive to create a deep-draft commercial harbor along the island's south coast just east of Kaunakakai.

The U.S. Congress originally authorized the creation of a deep-draft harbor at Kaunakakai, Molokai using traditional construction techniques as part of the River and Harbor Act of 1962. The project specifics appeared in House Document No. 484, 87<sup>th</sup> Congress, 2<sup>nd</sup> Session, and called for the excavation of a 500 ft wide by 40 ft deep entrance channel leading to a 35 ft deep harbor basin for commercial traffic, a smaller 15 ft deep berthing area for recreational craft and light-draft fishing vessels, protective breakwaters, and dock facilities. The new project would replace the existing Kaunakakai harbor built in 1934, which was only suitable for inter-island barges, small fishing boats and recreational craft. Most cargo bound to and from Molokai was transshipped through major ports on the other Hawaiian Islands. Neither cruise ships nor inter-island ferries could safely anchor at Molokai. Both the Libby and Del Monte Corporations had large pineapple plantations on Molokai and the Federal Government was sponsoring a multi-million dollar irrigation project for the eastern and central portion of the island making a sound transportation network critical. A new commercial harbor would vastly improve the island's stagnant economy and raise the inhabitants' standard of living. Even so, final funding authorization for the project was contingent on the establishment of industrial facilities (i.e., a pineapple cannery) to support transpacific commerce by either the State of Hawaii or private industry.

The Nuclear Cratering Group felt that all these factors made Molokai a leading candidate for a nuclear harbor demonstration project. Various status reports generated by the Nuclear Cratering Group between 1963 and 1965 indicate that the Honolulu Engineer District received funding to investigate a variety of nuclear harbor excavation projects including harbors that could accommodate shallow- and deep-draft boats, inter-island ferries and military vessels. By 1967, the Honolulu Engineer District selected a potential



Figure 4.21-1. Location of Project Kaunakakai Harbor in Hawaii (adapted from USA Relief Maps 2004).

location for a deep-draft harbor approximately nine miles west of the town of Kaunakakai near the small community of Kolo, Molokai (Figure 4.21-2). The draft feasibility study for Project Kaunakakai Harbor was in review by the end of 1967 with the final report issued in February 1969. Using predictive models based on data from the Danny Boy cratering experiment conducted at the NTS in March 1962, researchers developed a preliminary design concept. The initial plan called for the detonation of a 500 kt device at a depth of 880 ft in the basalt formation underneath the shallow coral reef along the coastline. The nuclear detonation would create a harbor basin approximately 1,600 ft in diameter and 500 ft deep at its center. The required 38 ft depth near the crater margins could be achieved with minimal dredging. Ejecta from the blast would form a crater lip at least 100 ft high to serve as a protective breakwater. Construction of the 1,800 ft long and 42 ft deep entrance channel would be accomplished with conventional explosives once the harbor basin was formed (Figures 4.21-3 and 4.21-4).

The feasibility study also provided a brief summary of environmental resources that could be affected by the harbor project. A recent inventory of the islands cultural resource by the Bishop Museum indicated that about 90 archaeological sites fell within a five-mile radius of the proposed harbor location. Most would be unaffected by the project, but three ancient fish ponds would be destroyed during construction. However, other better preserved ponds would not be harmed. The report's comparative cost analysis of the



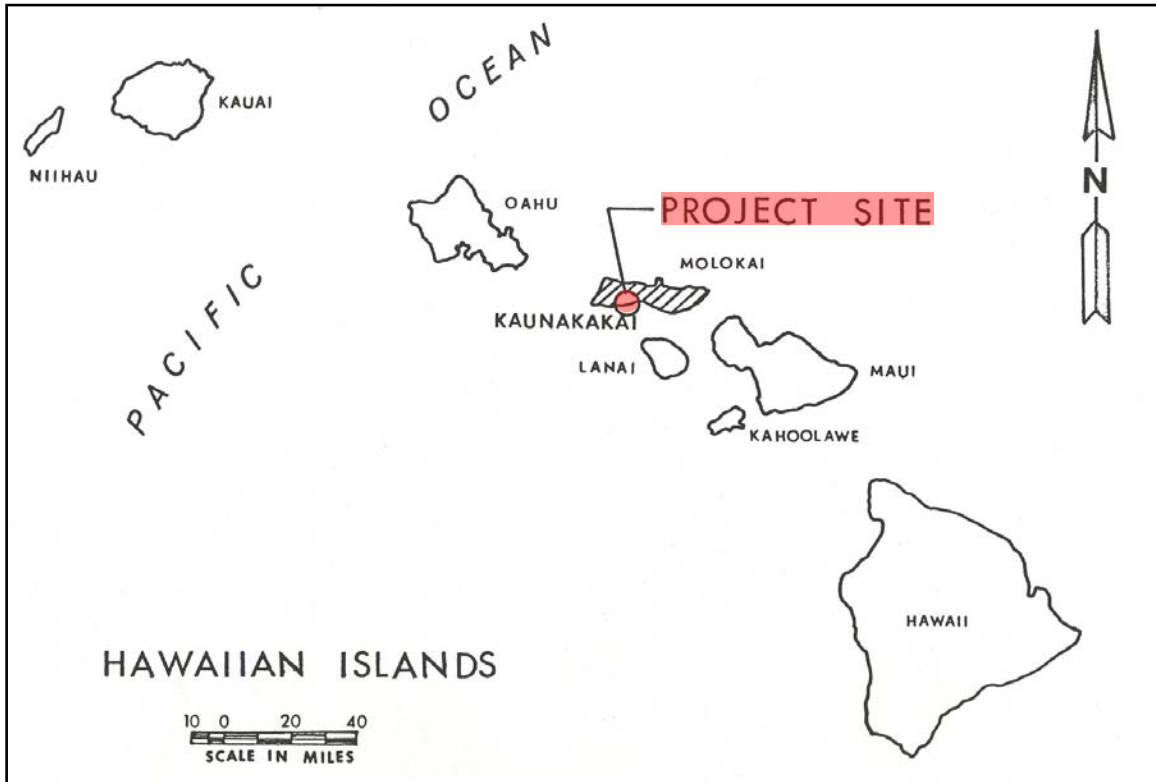


Figure 4.21-2. Proposed Location for the Kaunakakai Deep-Draft Harbor Project (adapted from U.S. Army Corps of Engineers, Honolulu District 1969, Figure 1).

nuclear excavation method versus conventional harbor construction gave a distinct advantage to the traditional approach. Including all harbor and channel excavation costs, construction of navigation aids, land acquisition, easements, and rights-of-way, and radiological safety precautions, the estimated cost of a nuclear excavated deep-draft harbor was nearly \$21.4 million. The projected cost of a commercial harbor built using conventional methods was about \$16.9 million. The Honolulu Engineer District, however, concluded that a nuclear harbor was both practical and feasible and recommended more detailed site investigations proceed in order to refine the design and better characterize potential side effects and safety requirements. Additional topographic, geological, hydrological, hydrographic, meteorological, ecological, population, and economic resources data gathering surveys would be necessary. The proponents also advocated a series of low-yield conventional explosive calibration tests with a full complement of seismic monitoring, crater characterization studies, and air blast measurements. The estimated timetable for the pre-construction phase of the Kaunakakai Nuclear Harbor project including the site characterization studies and project planning was 15 months. If the preliminary investigations found the proposed site suitable and the level of risk acceptable, the construction, execution, and operation phases of the project would take another 42 months.

As with the conventional harbor project, the expense of a large nuclear harbor could not be justified without an adequate industrial base, in this case a pineapple canning plant, and construction of a pineapple cannery could not occur until adequate infrastructure including a commercial harbor with support facilities (i.e., warehouses, loading dock, etc.) was in place. However, the 1969 feasibility study suggested that increasing population pressure and the growth of the tourism industry on the island of Oahu was causing the agricultural and livestock industries to shift the centers of operation to Molokai and Lanai. With this in mind; the possibility of a nuclear excavated harbor for Molokai deserved additional consideration. Even if the cost and time frame of a nuclear excavated harbor exceeded the construction of a similar facility using conventional methods by a bout \$4.5 million and 18 months, the value of demonstrating nuclear excavation technology might merit the additional expenditure.

Although the Kaunakakai Harbor project had support within both the National Cratering Group and the State of Hawaii, it never progressed beyond the feasibility study. The Del Monte and Libby Corporations remained unconvinced by the Federal government's promises and neither private industry nor the state committed the financial resources for extensive commercial development. The old shallow-draft harbor proved sufficient for the level of barge traffic necessary to transport Molokai's existing agricultural output and the U.S. Atomic Energy Commission and National Cratering Group placed the project on indefinite hold.

Project Kaunakakai was a Level 5 activity with work largely confined to concept development with a site visit(s). The proposed project area was visited in FY2003.

### **Field Visit**

The Desert Research Institute visited the area of the Project Kaunakakai Harbor on July 13, 2003. In the 1962 documentation on the proposed harbor and current topographic maps, there were several public roads to the coastline adjacent to the project area. Although this location could be observed from the pier near the town of Kaunakakai, some 9 miles away, multiple efforts to access the area, including the town of Kolo were unsuccessful. The roads from the inland that led directly to the location have been privatized and cannot be used by the public. The roads to the site along the coastline from the east have been truncated and closed by private land development, particularly agricultural fields. The coast road from the west is not maintained and could not be used by a passenger vehicle. During the visit, Desert Research Institute personnel learned that ancient fish ponds that would have been impacted by the Kaunakakai Harbor Project are now protected and preserved as a point of cultural significance.

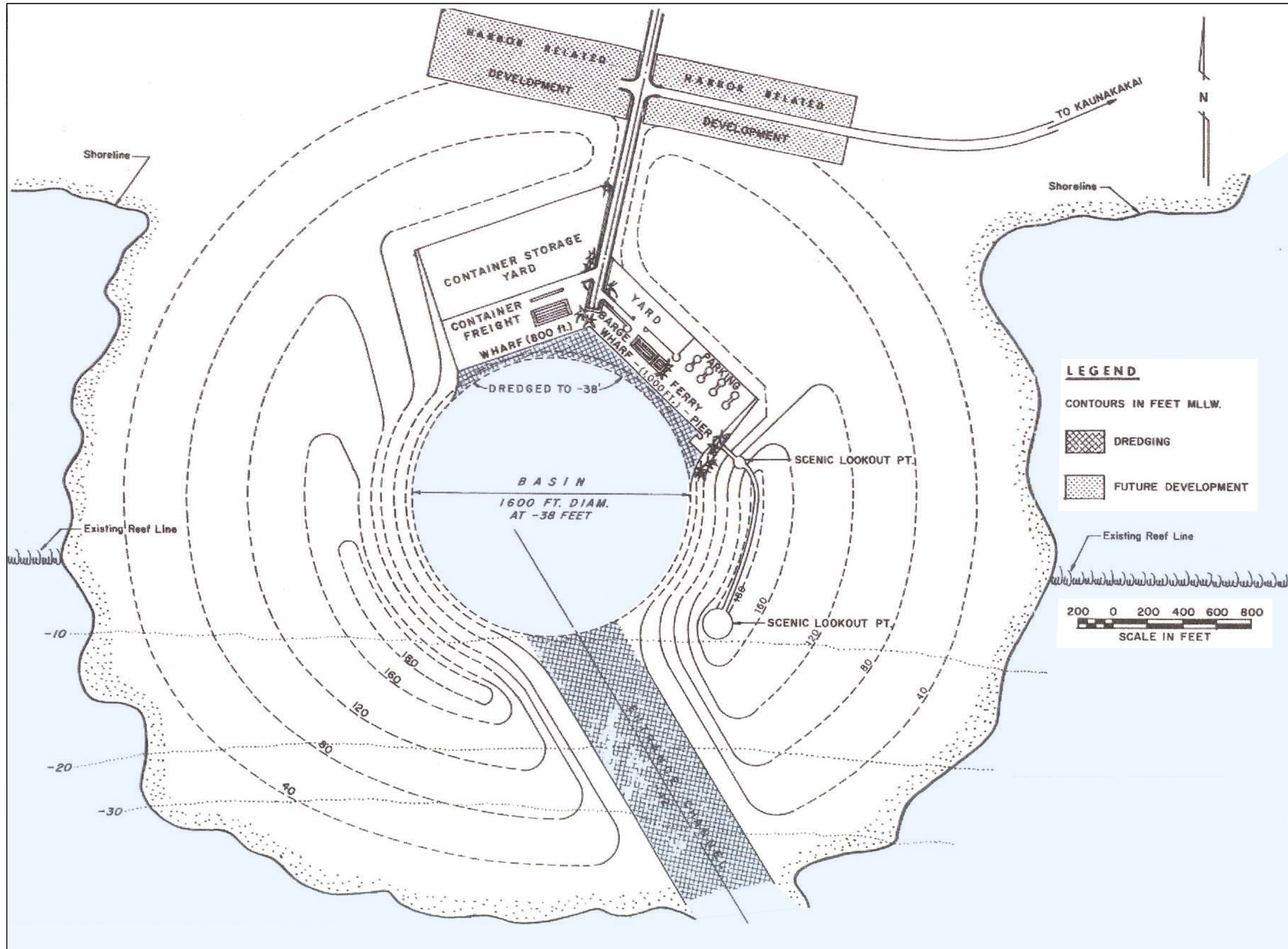


Figure 4.21-3. Conceptual model for the Kaunakakai Deep-Draft Harbor Project (adapted from U.S. Army Corps of Engineers, Honolulu District 1969, Plate 3).



Figure 4.21-4. Proposed Site for the Kaunakakai Deep-Draft Harbor Project (adapted from U.S. Army Corps of Engineers, Honolulu District 1969, Plate 1).

## CHRONOLOGICAL BIBLIOGRAPHY

- Lawrence Radiation Laboratory. U.S. Army Engineer Nuclear Cratering Group, 1963. "Funding Authorization for Kaunakakai Harbor Project Study." Letter from U.S. Army Engineer Nuclear Cratering Group to U.S. Army Corps of Engineers, Honolulu District, May 6.
- Graves, Ernest, 1964. "Status Report - Nuclear Explosives Studies for Civil Construction (Reports Control Symbol ENGCE-E-9)." Letter with encl. ("Status Report, Effective Date: 31 December 1963 - ENGCE-E-9") from Ernest Graves, Lawrence Radiation Laboratory, U.S. Army Engineer Nuclear Cratering Group, to Chief of Engineers, Department of the Army, February 4. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.
- Graves, Ernest, 1964. "Status Report - Nuclear Explosives Studies for Civil Construction (Reports Control Symbol ENGCE-E-9)." Memo with encl. ("Status Report, Effective Date: 31 March 1964 - ENGCE-E-9") from Ernest Graves, Lawrence Radiation Laboratory, U.S. Army Engineer Nuclear Cratering Group, to Chief of Engineers, Department of the Army, April 23. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.
- Slazak, Walter J., 1965. "Status Report - Nuclear Explosives Studies for Civil Construction (Reports Control Symbol ENGCE-E-9)." Memo with encl. ("Status Report, Effective Date: 31 December 1964 - ENGCE-E-9") from Walter J. Slazak, Lawrence Radiation Laboratory, U.S. Army Engineer Nuclear Cratering Group, to Chief of Engineers, Department of the Army, January 15. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.
- Hughes, Bernard C., 1965. "Status Report - Nuclear Explosives Studies for Civil Construction (Reports Control Symbol ENGCE-E-9)." Letter with encl. ("Status Report, Effective Date: 31 March 1965 - ENCGW-P-6(R1)") from Bernard C. Hughes, U.S. Army Engineer Cratering Group, to Chief for Engineers, Department of the Army, April 13. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.
- Hughes, Bernard C., 1968. "Status Report - Nuclear Explosives Studies for Civil Construction (RCS ENGCE-P-6 (R-1))." Letter with encl. ("Status Report, Effective Date: 31 December 1967") from Bernard C. Hughes, Lawrence Radiation Laboratory, U.S. Army Engineer Nuclear Cratering Group, to Chief of Engineers, Department of the Army, January 13. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.

U.S. Army Corps of Engineers. Honolulu District, 1969. Nuclear Excavation Feasibility Study for Kaunakakai Harbor, Molokai, Hawaii. Manuscript, Fort Armstrong, Honolulu, HI, February. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-078 [OUO].

Nordyke, Milo D., 1969. Telex from Milo D. Nordyke, Lawrence Radiation Laboratory, to John S. Kelly, May 7.

## 4.22 KETCH

### **Plowshare Program Nuclear Explosives for Underground Natural Gas Storage Pennsylvania**

In the early 1960s, the Columbia Gas System Service Corporation was working on new ideas for the economical storage of gas in areas without sufficient natural reservoirs. Columbia Gas contacted the U.S. Atomic Energy Commission's Division of Peaceful Nuclear Explosives in the spring of 1964 for assistance with this issue. Initial contact was followed by discussions with the U.S. Atomic Energy Commission and Lawrence Radiation Laboratory regarding the possibilities of constructing underground storage cavities with nuclear explosives.

Columbia Gas conducted an analysis of the feasibility and benefits of using nuclear explosives in their work in February of 1965, reaching the conclusion that it would be worthwhile to pursue this avenue of research. Columbia Gas contacted the U.S. Atomic Energy Commission in April of 1965, expressing strong interest in the concept and in working on a formal feasibility study with the U.S. Atomic Energy Commission and the U.S. Bureau of Mines. Potential project locations under consideration were within the Columbia Gas System Service Corporation's territory and included parts of New York, Pennsylvania, Ohio, Maryland, West Virginia, Virginia, and Kentucky. The U.S. Atomic Energy Commission stated that the execution of this project, named Ketch, was dependent upon availability of appropriate geology to hold gas in the nuclear chimney.

A feasibility study for the Ketch project began in 1965. During the first week of October, Columbia Gas personnel conducted a field visit to one of the locations under serious consideration, Pennsylvania Site No. 5. This site was in the Sproul State Forest, Clinton County, approximately 12 miles southwest of Renovo, in north-central Pennsylvania (Figure 4.22-1). In the early 1950s, the geological formation at this location, the Burnside Dome, had been drilled for natural gas by the Manufacturers Light and Heat Company, an operating company of Columbia Gas. No commercial quantities of gas were found in the immediate area but it was hoped that nuclear stimulation could improve the output of gas. As part of the feasibility research to determine the suitability of the location for a nuclear detonation, Columbia Gas inventoried and photographed all houses within a two-mile radius and all major structures within a 20-mile radius of this site.

By April of 1966, Columbia Gas had provided Lawrence Radiation Laboratory with research data including geologic and topographic maps, logs from existing wells in the area, weather information, population data and a description of Site No. 5. This was the preferred location for Project Ketch. The reasons the site was selected included its central location to a major energy market with supply issues, availability of a high pressure gas source in the vicinity, its remoteness from valuable structures or population centers, and a favorable geological setting. Ground zero was located in Clinton County, but the site

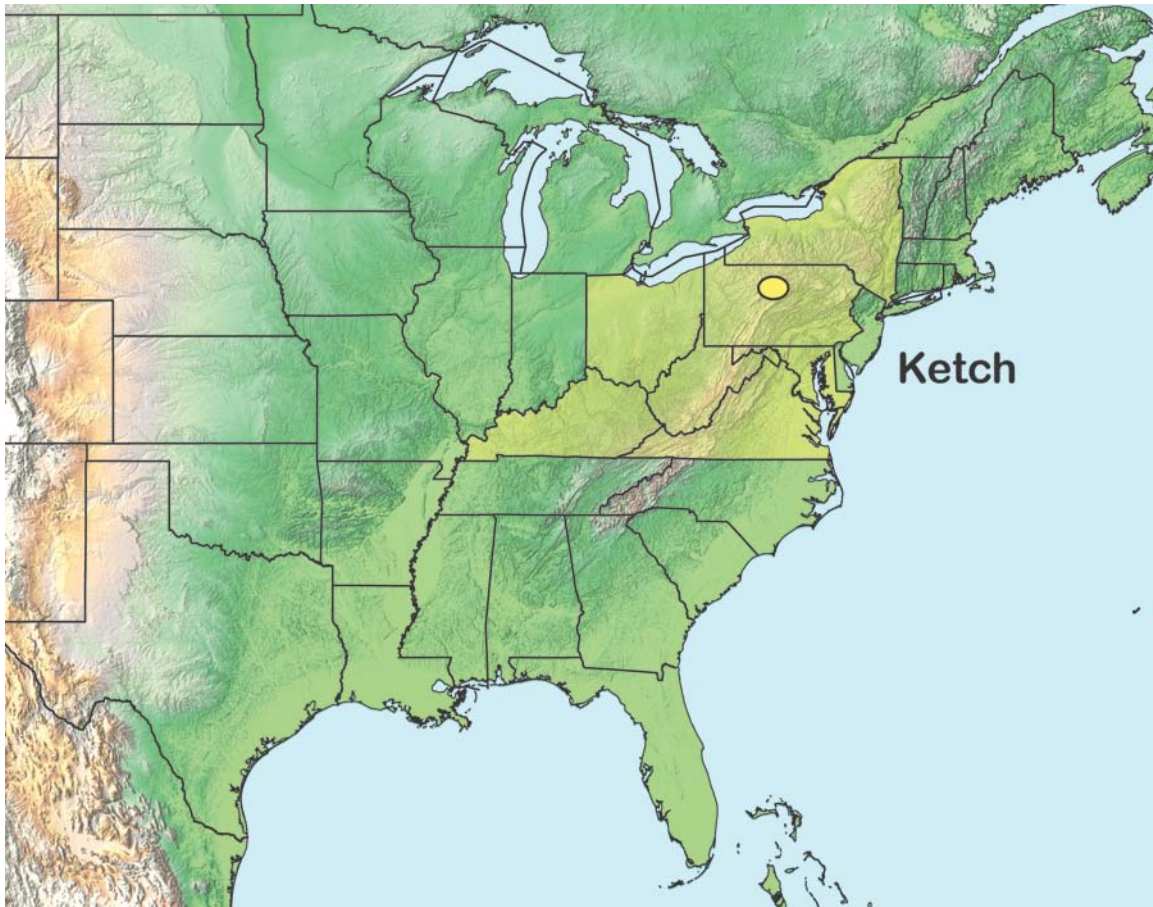


Figure 4.22-1. Location of Project Ketch in central Pennsylvania. The yellow-shaded area denotes the states originally considered for the project (adapted from USA Relief Maps 2004).

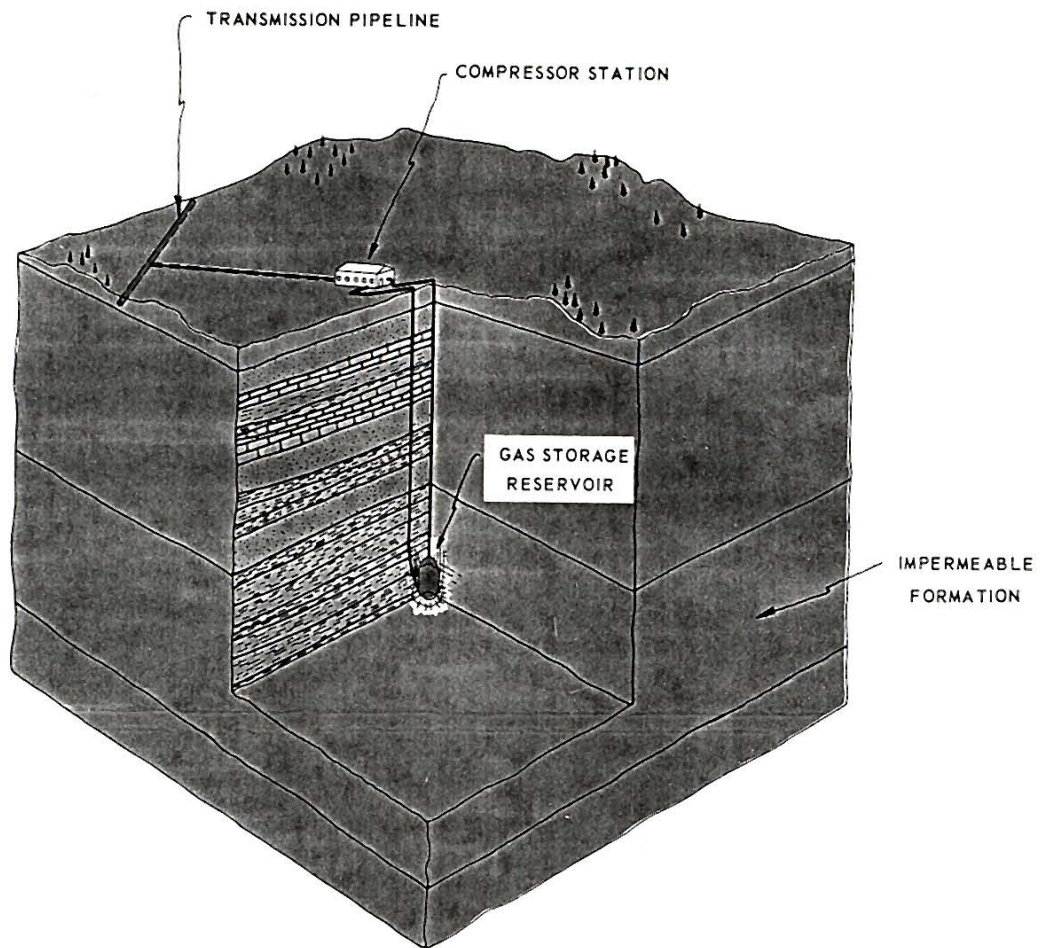
would extend into Centre County. At some time in 1966, the U.S. Atomic Energy Commission entered into a contract with Columbia Gas for a feasibility study.

After providing the data above, Columbia Gas suggested the next step in the process was to have Lawrence Radiation Laboratory and Atomic Energy Commission, Nevada Operations Office personnel review the research data and then make a site visit. If a favorable review resulted, the company proposed additional geological characterization studies. These could be accomplished by re-drilling a dry gas well abandoned by Columbia in 1953. However, several concerns remained, e.g., the removal of residual radioactivity, the permeability of the cavern walls, and the economic feasibility of nuclear created storage reservoirs (Figures 4.22-2 and 4.22-3). On August 31, 1966, Lawrence Radiation Laboratory completed a report presenting the technical concept and cost estimates for Project Ketch. During the feasibility study, Columbia decided that this approach could be beneficial economically and in January of 1967, Columbia sent a formal letter of intent to conduct the Ketch Project to the U.S. Atomic Energy Commission, pending completion and favorable evaluation of the study.



A completed draft of the feasibility study, prepared by the Columbia Gas System Service Corporation, Lawrence Radiation Laboratory, the U.S. Atomic Energy Commission, and the U.S. Bureau of Mines, was in circulation for comments in April 1967. On June 7, 1967, there was an informal scoping meeting that included representatives from the Pennsylvania Governor's Atomic Advisory Committee, Pennsylvania Bureau of Mines, Pennsylvania State University, Pennsylvania Department of Forestry and Waters, Lawrence Radiation Laboratory, Atomic Energy Commission, Nevada Operations Office, and Columbia Gas Services System Corporation. The day after this meeting many of the participants visited the proposed Project Ketch location. U.S. Atomic Energy Commission Nevada Operations Office and Lawrence Radiation Laboratory representatives identified a potential control point location approximately 12,000 ft southwest of the proposed ground zero. At least one more visit was made that month to the proposed Project Ketch location by representatives of the U.S. Atomic Energy Commission, Nevada Operations Office, its contractors, and Lawrence Radiation Laboratory to evaluate the site and obtain sufficient information to assist with cost estimates. A meeting was held in Harrisburg, Pennsylvania on June 24, 1967, to discuss the status of Project Ketch. In attendance were representatives of the Commonwealth of Pennsylvania, several Pennsylvania State agencies, Columbia Gas System Service Corporation, and the U.S. Atomic Energy Commission. The U.S. Atomic Energy Commission presented an overview of Plowshare and Ketch activities and warned the participants that funding for the project might not be available in 1968. The experience of the U.S. Atomic Energy Commission, Nevada Operations Office was emphasized and it was stated that this office would manage the detonation program and assume responsibility for public safety, if the project was executed. Also, the Commonwealth explained that it would be a third party to an agreement for Project Ketch between Columbia Gas and the U.S. Atomic Energy Commission and would have veto power over the project at any time.

The Project Ketch feasibility study, prepared by the Columbia Gas System Service Corporation, the U.S. Atomic Energy Commission, San Francisco Operations Office, Lawrence Radiation Laboratory and the U.S. Bureau of Mines, was issued in July 1967. Due to increased consumer demand and predicted future demand for natural gas, the need existed for more underground gas storage capacity. Project Ketch was an experiment designed to clarify several technical uncertainties and to determine if it was economically feasible to create underground gas storage with nuclear explosions. Four of the experiment's objectives were: 1) determination of the capability of the nuclear reservoir created by the detonation to store gas at various pressures, 2) determination of the volume of storage space created, 3) assessment of the feasibility of various methods for controlling and limiting the levels of radioactivity which might be introduced into gas stored in the nuclear chimney, and 4) definition of economic factors involved in this commercial application.



CUTAWAY SECTION SHOWING  
NUCLEAR GAS STORAGE FIELD

Figure 4.22-2. Nuclear gas storage reservoir (Columbia Gas System Service Corporation 1966, Figure 3).

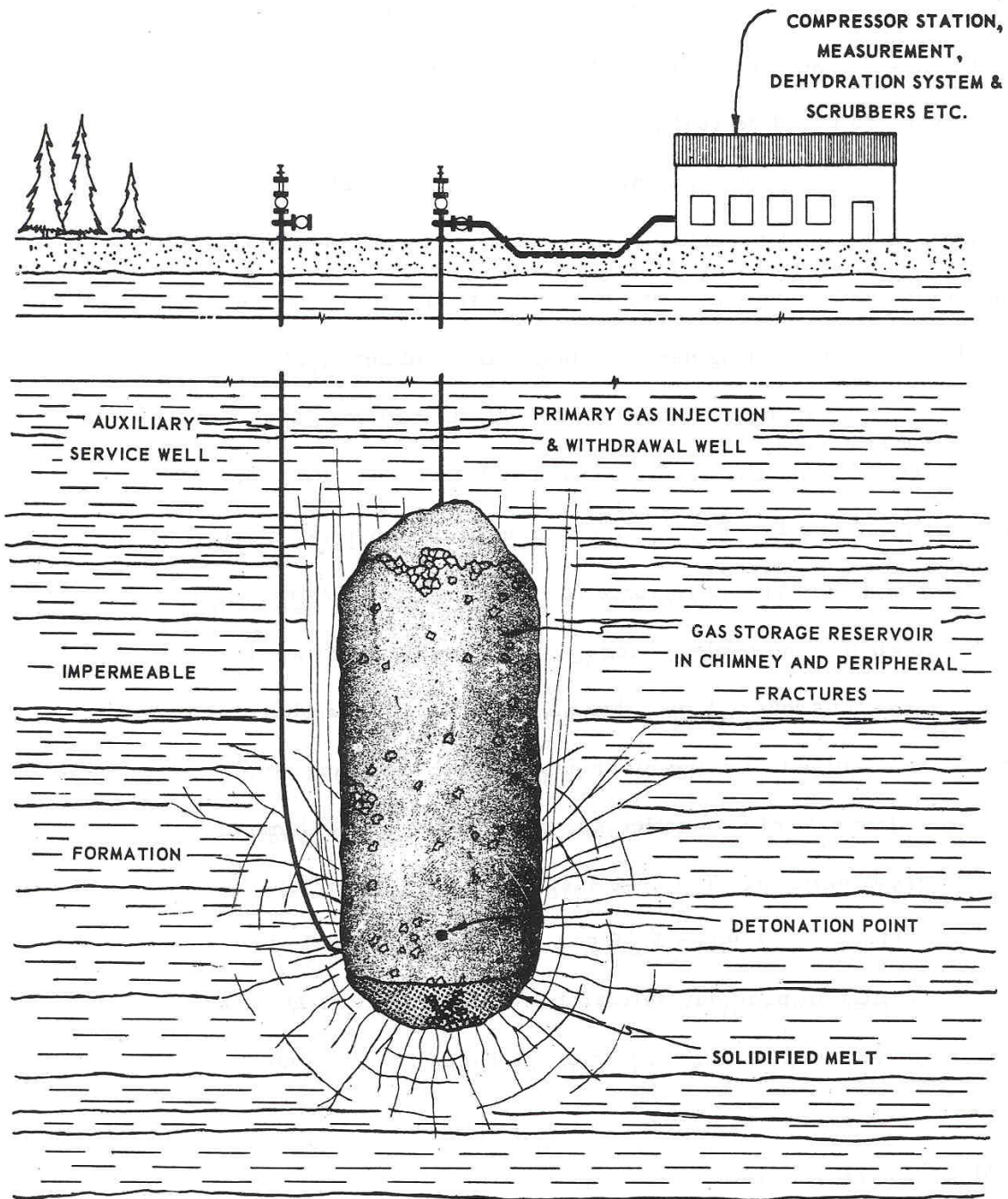


Figure 4.22-3. Gas storage in a nuclear reservoir (Columbia Gas System Service Corporation 1966, Figure 4).

The project proposed to detonate a 24-kt nuclear device at a depth of 3,300 ft in a shale formation (Figure 4.22-2). The detonation would create a rubble chimney with a radius of 90 ft and a height of 300 ft with a 465 million cubic foot gas storage capacity at 2,100 psi. Cracks and fissures would extend approximately 300 ft from the chimney. The natural gas storage would occur in the spaces between the broken rock and surrounding network of fractures. Stored under pressure, chimney capacity was projected at 400 to 600 million cubic feet. A device emplacement drill hole probably would be required, in addition to multiple experimental monitoring or observation wells. Once the radiological concerns had been resolved, two production wells would need to be drilled into the chimney, one primary injection/withdrawal well and a second auxiliary well.

Five phases were proposed for the project and included field testing and exploratory and environmental studies (8 months), detonating the nuclear explosion (6 months), decontamination of the chamber (11 months), construction of surface facilities and extensive post-shot testing programs (6 months), and finally, plant operation experiments and evaluation reports (14 months). The projected cost of the experiment is unclear; however, Columbia Gas estimated that a six million dollar investment in the project would break even over 35 years with a savings of \$684,000 using nuclear explosive technology versus conventional methods.

The feasibility study concluded that underground gas reservoirs created by nuclear explosives offered the possibility of a more efficient delivery system and cost savings that ultimately could be realized by the public. The Ketch experiment was needed to determine the specific effect of an underground nuclear explosion in a shale formation and whether a chimney created by the nuclear explosion would have the necessary characteristics for use as a gas reservoir. The potential locations in Pennsylvania were considered to be representative of those locations where it would be beneficial to apply this technology in the future. It also stated that the Ketch experiments could be executed without compromising public safety and it would fulfill the technical objectives providing a basis for an evaluation of the economics involved in this approach. The study group recommended that Phase I of Project Ketch be initiated at the study site to determine if the location was suitable for the experiment. Phase I would be started after receiving the necessary approval and permits, including those from the Commonwealth of Pennsylvania. This investigation would include a drilling program to better characterize the geological and hydrological conditions of the site along with meteorological and other environmental studies. If the results from this phase differed significantly from the information used for the predictive modeling, then the project would have to be redesigned, relocated, or terminated.

In August 1967, the Pennsylvania Governor authorized the U.S. Atomic Energy Commission to use Commonwealth land for Phase I, the planning and evaluation stage of Project Ketch. He based his decision on the recommendation of the Pennsylvania Advisory Committee on Atomic Energy Development and Radiation Control and other state agencies directly involved. The site, located within the Sproul State Forest, would be leased to the U.S. Atomic Energy Commission as long as an adequate and competent safety review demonstrated the test would not injure people and or the environment.

Columbia Gas invited U.S. Atomic Energy Commission Nevada Operations Office personnel to participate in briefings near the proposed Project Ketch site (Figure 4.22-4). Also involved in the briefings were the Division of Peaceful Nuclear Energy, the U.S. Atomic Energy Commission Headquarters, the General Counsel's office, and Columbia Gas. On October 11, 1967, representatives of these agencies met with various groups throughout the day to address their concerns regarding Project Ketch, especially the effects of the shock wave from a detonation. These were not public meetings and a request was made for meetings open to all in the near future.

A few days before this meeting, concerns began to surface in Pennsylvania regarding potential radioactivity associated with Project Ketch. On October 7, 1967, a doctor at the Department of Radiology, University of Pennsylvania Hospital, wrote to Pennsylvania's Secretary of the Department of Commerce expressing concern over possible levels of radioactivity from Project Ketch. This doctor had involvement in the state process for approval of Project Ketch, but at this time was uncomfortable with the way radioactivity was dealt with in PNE-1200, a brochure on Project Ketch. He recommended other agencies be advised and informed about the issues. In the midst of these discussions, the sixteenth meeting of the Plowshare Advisory Committee was held on the 10<sup>th</sup> and 11<sup>th</sup> of October, 1967, and this committee recommended that the next two projects conducted be Sloop and Ketch.



Figure 4.22-4. Gate and road to Ketch ground-zero, 1995 (Krygier 1998, Figure 7).

On February 2, 1968, a Senator from Pennsylvania wrote to the Chairman of the U.S. Atomic Energy Commission, forwarding correspondence and a scientific paper from a professor at the University of Pittsburgh questioning the advisability of conducting Project Ketch. The Senator asked for a response from the U.S. Atomic Energy Commission. Then a Pennsylvania Congressman delivered a speech in the House of Representatives on February 15, 1968 opposing the proposed Ketch project citing public safety and environmental concerns. The Congressman urged closer scrutiny of the U.S. Atomic Energy Commission programs to determine whether the need for its programs justified the costs. He also commented that funding for defense and security is one thing, but profit for private companies is another.

The public's concerns about the Ketch proposal began to have increasing strength with public officials, partly due to the fact that 1968 was a major election year. On April 4, 1968, the group, People against Ketch, was organized in Centre County, with the goal to stop the Ketch project. At the seventeenth meeting of the Plowshare Advisory Committee on April 15 and 16, 1968, the committee discussed the public acceptance problems with this project. The committee believed that to alleviate the rational concerns, it would be necessary to do everything possible to demonstrate how much experience the U.S. Atomic Energy Commission and its contractors had and how safe nuclear operations had been.

As more and more scrutiny was placed on the project, representatives of the U.S. Atomic Energy Commission and Columbia Gas Company made a presentation on the Ketch project at the Pennsylvania State University to an audience of 400 people on April 17, 1968. The question and answer session alone lasted more than three hours. A previous forum in Lock Haven, Pennsylvania, earlier in the year, had been criticized for pre-established limits on questions. Newspaper headlines from January to July included headings, such as, 'Ketch' Problem Comes into Focus, Public Right to Decide, Candidate Discusses Gas Blast, Cooper-Tanner Oppose Ketch, 2,500 on Petition against Ketch, Five-Hour Session on Project Ketch at State College Alters No Opinions, 'Project Ketch' Program on WPSX-TV Monday 10 p. m., Petitions Circulating on Ketch, and Scenic View Located Near Ketch Site.

A memorandum from the U.S. Atomic Energy Commission, dated April 26, 1968, stated that the U.S. Atomic Energy Commission, in addition to cooperating with Columbia Gas Company on various public relations efforts, had been working to develop a suitable lease to the company by Pennsylvania that would allow the Phase I site evaluations to be conducted as previously authorized by then Governor Shafer. On May 8, 1968, the Lawrence Radiation Laboratory issued a report on the biological hazards of radiation associated with the Ketch project and discussed the genetic effects of the burning of the natural gas which would be stored in the nuclear chimney created by the detonation, an issue of importance in the April 17<sup>th</sup> public forum.

It was announced on July 15, 1968, that Columbia Gas Company withdrew its request to lease land for project Ketch activities due to the increasing public opposition to the project. An article published in August 1968 stated that Pennsylvania rejected Project

Ketch because of opposition from the coal industry, conservationists, and residents. The states of Kentucky and West Virginia, however, were actively seeking the project and the Southern Interstate Nuclear Board contacted both the U.S. Atomic Energy Commission and Columbia Gas System, expressing an interest in the nuclear-created natural gas reservoir. Columbia Gas had received many offers of alternative sites, most of which were in Appalachia. At the time of the article, the company was reviewing the submissions trying to narrow the list to four or five. Several of the locations were in areas previously considered prior to selection of the Pennsylvania site. Columbia hoped to have some new proposals for the U.S. Atomic Energy Commission in 60 to 90 days.

Planning continued on Ketch. An October 9, 1968 telex from the U.S. Atomic Energy Commission Headquarters to the U.S. Atomic Energy Commission Nevada Operations Office and Lawrence Radiation Laboratory advised that under no circumstances should the recipients participate or encourage visits to potential Ketch sites until November 5, 1968 (Presidential Election day), and that this directive would be coordinated with Columbia Gas. It also stated that future scheduling would have to be approved by the Division of Peaceful Nuclear Energy. A March 5, 1970 U.S. Atomic Energy Commission Plowshare Program Statement for FY 1971 Authorization Hearings stated that Columbia Gas System Service Company was currently re-evaluating the Ketch project. Later in 1970, Project Ketch was listed as inactive.

Project Ketch was a Level 4 activity because fieldwork was confined to visual field inspections and used data from existing wells during the feasibility study.

## **CHRONOLOGICAL BIBLIOGRAPHY**

U.S. Atomic Energy Commission, 1966. Chapter 12 - The Plowshare Program. In *Annual Report to Congress of the Atomic Energy Commission for 1965*, pp. 191 -209, January. U.S. Atomic Energy Commission, U.S. Government Printing Office, Washington D.C.

U.S. Atomic Energy Commission. Nevada Operations Office, 1966, Briefing Material for the Plowshare Program. Manuscript, U.S. Atomic Energy Commission, April. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV.

Darrow, R. G., 1966. Letter with encls. (items related to site selection for the Ketch event) from R. G. Darrow, Columbia Gas System Service Corporation, New York, to Milo Nordyke, April 11. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0162639.

- Edwards, Donald H., 1966. Letter from Donald H. Edwards, U.S. Atomic Energy Commission, Nevada Operations Office, to O. R. Placak, July 1. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0162681.
- Rabb, David D., 1966. Plowshare Program, October 1, 1965 – July 15, 1966, Vol. II, No. 2. University of California, Lawrence Radiation Laboratory, *Report UCRL-50008-66-1*, July 15. Livermore, CA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.
- Columbia Gas System Service Corporation, 1966. Project Ketch (A Feasibility Study On Creating Natural Gas Storage with Nuclear Explosions). Manuscript, Columbia Gas System Service Corporation, U.S. Atomic Energy Commission, U.S. Bureau of Mines, and Lawrence Radiation Laboratory, September. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV.
- Rabb, David D., 1966. Plowshare Program, July 16, 1966 – October 31, 1966, Vol. II, No. 3. University of California, Lawrence Radiation Laboratory, *Report UCRL-50008-66-2*, October 31. Livermore, CA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.
- Werth, Glenn C., [between 1966 and 1973], Handwritten notes on Plowshare program meetings from Glenn C. Werth, U.S. Atomic Energy Commission, Division of Peaceful Nuclear Explosives, 1966-1973. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-118.
- Commonwealth of Pennsylvania, 1967. Proposed Statement (Project Ketch). Statement from Commonwealth of Pennsylvania. Harrisburg, PA. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0188115.
- Oil, Gas Projects, 1967. Oil, Gas Projects Perk Up AEC's Plowshare. Government, 1967. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.
- U.S. Atomic Energy Commission, 1967. *Plowshare Program During 1966: Based on the Annual Report to Congress for 1966 of the U.S. Atomic Energy Commission*. U.S. Atomic Energy Commission, U.S. Government Printing Office, Washington, D.C. On file at Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029; and Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV.



- U.S. Atomic Energy Commission, 1967. Chapter 11 - Plowshare Program. In *Annual Report to Congress of the Atomic Energy Commission for 1966*, pp. 239-258, January. U.S. Atomic Energy Commission, U.S. Government Printing Office, Washington D.C.
- U.S. Atomic Energy Commission, 1967. Report on Project Ketch Meeting, Nuclear Excavation for Underground Gas Storage. Notes from meeting with U.S. Atomic Energy Commission, Commonwealth, and Columbia Gas System Service Corporation, January 24. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0188125.
- Werth, Glenn C., 1967. Program Activities for Plowshare. University of California, Lawrence Livermore National Laboratory, *Report UCRL-124785*, February 3. Livermore, CA. On file at: Technical Reports Library, Lawrence Livermore National Laboratory, Livermore, CA.
- U.S. Atomic Energy Commission, 1967. Press Release, Subject: AEC to conduct feasibility study for using nuclear explosives to create underground gas storage (Project Ketch), from U.S. Atomic Energy Commission, February 16. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.
- U.S. Atomic Energy Commission, 1967. Nuclear Underground Tests in Planning or Feasibility Stage. Table, March 6. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0188117.
- Werth, Glenn C., 1967. Plowshare Program Goals. University of California, Lawrence Livermore National Laboratory, *Report UCRL-126674*, March 13. Livermore, CA. On file at Technical Reports Library, Lawrence Livermore National Laboratory, Livermore, CA.
- Nordyke, Milo D., 1967, "Status Review of Field Project Studies." Memo from Milo Nordyke, Lawrence Radiation Laboratory, to G. Higgins, April 14. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore CA, File PLO-026.
- U.S. Atomic Energy Commission, 1967. "Statement on the Civilian Applications of Nuclear Explosives (Plowshare) Program, U.S. Atomic Energy Commission FY 1968 Authorization Hearings Before the Joint Committee on Atomic Energy." Statement from U.S. Atomic Energy Commission, April 17. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-028.

- Rabb, David D., 1967. Plowshare Program February 1, 1967 – April 30, 1967, Vol. II, No. 5. University of California, Lawrence Radiation Laboratory, *Report UCRL-50008-67-2*, April 30. Livermore, CA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.
- Toman, John, 1967. "Project Ketch Post-Shot Programs." Memo from John Toman, Lawrence Radiation Laboratory, to Distribution, May 2. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0162661.
- Ingram, Frank L., 1967. Meeting regarding activities in Water Saturated Shale Experiment, South Dakota. Telex from Frank L. Ingram, U.S. Atomic Energy Commission, to Henry G. Vermillion, May 29. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0188109.
- U.S. Atomic Energy Commission. Nevada Operations Office, 1967. Press Release, Subject: Visit by Atomic Energy Commission to Clinton and Centre Counties, Pennsylvania for Ketch Event Feasibility Study, from U.S. Atomic Energy Commission, June 6. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0162648.
- Peterson, M. G., 1967. "Project Ketch Phase 1 Scope." Letter with Encl. ("Technical Program, Engineering, Construction and Support, Scope of Work, Ketch - Phase I") from M. G. Peterson, Lawrence Radiation Laboratory, to W. D. Smith, Jr., June 7. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.
- Kase, K. S., 1967. "Projects Sloop and Ketch Operations Plans." Memo from K. R. Kase, Hazards Control, Off-Site Field Representative, to J. A. Button, June 12. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.
- Moore, William E., 1967. "Cost Estimate - Ketch Site Investigation Trip." Memo from W. E. Moore, U.S. Department of Health, Education and Welfare, Las Vegas, NV, to Project Ketch File, June 14. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0162658.
- Pearson, Norman L., 1967. "Ketch Trip Report - Near Renova, Pennsylvania PDA:NLP-682." Memo from Norman L. Pearson, U.S. Atomic Energy Commission, to James E. Reeves and Robert Miller, June 14. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0188101.

- Thalgott, Robert H., 1967. "Project Ketch Site Reconnaissance." Letter from Robert H. Thalgott, U.S. Atomic Energy Commission, Nevada Operations Office, to John R. McBride, June 16. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0162656.
- Holmes & Narver, Inc., 1967. Project Ketch, Preliminary Planning Estimate Engineering, Construction, & Support (Revised June 21, 1967). Report, June 21. On file at: Archives and Research, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.
- Holmes & Narver, Inc., 1967. Project Ketch, Supplement to Preliminary Planning Estimate Engineering, Construction & Support (Revised June 21, 1967). Report, June 21. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.
- Moore, William E., and J. S. Coogan, 1967. "Project Ketch Trip Report." Letter from William E. Moore and J. S. Coogan, U.S. Department of Health, Education and Welfare, Las Vegas, NV, to John R. McBride, June 27. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0162655.
- Forrest, Robert M., and Richard S. Hague, 1967. Project Ketch: A Feasibility Study on Creating Natural Gas Storage with Nuclear Explosions. U.S. Atomic Energy Commission, Report PNE 1200, July. Washington, D.C. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0176867; and Technical Reports Library, Lawrence Livermore National Laboratory, Livermore, CA.
- Sugden, James A., 1967. "Revised Communications Cost Estimates – Project Ketch." Letter from James A. Sugden to A. M. Generaux, July 6. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.
- Edwards, Donald H., 1967. "DPNE (Plowshare) Work Authorization 67-40, Project Ketch Cost Estimates." Letter from Donald H. Edwards, U.S. Atomic Energy Commission, Nevada Operations Office, to Oliver R. Placak, July 7. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Las Vegas, NV, Accession No. NV0162652.
- Shafer, Raymond P., 1967. "Project Ketch." Letter from Raymond P. Shafer, Governor, Commonwealth of Pennsylvania, to Glenn T. Seaborg, August 11. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0165023.

- Ingram, Frank L., 1967. "Pennsylvania Agrees to Phase I of Project Ketch." Letter from Frank L. Ingram, U.S. Atomic Energy Commission, Division of Public Information, to Files, August 15. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0188174.
- Renfro, H. B., 1967. "Plowshare Committee, Atomic Industrial Forum." Memo from H. B. Renfro to G. Werth, August 18.
- Columbia Gas System Service Corporation, 1967. Project Ketch: The Possible Use of a Nuclear Explosive to Create Underground Natural Gas Storage. Manuscript, Columbia Gas System Service Corporation, U.S. Atomic Energy Commission, San Francisco Operations Office, Lawrence Radiation Laboratory, and U.S. Bureau of Mines, August 28. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0075555 and NV0188171 (Figureures only).
- Cohen, Gerald D., and Francis M. Sand, 1967. Water Resource Applications, Underground Storage of Natural Gas, and Waste Disposal Using Underground Nuclear Explosions. *Mathematica*, August 31. Princeton, New Jersey. U.S. Atomic Energy Commission, Report PNE 3008. Washington, D.C. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV and Defense Threat Reduction Information Center, Albuquerque, NM.
- Moore, William E., 1967. "Project Ketch." Letter from William E. Moore, U.S. Department of Health, Education, and Welfare, Las Vegas, Nevada, to Charles L. Weaver, September 7. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0162646.
- Chamberlain, Richard H., 1967. Letter from Richard H. Chamberlain, Hospital of the University of Pennsylvania, Department of Radiology, to Clifford L. Jones, October 7. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0061968.
- Plowshare Advisory Committee, 1967. Plowshare Advisory Committee, Report of Sixteenth Meeting. Meeting held at Lawrence Radiation Laboratory, Livermore, CA, October 10-11. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029 [OUO].
- Vermillion, Henry G., 1967. "Project Ketch Briefings in Pennsylvania." Memo from Henry G. Vermillion, U.S. Atomic Energy Commission, Nevada Operations Office, to Files, October 18. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0188167.

- Rabb, David D., 1967. Plowshare Program August 1, 1967 - October 31, 1967, Vol. II, No. 7. University of California, Lawrence Radiation Laboratory, *Report UCRL-50008-67-4*, October 31. Livermore, CA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.
- Kelly, John S., 1967. "Redirection of Plowshare Industrial Effort." Memo from John S. Kelly through General Manager, U.S. Atomic Energy Commission, to Seaborg et al., November 21. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-027.
- Jackson, Melvin W., 1967. Ten Years of Plowshare. *Civil Engineering*, December. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.
- Applied Nuclear Company, [Post 1967]. Applied Nuclear Company and Plowshare. Report to U.S. Atomic Energy Commission from Applied Nuclear Company, La Jolla, CA. On file at: Technical Reports Library, Lawrence Livermore National Laboratory, Livermore, CA.
- U.S. Atomic Energy Commission, 1968. Chapter 11 - The Plowshare Program. In *Annual Report to Congress of the Atomic Energy Commission for 1967*, pp. 199-208, January. U.S. Government Printing Office, Washington, D.C.
- U.S. Atomic Energy Commission, 1968. "Civilian Applications of Nuclear Explosives (Plowshare) Program – Operating Costs, FY 1969 Budget Estimates: Appropriation – Operating Costs." On file at: Archives and Records Office, Lawrence Berkeley National Laboratory, Berkeley, CA, File 434-900205, 28/48.
- Vermillion, Henry G., 1968. Letter from H. G. Vermillion to G. K. Plumleigh, January 24. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0188360.
- Renovo Daily Record, 1968. Physicist Agrees with Local Man in Opposition to Project Ketch. *Renovo Daily Record*, January 31. Renovo, PA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.
- Scott, Hugh, 1968. Letter from Hugh Scott, U.S. Senator, Pennsylvania, to Glenn T. Seaborg, February 2. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0176863 and NV0075920.

- Seaborg, Glenn T., 1968. The Progress of the Peaceful Atom. Paper presented at the Governor's Industrial Safety Conference, February 7, 1968, San Francisco, California. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Las Vegas, NV, Accession No. NV0148558.
- Werth, Glenn C., 1968. "Plowshare Reductions." Memo from G. C. Werth, Lawrence Radiation Laboratory, to Distribution, February 15. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.
- O'Neill, Robert D., 1968. "Congressman Saylor Opposed to Project Ketch." Memo with encl. ("Project Ketch: Underground Explosion of AEC," Congressional Record, February 15, 1968, Hon. John P. Saylor) from Robert D. O'Neill to Seaborg et al., February 16. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0176862.
- Nucleonics Week, 1968. Pennsylvania Will Provide Land for Project Ketch, but with a Loophole. *Nucleonics Week*, March 21. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0162643.
- Centre Daily Times, 1968. Rep. Johnson Asks End to Project Ketch. *Centre Daily Times*, April. State College and Bellefonte, PA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.
- Renovo Daily Record, 1968. People Against Project Ketch in Centre County. *Renovo Daily Record*, April 8. Renovo, PA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.
- Centre Daily Times, 1968. Coordinator Gives Talk on Ketch. *Centre Daily Times*, April 9. State College and Bellefonte, PA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.
- Centre Daily Times, 1968. Talk Scheduled on Project Ketch. *Centre Daily Times*, April 9. State College and Bellefonte, PA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.
- Express, 1968. Ketch Opponents Seeking Speaker. *The Express*, April 9. Lock Haven, PA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.
- Adams, Franklin S., 1968. Letters to the Editor: Public Right to Decide. *Centre Daily Times*, p. 4, April 10. State College, Bellefonte, PA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.

Centre Daily Times, 1968. Ketch Program Topic Changed. *Centre Daily Times*, April 10. State College and Bellefonte, PA., On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.

Daily Journal, 1968. Rotary Club Told of Project Ketch. *Daily Journal*, April 10. Philipsburg, PA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.

Express, 1968. 2,500 on Petition Against Ketch, Will Present it to Gov. *Express*, April 10. Lock Haven, PA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.

Harris, P. A., 1968. Letters to the Editor: Dead Sheep a Lesson. *Centre Daily Times*, April 10, p.4. State College and Bellefonte, PA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.

Holman, Ella, 1968. Insurance No Answer. *Centre Daily Times*, p. 4, April 10. State College and Bellefonte, PA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.

Centre Daily Times, 1968. Wants True 'Open' Forum. *Centre Daily Times*, April 12. State College and Bellefonte, PA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.

Express, 1968. Ketch Forum on Wednesday. *Express*, April 13. Lock Haven, PA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.

Centre Daily Times, 1968. Ketch Forum Scheduled at University. *Centre Daily Times*, April 15. State College and Bellefonte, PA. On file at: Archives and Research, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.

Centre Daily Times, 1968. Scenic View Located Near Ketch Site. *Centre Daily Times*, April 15. State College and Bellefonte, PA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.

Progress, 1968. Con-Con, Ketch, Candidates Aired. *Progress*, April 15. Clearfield, PA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.

Renovo Daily Record, 1968, Benny Says. *Renovo Daily Record*, April 15. Renovo, PA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.

Daily Journal, 1968. University Sets 'Ketch' Review. *Daily Journal*, April 16. Philipsburg, PA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.

Plowshare Advisory Committee, 1968. Plowshare Advisory Committee, Report on Seventeenth Meeting. Meeting held at U.S. Atomic Energy Commission, Nevada Operations Office, Las Vegas, NV, April 15-16. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029 [OUO].

Progress, 1968. WSPX-TV to Air Public Forum on Project Ketch Tonight. *Progress*, April 16. Clearfield, PA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.

Centre Daily Times, 1968. Public Ketch Forum Tonight. *Centre Daily Times*, August 17. State College and Bellefonte, PA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.

Express, 1968. PSU 'Project Ketch' Forum Live Coverage on WPSX-TV. *Express*, April 17. Lock Haven, PA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.

Renovo Daily Record, 1968. Local Men Plan to Attend Forum on Project Ketch. *Renovo Daily Record*, April 17. Renovo, PA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.

Centre Daily Times, 1968. 400 Attend Lengthy Panel Session on Project Ketch. *Centre Daily Times*, Vol. 71, No. 15, April 18. State College and Bellefonte, PA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.

Express, 1968. Clemson Calls Ketch Main Issue in Campaign. *The Express*, April 18. Lock Haven, PA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.

Express, 1968. Cooper-Tanner Oppose Ketch. *Express*, April 18. Lock Haven, PA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.

Renovo Daily Record, 1968, Benny Says. *Renovo Daily Record*, April 18. Renovo, PA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.

Express, 1968. Five-Hour Session on Project Ketch at State College Alters No Opinions. *The Express*, p. 4, April 19. Lock Haven, PA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.



- Centre Daily Times, 1968. Editorial: 'Ketch' Problem Comes into Focus. *Centre Daily Times*, April 22, p. 4. State College and Bellefonte, PA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.
- McCool, W. B., 1968. "Atomic Energy Commission Status of Plowshare Industrial Projects." Memo with encl. ("Status of Plowshare Industrial Projects," memo from John S. Kelly, U.S. Atomic Energy Commission, Division of Peaceful Nuclear Explosives, to List) from W. B. McCool, U.S. Atomic Energy Commission to Distribution, April 26. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029 [OUO].
- Anspaugh, Lynn R., and William L. Robison, 1968. Quantitative Evaluation of the Biological Hazards of Radiation Associated with Project Ketch. University of California, Lawrence Radiation Laboratory, *Report UCID-15325*, May 8. Livermore, CA. On file at: Technical Reports Library, Lawrence Livermore National Laboratory, Livermore, CA.
- People Against Ketch, 1968. Pennsylvanians Are You Against Underground Nuclear Blasting in Your State Forests? Notice from People Against Ketch, panel discussion on Project Ketch, State College, PA [June]. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.
- Renovo Daily Record, 1968. Goddard Acknowledges Ketch Petition Receipt. *Renovo Daily Record*, June 12. Renovo, PA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.
- Centre Daily Times, 1968. Petitions Circulating on Ketch. *Centre Daily Times*, June 13. State College and Bellefonte, PA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.
- Hoke, John H., 1968. Letters to the Editor: Moderation for Ketch. *Centre Daily Times*, June 13. State College and Bellefonte, PA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.
- Lukens, John E., 1968. Letters to the Editor: Other Side. *Centre Daily Times*, June 13. State College and Bellefonte, PA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.
- Centre Daily Times, 1968. Good Evening! Other Blasts Studied. *Centre Daily Times*, June 14. State College and Bellefonte, PA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.
- Centre Daily Times, 1968. Ketch Topic For Special TV Program. *Centre Daily Times*, June 15. State College and Bellefonte, PA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.

- Express, 1968. Project Ketch' Program on WPSX-TV Monday 10 p.m. *Express*, June 15. Lock Haven, PA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.
- Centre Daily Times, 1968. Fulmer Seeking Immediate Halt to Ketch Plan. *Centre Daily Times*, June 17. State College and Bellefonte, PA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.
- Progress, 1968. Penn State Channel to Air Project Ketch. *Progress*, June 17. Clearfield, PA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.
- Renovo Daily Record, 1968. Benny Says. *Renovo Daily Record*, June 19. Renovo, PA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.
- Centre Daily Times, 1968. C Commissioners Join Protests Against Ketch. *Centre Daily Times*, June 20. State College and Bellefonte, PA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.
- C&EN, 1968. AEC's Plowshare Program was Dealt a Severe Setback. *C&EN*, July 15. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.
- Rabb, David D., 1968. Plowshare Program, May 1, 1968 – July 31, 1968, Vol. II, No. 1. University of California, Lawrence Radiation Laboratory, *Report UCRL-50008-68-3*, July 31. Livermore, CA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030 [OUO].
- Nucleonics Week, 1968. Project Ketch, the Plowshare Test Rejected by Pennsylvania. *Nucleonics Week*, August 8. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0162643.
- Centre Daily Times, 1968. Candidate Discusses Gas Blast. *Centre Daily Times*, August 16. State College and Bellefonte, PA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.
- Kelly, John S., 1968. Telex from John S. Kelly, U.S. Atomic Energy Commission, to G. Werth, October 9. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0188175.
- U.S. Atomic Energy Commission. Division of Technical Information, 1969. Status of Nuclear Test Reports. U.S. Atomic Energy Commission, Report TID-9533. Washington, D.C. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0105641.

- U.S. Atomic Energy Commission, 1969. Chapter 11 - Peaceful Nuclear Explosions. In *Annual Report to Congress of the Atomic Energy Commission for 1968*, pp.195-202, January. U.S. Government Printing Office, Washington, D.C.
- Nordyke, Milo D., 1969. Underground Engineering Applications. Paper prepared for The Symposium on Public Health Aspects of Peaceful Uses of Nuclear Explosives, Las Vegas, April. University of California, Lawrence Radiation Laboratory, *Preprint UCRL-71453*, April. Livermore, CA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-103.
- Hosmer, Craig, 1969. Remarks of Rep. Craig Hosmer to Joint Committee on Atomic Energy, Symposium on the Public Health Aspects of Peaceful Nuclear Explosives, Las Vegas, NV, April 8. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.
- Plowshare Advisory Committee, 1969. Plowshare Advisory Committee, Report on Nineteenth Meeting. Meeting held at Lawrence Radiation Laboratory, Livermore, CA, November 4-5. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029 [OUO].
- U.S. Atomic Energy Commission, 1970. Chapter 11 - Peaceful Nuclear Explosives. In *Annual Report to Congress of the Atomic Energy Commission for 1969*, pp. 195-203, January. U.S. Government Printing Office, Washington D.C.
- Coffer, H. F., and G. H. Higgins, 1970. Future Contained Nuclear Explosives Experiments. In *Education for Peaceful Uses of Nuclear Explosives*, Lynn E. Weaver, editor, pp. 45-63. University of Arizona Press, Tucson, AZ.
- U.S. Atomic Energy Commission, 1970. *Plowshare Program During 1969: Based on the Annual Report to Congress for 1969 of the U.S. Atomic Energy Commission*. U.S. Atomic Energy Commission, U.S. Government Printing Office, Washington, D.C. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV.
- U.S. Atomic Energy Commission, 1970. "Plowshare Program Statement, JCSE FY 1971 Authorization Hearings." Statement from U.S. Atomic Energy Commission, March 5. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-028.
- Evans, Roy B., and David E. Bernhardt, 1970. "Probable Scheduling of Plowshare Events." Memo from Roy B. Evans and David E. Bernhardt, U.S. Department of Health, Education, and Welfare, Southwestern Radiological Health Laboratory, to Francis N. Buck, May 8. On file at Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0173142 [OUO].

- Bulletin of the Atomic Scientists, 1970. *Bulletin of the Atomic Scientists*, pp. 88-91, June. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.
- Whan, Glenn A., 1973. Plowshare Technology Assessment, Final Report, Implications to State Governments. Report to the Western Interstate Nuclear Board, Lakewood, CO, from Glenn A. Whan, Chemical and Engineering Department, University of New Mexico. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV.
- Crump, Joseph R., 1975. PNE (Peaceful Nuclear Explosion) Activity Projections for Arms Control Planning, Vol. I. Report to the U.S. Arms Control and Disarmament Agency, Contract No. ACDE/PAB-253, from Gulf Universities Research Consortium, Galveston, TX, April 10.
- Toman, J., and A. Tewes, 1976. The Potential of Plowshare for Resource Development. University of California, Lawrence Livermore Laboratory, *Preprint UCRL-78309*, June 14. Livermore, CA. On file at: Technical Reports Library, Lawrence Livermore National Laboratory, Livermore, CA.
- Shafer, David S., William. C. Beck, Dwight Treadwell, and Stephen. A. Mellington, 1995. Inventory of Potential Environmental Restoration Liabilities Associated with Plowshare And Vela Uniform Program Sites. Manuscript, U.S. Department of Energy, Office of Environmental Restoration. On file at: Desert Research Institute, Las Vegas, NV.
- U.S. Department of Energy. Nevada Operations Office, 1997. P lowshare Program Executive Summary. Report from U.S. Department of Energy, December 22.
- Krygier, J. B., 1998. Project Ketch: Project Plowshare in Pennsylvania. Originally published in *Ecumene*, Vol. 5, No. 3, pp. 311-322.  
[http://www.owu.edu/~jbkrygie/krygier\\_html/ketch2.html](http://www.owu.edu/~jbkrygie/krygier_html/ketch2.html), last accessed on December 4, 2007.
- Interim Public Information, n.d. "Interim Public Information Plan for Ketch Study." On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0188098.
- Kihss, Peter, n.d. Atom Blasts...To Make Gas Storage Pits. Newspaper Article. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.
- U.S. Department of Energy. Nevada Operations Office, n.d. The Plowshare Program (Draft). Report from U.S. Department of Energy.

## **4.23 LAKE TAHOE SEWAGE**

### **Plowshare Program Nuclear Chimneys for Sewage Disposal California**

A June 1963 study by Engineering-Science, Inc looked at various methods for preventing future pollution of Lake Tahoe. This study included an examination of the lake environment, the existing sewage system, and the effects of sewage effluent on the lake as well as possible solutions. A point-source of water pollution was treated sewage effluent containing dissolved nitrates and phosphates that entered the lake system via ponds, trenches, surface spraying, etc. The study recommended exporting treated sewage effluent from the Lake Tahoe Basin.

The project concept for Lake Tahoe Sewage developed from a Lawrence Radiation Laboratory study to determine whether large-diameter deep wells produced by nuclear explosives would provide a feasible solution for disposal of sewage effluent from the Lake Tahoe Basin (Figure 4.23-1). The concept was based on the idea that storage of effluent below the regional water table, and/or in a location where water would be filtered through a surrounding medium, would isolate waste material from the environment. Results of a preliminary study for Lake Tahoe were presented in a June 1964 report. The feasibility of the project was evaluated based on the selection of an appropriate site for the wells and calculations of different parameters for four hypothetical wells to determine use life, safety considerations, and cost. Critical to the technical feasibility was selection of a site with a deep enough rock formation to create a nuclear chimney with sufficient size to receive large amounts of effluent and sufficient effective porosity and permeability to allow reasonable flow rate through the formation. Volcanic flows on the north and northeast side of the lake were considered suitable although additional fieldwork was required to determine more precisely thickness, porosity, and permeability before a location for the project could be identified. The calculations for the hypothetical wells suggested that construction of two or more wells might be necessary to handle the volume of effluent over the next 50 years. According to the report, additional field data from exploratory drilling and hydraulic testing would be necessary to confirm the assumptions of the calculations. A number of safety considerations also needed to be addressed including ground shock, venting, and water contamination.

During April 1964, a meeting was convened between personnel from the Lawrence Radiation Laboratory and the Board of Consultants for the Lake Tahoe Area Council. The Board of Consultants expressed interest in the idea of using an injection well produced by a nuclear explosive for storing effluent and requested that Lawrence Radiation Laboratory provide details and cost estimates to their consulting firm, Engineering-Science, Inc. An August 1964 letter confirms that the Lawrence Radiation Laboratory was ready and willing to provide the results of their work on the use of nuclear explosives for waste disposal. However there is no additional documentation about this proposed project until 1971.



Figure 4.23-1. Location of proposed Lake Tahoe Sewage Project (adapted from USA Relief Maps 2004).

At the request of the Director of the U.S. Atomic Energy Commission, Division of Peaceful Nuclear Explosives, a review was undertaken by Lawrence Radiation Laboratory of past studies of the possible use of large-diameter deep wells created by nuclear explosives to dispose of sewage. The 1971 review states that while the approach for Lake Tahoe received serious attention, and was considered to be technically feasible, possible damage from seismic effects resulting from the construction of nuclear chimneys of sufficient size to handle the effluent load and the need for additional studies about fluid flow from nuclear chimneys posed serious drawbacks. More importantly, a nuclear

method did not compete economically with traditional methods of disposal. The 1971 report concluded that disposal of sewage into nuclear chimneys did not provide an economic and/or environmental advantage over alternative methods, and concluded that the project concept did not warrant further study.

In sum, the use of nuclear chimneys to store effluent at Lake Tahoe was only given brief consideration. In 1965, an advanced treatment facility was installed, but the effluent from this plant was not considered clean enough for discharge to Lake Tahoe. By 1968 all of Lake Tahoe's treated sewage was pumped out of the Lake Tahoe Basin.

Lake Tahoe Sewage was a Level 5 activity. Activity for the project was confined to conceptual design and background research based on available data.

## **CHRONOLOGICAL BIBLIOGRAPHY**

Korver, John A., 1964. Lake Tahoe Sewage Disposal Study (Draft). Manuscript, Lawrence Radiation Laboratory, UOPKA 64-17, March 25. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-100.

Korver, John A., 1964. "Presentation of a Nuclear Solution for the Lake Tahoe Sewage Problem to the Lake Tahoe Board of Consultants." Memo from John A. Korver, Lawrence Radiation Laboratory, to Distribution, April 27. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-100.

Ludwig, Harvey F., 1964. Letter from Harvey F. Ludwig, Engineering-Science, Inc., Arcadia, CA, to Gerald Johnson, August 5. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-100.

Johnson, Gerald W., 1964. Letter from Gerald W. Johnson, Lawrence Radiation Laboratory, to Harvey F. Ludwig, August 17. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-100.

Weinberger, Leon, [1964]. Note from Leon Weinberger, Chief of Research under McCallum, to 'Jerry'." On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-100.

Cohen, Jerry J., 1971. "Summary of Investigations into Sewage Disposal by Plowshare Methods." Memo from J. J. Cohen, Lawrence Radiation Laboratory, to A. E. Lewis, January 8.

Werth, Glenn C., 1971. Letter from Glenn C. Werth, Lawrence Radiation Laboratory, to John S. Kelly, January 25.

**THIS PAGE INTENTIONALLY LEFT BLANK**



## **4.24 NAWAPA**

### **Plowshare Program Nuclear Explosives for Construction of a Water Containment and Distribution System United States, Canada, and Mexico**

NAWAPA is an acronym for the North American Water and Power Alliance, a proposed international water development consortium consisting of the United States, Canada and Mexico. The 1964 NAWAPA proposal prepared by the Ralph M. Parsons Company, an engineering construction firm out of Los Angeles, was a proposal for a water diversion project to collect the tremendous quantities of water that fall annually in catchment basins in Alaska and Canada and store it in an interconnected system of reservoirs (Figure 4.24-1). The water would then be redistributed to generate power and be available for irrigation, industrial usage, and domestic consumption in water-scarce areas of Canada, the western United States, and northern Mexico. In addition, some water would be diverted to the Great Lakes to alleviate falling water levels and pollution. According to the proposal, the NAWAPA water management system would open up lands for industrial and agricultural development. It would also address the existing piecemeal regional water control measures and water use agreements with the goal of providing an overall solution to increasing water needs.

The \$100 billion plan for an international water distribution system called for building dams, reservoirs, and canals in a series of regions (Figures 4.24-2 and 4.24-3). NAWAPA facilities (i.e., canals, reservoirs, tunnels, etc.) were planned for 15 states and the Great Lakes, but the water distribution system would serve at least another half dozen states using existing rivers and waterways. Alaska, the Canadian Yukon, and British Columbia would form a vast water collection region. A large portion of water would then be diverted to a 500 mile long storage reservoir constructed in the Rocky Mountain Trench, British Columbia, and from there water would be redistributed by means of a reservoir and canal system. The water distribution system would cross various river basins in the Rocky Mountains west of the continental divide using lift pumping systems and tunnels in a water transfer region. Water would then be distributed to the states west of the divide and throughout the southwestern United States and northern states of Mexico. Another water distribution region would cross the Canadian Prairie Provinces and extend into the sub-arid High Plains of the northern United States. Finally, water would be transported by a canal system to Lake Superior.

In the spring of 1964, a series of newspaper articles from Canada and across the U.S. reported on the NAWAPA proposal (Figure 4.24-4). Politicians and water experts from all three countries commented on NAWAPA and a special U.S. Senate Subcommittee on Western Water Development planned to support the cost of an engineering feasibility study. However, these reports and discussions did not mention a nuclear component for the project.

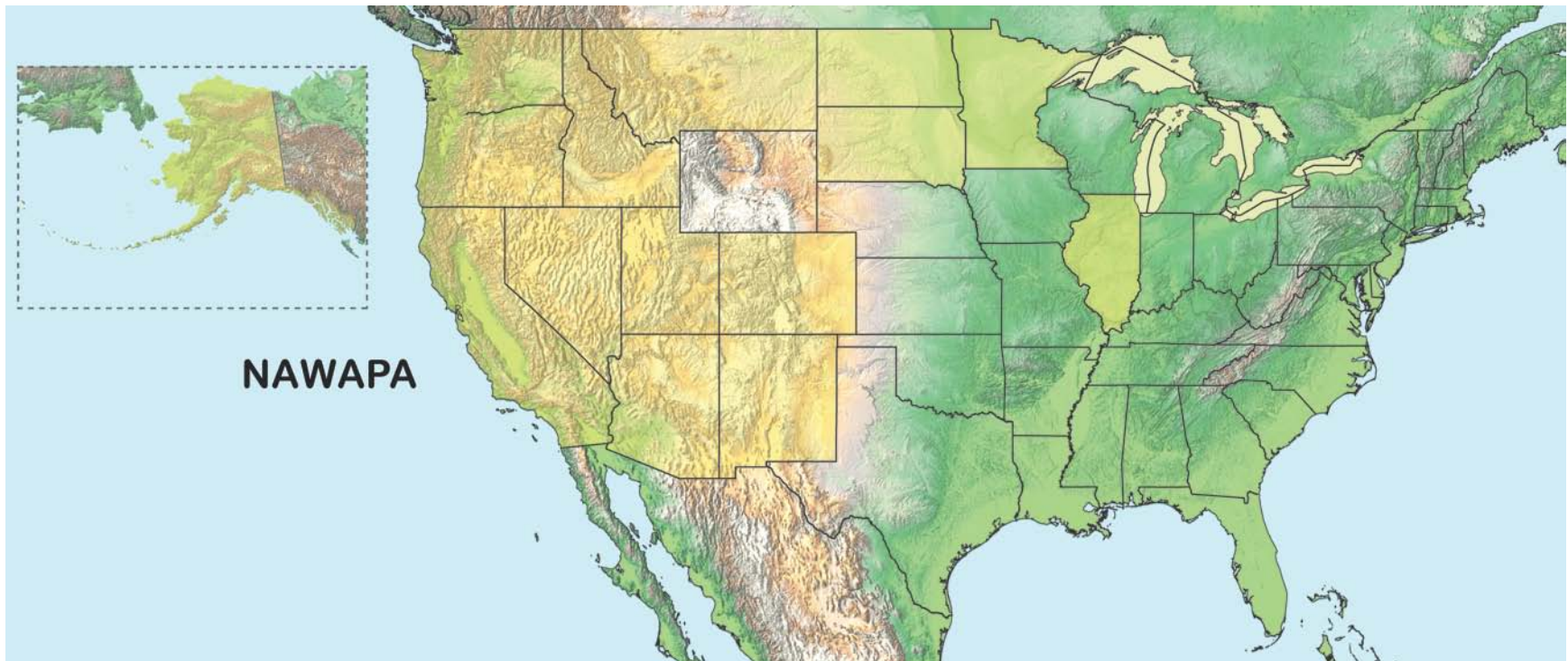


Figure 4.24-1. Map showing location of states and Great Lakes (yellow shading) in the United States included in the proposed NAWAPA project (note: not all locations were proposed for a nuclear component) (adapted from USA Relief Maps 2004).

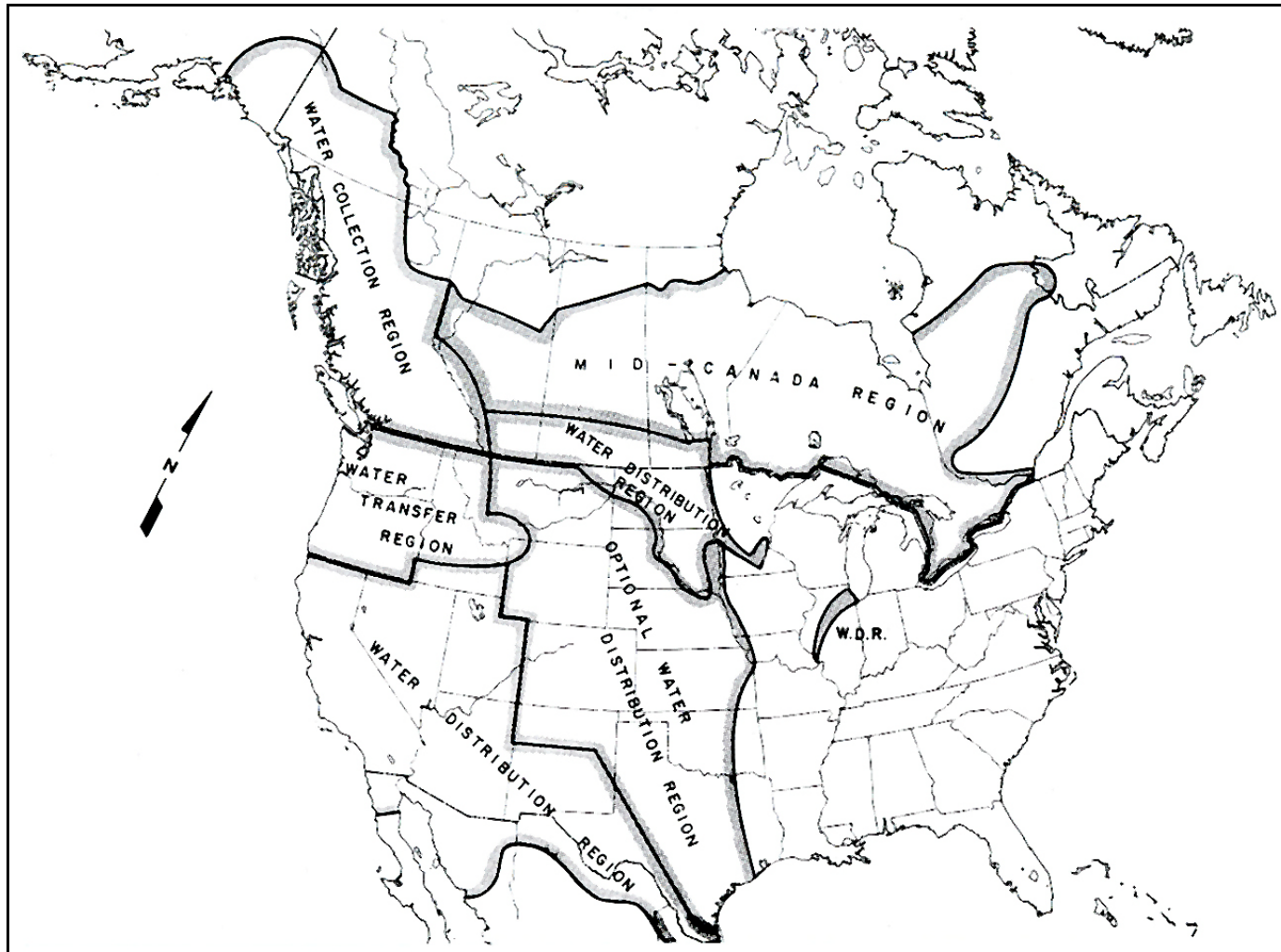


Figure 4.24-2. Map showing proposed water collection regions, transfer regions, and distribution regions (Ralph Parsons Engineering Company 1964b).

The nuclear applications for NAWAPA were summarized in a report from the Parsons Company prepared for the U.S. Atomic Energy Commission dated July 28, 1964. Parsons Company proposed that nuclear explosive technology be used to reduce construction and operating costs and, more importantly, reduce construction time from the projected 30 years using conventional methods. The proposal estimated that the NAWAPA project would require the movement of 32 billion cubic yards to construct dams, canals and reservoirs and nuclear excavation technology might be employed for some of these tasks. The proposal also suggested that nuclear excavation be used for construction of a tunnel in the Rocky Mountain Region 20 to 100 ft in diameter and 20 to 80 miles long, needed to maintain a high elevation grade for maximum use of gravity flow. Another idea was to use nuclear explosives to denude areas of vegetation in proposed reservoir impoundments. Finally, a nuclear steam drive concept was suggested for a large system pump capacity to move water to higher elevations in remote areas. An analysis estimated that the use of nuclear energy would produce significant cost savings over conventional methods. The Parsons Company argued that a side benefit of the project would be the opportunity for nuclear excavation to gain credibility and to improve and develop nuclear excavation techniques for other programs.

The Lawrence Radiation Laboratory responded expressing interest in the nuclear energy component of the program; however, the NAWAPA proposal did not involve the participation of Plowshare Program researchers. In late July 1964, the U.S. Atomic Energy Commission, San Francisco Operations Office, followed up on a July 28 meeting with Parsons Company, expressing interest in pursuing the project. This was followed by an August meeting and correspondence in September stating that the NAWAPA proposal was being reviewed by Plowshare Program personnel. Unfortunately, no documentation is available concerning the outcome of this review, but it is likely that authorization for feasibility studies for the project were not funded by Congress. Discussions about NAWAPA as a water development plan continued, but, except for a single memo, there is no documentation about using nuclear excavation technology for NAWAPA beyond 1964. The exception is a Lawrence Radiation Laboratory memo dated May 2, 1968. During the spring of 1968, J. B. Knox from Lawrence Radiation Laboratory held a seminar at UCLA on nuclear explosives and water resource development. In a meeting following the seminar that included members of the university faculty there was discussion supporting a nuclear component of the NAWAPA project.

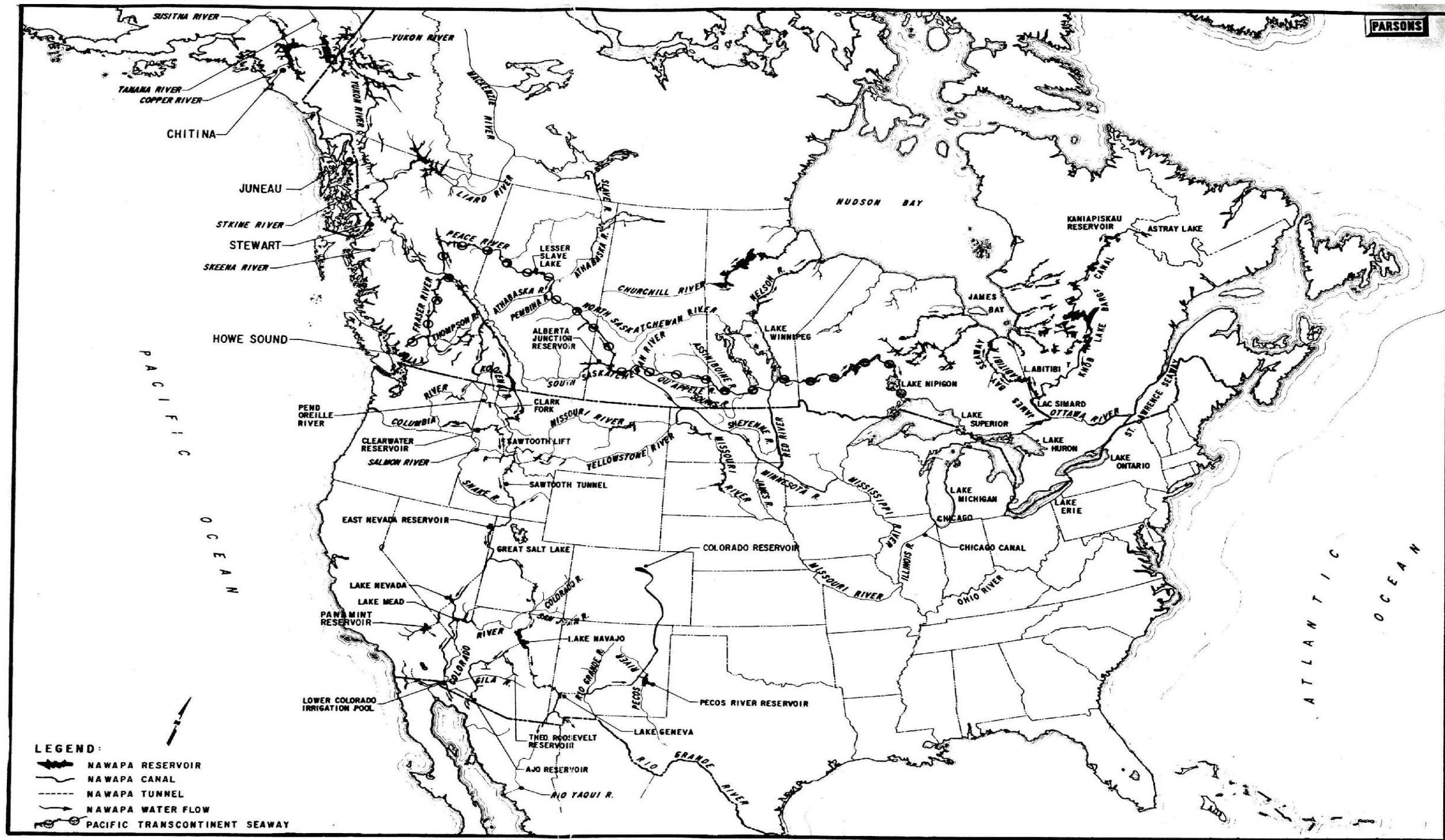


Figure 4.24-3. Map of proposed NAWAPA water and power system (Ralph Parsons Engineering Company 1964b).

**THIS PAGE INTENTIONALLY LEFT BLANK**



Figure 4.24-4. Newspaper article reporting on the NAWAPA proposal (Hewitt 1964, *The Calgary Herald*).

The plan to use nuclear explosives to implement the NAWAPA project was a Level 5 activity. No fieldwork was conducted and activity was confined to developing the project concept.

## CHRONOLOGICAL BIBLIOGRAPHY

Hewitt, Ted, 1964. \$100 Billion Water Plan Envisages Banff Reservoir. *The Calgary Herald*, March 18.

Christian Science Monitor, 1964. Giant Plan Proposed: Water for a Continent. *The Christian Science Monitor*, March 20.

Herbert, Ray, 1964. L.A. Water Chief Urges Alaska Project Study. *Los Angeles Times*, March 22.

- Christian Science Monitor, 1964. Think Very Big. *The Christian Science Monitor*, April 3.
- Nash, Knowlton C., 1964. Vast Waterway to Link Vancouver, Great Lakes? *The Financial Post*, May 2.
- Post-Times-Herald, 1964. Water for North America. *Post-Times-Herald*, May 2. Washington, D.C.
- Press-Chronicle, 1964. Thinking Big on Water. *Press-Chronicle*, May 5. Johnson City, TN.
- Sacramento Bee, 1964. This Plan May Not Seem Fantastic in Year 2000. *The Sacramento Bee*, May 12.
- Robinson, James, 1964. Water, \$100 Billion Worth of It. *The Miami Herald*, May 17.
- Ralph Parsons Engineering Company, 1964a. NAWAPA, North American Water and Power Alliance, Summary Report for New Mexico. Manuscript, Ralph M. Parsons Company, July 7. Los Angeles, CA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-078.
- Ralph Parsons Engineering Company, 1964b. NAWAPA, North American Water and Power Alliance, Summary Report for U.S. Atomic Energy Commission Nuclear Applications. Manuscript, Ralph M. Parsons Company, July 28. Los Angeles, CA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-078.
- Philip, John F., 1964. Letter from John F. Philip, U.S. Atomic Energy Commission, San Francisco Operations Office, to R. P. Kelly, July 31. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-078.
- Philip, John F., 1964. Letter with encls. (List of Attendees at July 28 Meeting, List of Reports forwarded to Parsons Co.) from John F. Phillip, U.S. Atomic Energy Commission, San Francisco Office, to Gerald W. Johnson, July 31. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-078.
- Poll, Charles M., 1964. Letter from Charles M. Poll, Ralph M. Parsons Company, to Gerald W. Johnson, August 28. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-078.



- Kelly, Roland P., 1964. "NAWAPA System Plan and Schematic Flow Chart." Letter from Roland P. Kelly, Ralph M. Parsons Company, to Gerald W. Johnson, September 3. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-078.
- Johnson, Gerald W., 1964, Letter from Gerald W. Johnson, Lawrence Radiation Laboratory, to John F. Philip, September 8. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-078.
- Johnson, Gerald W., 1964. Letter from Gerald W. Johnson, Lawrence Radiation Laboratory, to Charles M. Poll, September 8. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-078.
- Engineering News-Record, 1964. Washington Observer. *Engineering News-Record*, October 1. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-078.
- News & Views, [1964]. North American Water and Power Alliance. *News & Views*, No. 7. Ralph M. Parsons Company, Los Angeles, CA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-078.
- Knox, J. B., 1968. "Discussions with Prof's Al Bush (a Director of MWD) and Pillsbury (UCLA, Head of the State's Water Resources Center)." Memo from J. B. Knox, Lawrence Radiation Laboratory, to Distribution, May 2. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.
- Ela, Jonathan, 1972. From Sea to Shining Sea or through the Rockies at 31 Knots. *Sierra Club Bulletin*, pp. 26-27, June. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.
- Yanity, Brian, 2007. Alaska's Megaproject Mentality, part two; insurgent 49. <[http://www.insurgent49.com/yanity\\_megaproject\\_two.html](http://www.insurgent49.com/yanity_megaproject_two.html)>.

**THIS PAGE INTENTIONALLY LEFT BLANK**

## 4.25 NEW MADRID EARTHQUAKE

### **Vela Uniform Program Earthquake Seismic Data Missouri**

The Vela Uniform Program was established in 1959 in an effort to upgrade the United States capability to detect nuclear explosions through seismic monitoring. Charged with developing techniques and instrumentation capable of distinguishing between explosive and natural seismic sources, the U.S. Department of Defense created the Advanced Research Projects Agency to oversee the Vela Program. Under its administrative umbrella, the Long Range Seismic Measurements Program began. By early 1960, 20 mobile monitoring stations were actively recording seismic data. Within a few months, this number increased to 40. The stations formed a network designed to collect and analyze data from a series of planned domestic underground nuclear tests as well as comparative data from foreign nuclear detonations, conventional explosives, and natural seismic events.

The mobile detection stations were in operation when an earthquake occurred near New Madrid, Missouri, in early 1962. Data gathered from the February 2 tremor was used for Long Range Seismic Measurements investigations. Sponsored by Advanced Research Projects Agency, Project New Madrid Earthquake involved the analysis of monitoring data derived from the magnitude 4.3 quake that occurred in southeastern Missouri near the Kentucky-Tennessee-Missouri border (Figure 4.25-1). The quake's epicenter was at approximately 36°37'N Latitude 89°51' W Longitude at a depth of 4 km below the surface. The seismic event occurred at 06:43:30 GMT.

The Geotechnical Corporation of Dallas, Texas supplied the seismic recording equipment for the mobile stations. Instrumentation in the vans or small semi-trailers consisted of three-component short-period Benioff seismometers (models 6102 or 4681) and three-component long-period Sprengnether seismographs (models 100 or 201). Both types of instruments recorded the ground motion waves on 35-mm film and 14-channel magnetic tape. When operational, the mobile units and data collection devices received continuous GMT signals.

Thirty-nine of the 40 mobile detection stations distributed at various locations throughout the continental United States recorded short-pulse signals from the New Madrid Earthquake. None of the stations registered any long-period seismic signals. At the time of the quake, most of the mobile observatories were concentrated in the western U.S. The closest station to the New Madrid epicenter was located near Murfreesboro, Arkansas. Results of the data analysis were comparable to those reported for the Colona Earthquake (see Chapter 9 this volume). Seismic signals produced by the earthquake were higher in frequency and had a different attenuation rate than those generated by most nuclear explosions. A comparison between the New Madrid Earthquake data and the seismic record of the 1964 Salmon nuclear detonation in Mississippi confirmed these findings.

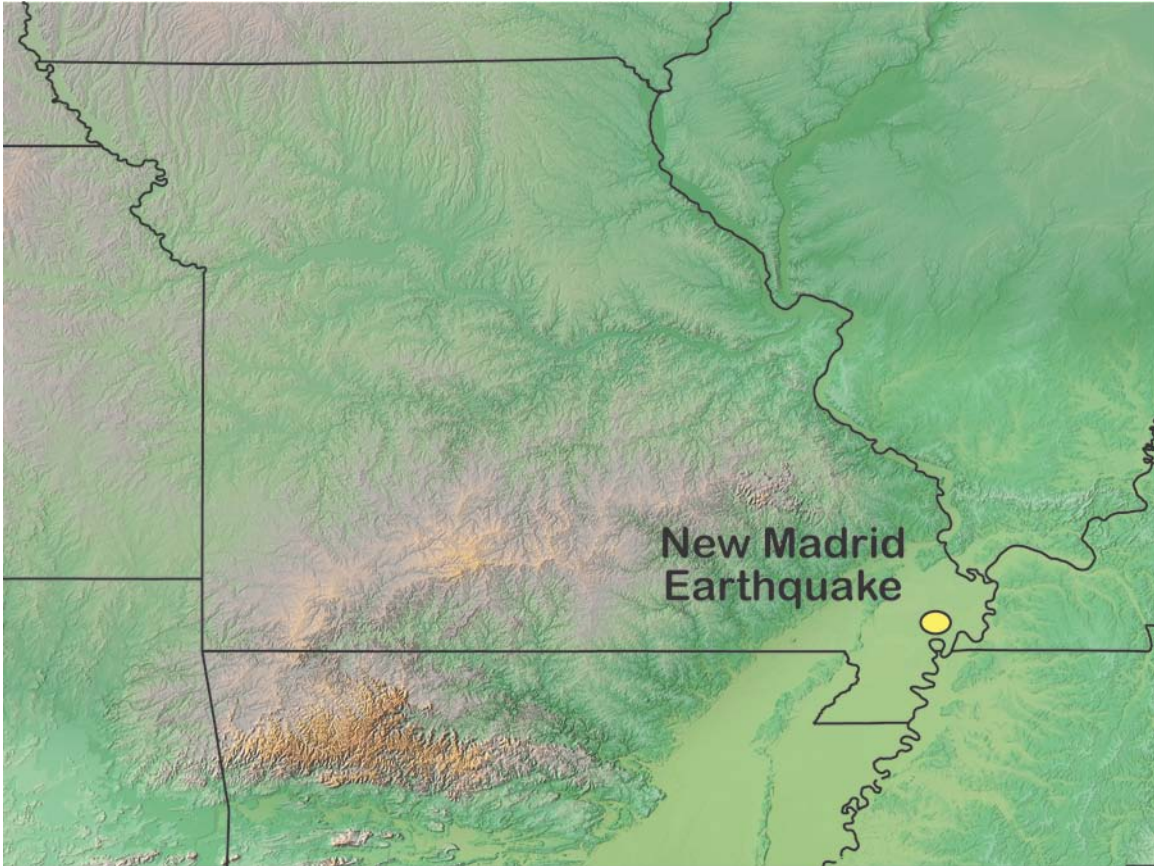


Figure 4.25-1. Location of the New Madrid Earthquake in New Madrid, Missouri (adapted from USA Relief Maps 2004).

As with the other Long Range Seismic Measurements earthquake monitoring efforts, field activity for Project New Madrid Earthquake was limited to the temporary placement of the mobile seismic observatories. Typically, the units were relocated shortly after recording a seismic event. Some locations, however, were reused frequently because of their proximity to the Nevada Test Site or active seismic zones.

The New Madrid Earthquake was a Level 4 activity due to the use of data from existing instrumentation.

#### **CHRONOLOGICAL BIBLIOGRAPHY**

Geotechnical Corporation, 1962. New Madrid Earthquake, February 2, 1962: Long Range Seismic Measurements Project 8.4. Report to Air Force Technical Applications Center from Geotechnical Corporation, Dallas, TX. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV.

Shugart, T. R., 1965. Comparison of Seismic Effects of Salmon Event Versus New Madrid Earthquake of February 2, 1962. Manuscript, U.S. Department of Commerce, Coast and Geodetic Survey, Washington Science Center, Rockville, MD. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV; and Technical Reports Library, Lawrence Livermore National Laboratory, Livermore, CA.

Farrell, W. E., 1985. Sensors, Systems and Arrays: Seismic Instrumentation Under Vela-Uniform. In *The Vela Program: A Twenty-Five Year Review of Basic Research*, Ann U. Kerr, editor, pp. 465-505. Defense Advanced Research Projects Agency, Arlington, VA.

**THIS PAGE INTENTIONALLY LEFT BLANK**

## **4.26 NOME HARBOR**

### **Plowshare Program Nuclear Excavation of a Harbor Alaska**

In the late 1950s, Lawrence Radiation Laboratory was searching for a project to demonstrate the utility of nuclear explosive excavation technology. One project concept the laboratory focused on was construction of a harbor. In this application nuclear explosives would be used to produce protected waterways with sufficient depth for use by deep draft vessels. The E. J. Longyear Company from Minneapolis, Minnesota, was subcontracted by the Lawrence Radiation Laboratory in February 1958 to prepare a report on the mineral potential and proposed deep water harbor locations in northwestern Alaska. The idea behind this report was that a new harbor, besides meeting the needs of nearby residents, should be useful for commercial mineral shipments. Recommendation of a harbor with economic potential was based on the premise that most of the valuable mineral resources would be coal and oil needing transport by freight, requiring a large harbor and facilities. The Longyear Company delivered their report in April 1958. Four possible locations were examined along the Alaskan coastline including a harbor at Nome (Figure 4.26-1). However, based on the analysis, the first choice for a harbor was not Nome but at Cape Thompson (Project Chariot), and the second choice was for a harbor on Norton Sound near Cape Darby (see Cape Darby Harbor – Chapter 4.6). A deep water harbor at Nome was not considered viable because it would be too distant from the locations of mineral resources and areas needing commercial shipments. The gold, tin, and other mining resources of the Seward Peninsula produced a small volume of freight that the report recommended would be better handled through the development of a small harbor facility at Port Clarence to the north.

In July 1958, scientists representing the U.S. Atomic Energy Commission and Lawrence Radiation Laboratory traveled to Alaska to introduce a number of possible projects that would demonstrate the feasibility of nuclear excavation technology as well as provide economic opportunities for the state. At meetings in Juneau and Anchorage, and during a conference in Fairbanks, a number of projects were proposed including a harbor near Nome (Cape Darby Harbor), but not specifically at Nome. Yet, six years later in a July 1964 U.S. Atomic Energy Commission, Division of Peaceful Nuclear Explosives report on nuclear excavation projects, a harbor at Nome was suggested as a project. The report notes that the existing small boat harbor had only limited depth and the area served as the commercial and supply center for northwest Alaska with all supplies shipped by boat to and from this port (Figure 4.26-2), and local interest in a harbor facility was high. A harbor at Nome also appears as a project in a series of tables in summary reports of nuclear excavation technology from 1969 and 1970. The tables list a sampling of locations that had potential for nuclear excavation, but were no longer under consideration.

Nome Harbor was a L level 5 activity. Data for analysis was obtained from published sources and other records, no field activity was conducted.



Figure 4.26-1. Location of proposed Nome Harbor on the Seward Peninsula, Alaska (adapted from USA Relief Maps 2004).



Figure 4.26-2. Aerial view of the small boat harbor at Nome (<http://www.nomealaska.org>, last accessed October 2007).



## CHRONOLOGICAL BIBLIOGRAPHY

- E. J. Longyear Company, 1958. The Mineral Potential and Proposed Harbor Locations in Northwestern Alaska. Report to University of California Radiation Laboratory from E. J. Longyear Company, April 18. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.
- U.S. Atomic Energy Commission, 1964. Suggested Nuclear Excavation Projects and Possible Nuclear Excavation Projects. Manuscript, Division of Peaceful Nuclear Explosives, July. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.
- Congressional Information Bureau, Inc., 1965. *Daily News Service*, Vol. 11, No. 22, Congressional Information Bureau, Inc., May 31. Washington, D.C. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-100.
- Vortman, L. J., 1969. Nuclear Excavation. Report, SC-DC-69-1716, Underground Physics Division, Sandia Laboratories, Albuquerque, NM, March. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-104.
- Toman, John, 1970. Summary of Nuclear-Excavation Applications. Paper prepared for Proceedings of the ANS Topical Meeting, Engineering with Nuclear Explosives, Las Vegas, Nevada, January 14-16, 1970. University of California, Lawrence Radiation Laboratory, *Preprint UCRL-72220*, January 29. Livermore, CA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-104.
- Toman, John, 1970. Summary of Nuclear-Excavation Applications. In *Symposium on Engineering with Nuclear Explosives: Proceedings*, Report CONF-700101, Vol. 1, pp. 245-279, May. American Nuclear Society, Hinsdale, IL.

**THIS PAGE INTENTIONALLY LEFT BLANK**

## 4.27 NORTH SLOPE HARBOR

### Plowshare Program Nuclear Construction of an Offshore Loading Facility Alaska

Commercial exploration for oil on Alaska's North Slope began in the 1960s, and in 1968 a major oil field was discovered in the Prudhoe Bay area. The U.S. Coast Guard undertook a study, named the Polar Transportation Study, to explore transportation solutions for moving oil to market areas on the east and west coasts of the United States. One option was the construction of a trans-Alaskan pipeline to Valdez on the Prince William Sound to serve western markets, but this option did not provide a solution for transporting oil to refineries in the east. To accomplish this objective a year-round tanker route through the Northwest Passage was considered. However, this transportation route would depend on the feasibility of producing ice-breaking tankers that could successfully navigate the Arctic route as well as constructing a loading facility along the northern coast of Alaska. The project concept for a North Slope Harbor developed from the latter concern (Figure 4.27-1).



Figure 4.27-1. Location of proposed North Slope Harbor on the coast of Beaufort Sea in the vicinity of Prudhoe Bay, Alaska (adapted from USA Relief Maps 2004).

A memo dated September 30, 1968, from the Science Advisor of the U.S. Coast Guard to the Lawrence Radiation Laboratory, points out an interesting contradiction. During the late 1950s and early 1960s, the U.S. Atomic Energy Commission and Lawrence

Radiation Laboratory were interested in constructing a nuclear-excavated harbor in northwestern Alaska as a demonstration project for the Plowshare Program and considered a number of locations along the northwestern and northern coast for the project (Project Chariot, Cape Darby Harbor – see Chapter 4.6, this volume, Nome Harbor – see Chapter 4.26, this volume, and Point Barrow Harbor – see Chapter 4.30, this volume). However, currently, when there was strong renewed interest in a deep water harbor or loading facility, a nuclear option was not being discussed. This query initiated an exchange of letters between the U.S. Coast Guard, the U.S. Army Corps of Engineers, the U.S. Atomic Energy Commission and Lawrence Radiation Laboratory.

Correspondence between the various agencies lead to a meeting being held at the offices of the U.S. Coast Guard in Washington, D.C. on January 22, 1969. Participants included representatives from the U.S. Coast Guard, U.S. Army Corps of Engineers (including the U.S. Army Engineer Nuclear Cratering Group), and the U.S. Atomic Energy Commission. At the meeting, information was provided about nuclear excavation techniques as they pertained to harbor development and suggestions concerning design criteria as well as follow-up information to proceed with the project. Following the meeting, Thomas J. McCarvill from the Division of Peaceful Nuclear Explosives, suggested that the U.S. Coast Guard also consider the feasibility of using underground storage facilities created by nuclear explosives for oil storage. McCarvill also mentioned the possibility of using transport submarines to reach a harbor on the coast of Alaska, an idea that had been suggested by the Congressional Information Bureau in 1965.

Meanwhile, the Humble Oil and Refining Company had leased an 115,000 ton tanker, SS Manhattan, to undertake an ice tanker test program to determine the feasibility of transporting oil year-round from the north coast of Alaska eastward through the Northwest Passage and onward to the eastern U.S. The test program involved extensive modification of the tanker to strengthen the hull along the waterline, installation of an icebreaking bow, and strengthening the propellers (Figure 4.27-2). The U.S. Coast Guard, Department of Transportation agreed to provide assistance with the project.

During March 1969, a meeting was held with representatives of ESSO (now Exxon Mobile Corporation), their domestic affiliate Humble Oil and Refining Company, and Lawrence Radiation Laboratory to discuss the possibility of using Plowshare techniques to develop an offshore harbor facility near Prudhoe Bay. The technical feasibility of constructing the harbor was discussed as was the application of nuclear explosives to create chimneys for undersea petroleum storage, an idea being investigated by the Lockheed Missiles & Space Company (see Offshore Fuel Oil Storage – Chapter 5.57). The scheme for an offshore harbor was based on using the lips of nuclear crater(s) as a breakwater (Figure 4.27-3). A primary requirement was that the crater be sufficiently large and deep to accommodate oil tankers, as well as having a crater lip that was high enough to provide protection from wave action and ice (Figure 4.27-4). Following the meeting, in a March 17 memo, Glenn Werth of the Lawrence Radiation Laboratory, outlined three problems with constructing a loading facility. First, ice-pack conditions characterized the north coast of Alaska over much of the year and an undersea pipeline about 20 miles long would be necessary to transport oil to the offshore loading facility. Second, extensive offshore production was anticipated creating uncertainty

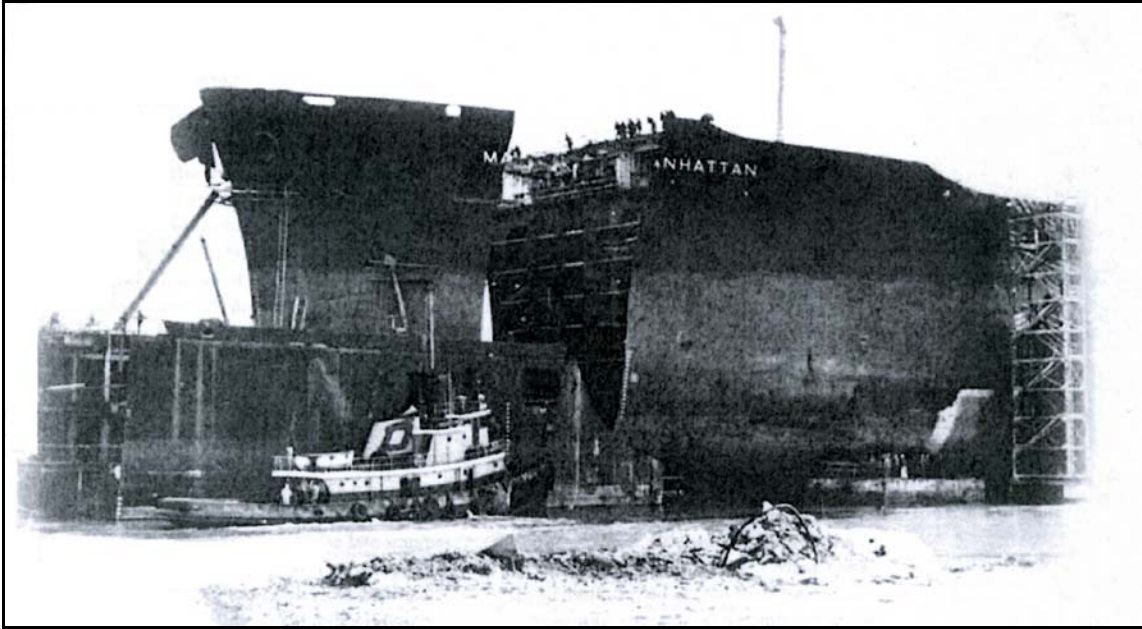


Figure 4.27-2. Photo of the Manhattan being modified for Arctic voyage (Surveyor 2005).



Figure 4.27-3. Depiction of an offshore Arctic loading facility constructed from a nuclear explosion (Lawrence Livermore National Laboratory n.d., Negative No. GLC-697-4013).

about the optimum location for the project. Finally, initial geological investigations indicated that the first 2,000 ft of subsurface sediment was predominantly saturated silty-sand and coarse sand. The phenomenology of crater formation in a saturated medium was not well understood, but it was likely that, in order to produce a crater with crater lips high enough to be useful for a loading facility, megaton single yields or row detonations in the 200-500 kt yield range would be required.

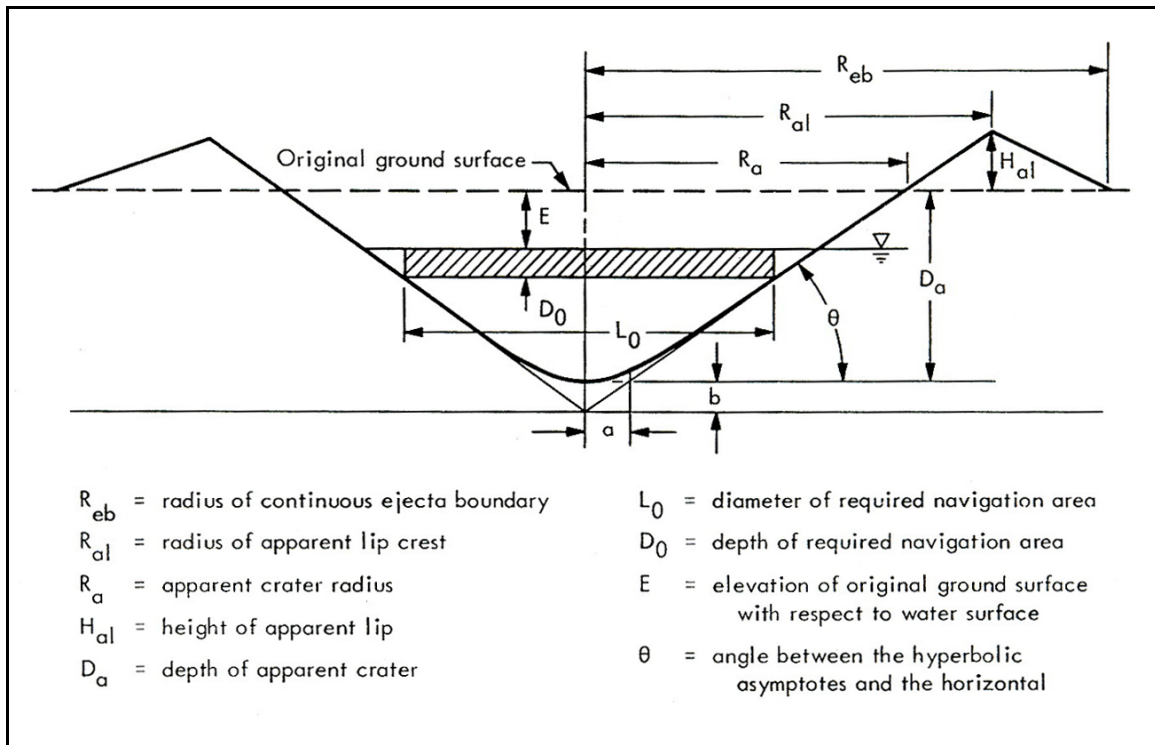


Figure 4.27-4. Schematic of the cross section of a hyperbolic crater for a harbor application (Hughes 1968, Figure 9.9).

At the request of ESSO and the Humble Oil Company, a meeting was held on April 3, 1969 with John Kelly, the Director of the Division of Peaceful Nuclear Explosives, to discuss the project. According to Humble Oil, construction of a loading facility in the Prudhoe Bay area would need to be completed by 1973 to meet oil transportation demands. On April 9 technical discussions took place in Houston, Texas, between Humble Oil and Lawrence Livermore Laboratory, and with input from the Lawrence Radiation Laboratory, Humble Oil proposed a drilling program designed to obtain detailed information about the geology of the area. The plan called for drilling four holes off the north coast. Two holes were to be drilled from grounded ice islands in about 85 ft of water, one off Prudhoe Bay and another off Brownlow Point. A third hole was planned at Brownlow Point and the fourth at Midway Island. By April 21, a preliminary draft of an agreement for Humble Oil Company and the U.S. Atomic Energy Commission to participate in a North Slope Harbor feasibility study was in review. According to a May 2

memo meetings between the U.S. Atomic Energy Commission and Humble Oil concerning project feasibility were to start on May 10, 1969.

Another technical meeting on the harbor project was held at the end of April 1969. At this meeting, and in follow-up correspondence, discussion focused on issues concerning the drilling program, as well as the geological parameters necessary to use nuclear explosives to build a facility in 100 ft of water. A nuclear application required a stable crater with a rim with sufficient height to protect ships and facilities from floating sea-ice. Various configurations of crater, retarc, and row-crater solutions for a shelter island or harbor were proposed, but additional data were required to develop the crater design. In June, representatives from Humble Oil Company and Lawrence Radiation Laboratory met in Houston, Texas to proceed with preparation of a technical concept for the project. A tentative schedule set completion of the harbor by April 1973. To accomplish this deadline, Humble Oil set a date of mid-1970 to decide if a nuclear option was technically and politically feasible.

The final correspondence available for North Slope Harbor dates to August 1969. In a draft letter from the Vice President of Humble Oil to Glenn Seaborg, the Chairman of the U.S. Atomic Energy Commission, Humble Oil requested that direct contact between the organizations concerning the harbor project be suspended because Humble Oil was focusing management and technical attention on a Trans-Alaskan Pipeline to Valdez.

In September 1969, after discussion between the various agencies had ended, the harbor project concept was announced in a series of articles in the *Wall Street Journal*, *Houston Chronicle*, *Oil Daily*, *Houston Post*, *Oil and Gas Journal*, and likely other newspapers. The articles reported on a press conference in Houston, Texas, where Edward Teller, announced that studies were underway to use nuclear excavation techniques for a harbor facility off the north coast of Alaska to serve oil tankers but stated that funding for the project would need to come from private enterprise.

At the same time that Teller announced studies for a North Slope Harbor, the ice tanker test, were in progress. The ice-reinforced SS Manhattan returned to New York from a 4,400 mile long voyage to Prudhoe Bay on October 30, 1969. The tanker carried a symbolic barrel of oil and was the first commercial ship to cross the Northwest Passage (Figures 4.27-5). While the voyage was successful, there was some damage to the tanker and the use of ice-reinforced tankers to navigate the Northwest Passage was not considered cost effective. Also, by the time the voyage was completed interest in a North Slope Harbor had faded. Commercial production of oil from the Prudhoe Bay area began in 1977 when the Alyeska Pipeline Service Company completed the pipeline between Prudhoe Bay and the Port at Valdez.

The North Slope Harbor was a Level 4 or Level 5 activity. Additional documentation is needed to determine if any drilling was conducted.

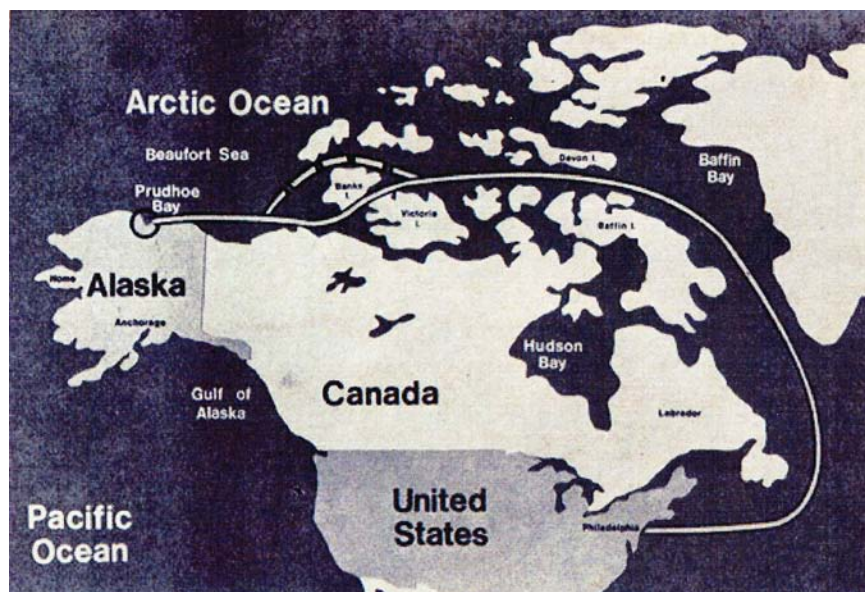


Figure 4.27-5. Route of the ice breaker Manhattan through the Northwest Passage on historic voyage in 1969 (<http://www.sunshiporg.homestead.com/manhattan.html>, last accessed October 2007).

## CHRONOLOGICAL BIBLIOGRAPHY

- Congressional Information Bureau, Inc., 1965. *Daily News Service*, Vol. 11, No. 22, Congressional Information Bureau, Inc., May 31. Washington, D.C. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-100.
- Hughes, Bernard C., 1968. Nuclear Construction Engineering Technology. Lawrence Radiation Laboratory, U.S. Army Engineer Nuclear Cratering Group, *NCG Technical Report No. 2*, September. Livermore, CA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-104.
- Bates, Charles E., 1968. Letter from Charles C. Bates, Science Advisor, U.S. Coast Guard, to Glenn Werth, September 30. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA. File PLO-074.
- Sterrett, T. S., 1968. "Nuclear Harbors, Northern Alaska." Memo from Thomas S. Sterrett, Lawrence Radiation Laboratory, to Milo D. Nordyke, October 9. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-074.



- Bates, Charles C., 1968. Letter from Charles C. Bates to John Kelly, October 28. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-074.
- Trimble, P. E., 1968. "Nuclear Devices for the Development of Deep Water Ports; Meeting between U.S. Coast Guard and U.S. Army Corp of Engineers." Memo from P. E. Trimble, U.S. Coast Guard, to Chief of Engineers, U.S. Army Corps of Engineers, December 24. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-074.
- Smeder, O. R., 1968. "Ice Tanker Test in Arctic Regions." Memo with encls. (proposed "Operation Plan;" agreement between the Humble Oil and Refining Company and the Department of Transportation; letter from Humble, October 24; and letter from Secretary Boyd, November 14) from O. R. Smeder, Rear Admiral, U.S. Coast Guard, to Chief of Staff, December 27. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-074.
- Cassidy, William F., 1969. Letter with encl. (letter from P. E. Trimble, December 24) from William F. Cassidy, Department of the Army, Office of the Chief of Engineers, to Admiral Willard Smith, January 6. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-074.
- Hughes, Bernard C., 1969. Nuclear Excavation Technology Pertaining to Harbor Development. Paper presented at meeting with Coast Guard, Corps, and PNE at USCG, January 22. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-074.
- U.S. Coast Guard, 1969. "Participants of a Meeting with Coast Guard, Corps, and PNE at USCG, January 22, 1969." List of Participants, January 22. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-074.
- McCarvill, Thomas J., 1969. Letter from Thomas J. McCarvill, U.S. Atomic Energy Commission, Division of Peaceful Nuclear Explosives, to Charles C. Bates, January 31. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-074.
- Bates, Charles C., 1969. Letter from Charles C. Bates to Thomas J. McCarvill, February 14. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-074.
- McCarvill, Thomas J., 1969. "Report on Meeting with the U.S. Coast Guard and Corps of Engineers." Memo from Thomas J. McCarvill, U.S. Atomic Energy Commission, Division of Peaceful Nuclear Explosives, to Files, March 10. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-074.

- Nordyke, Milo D., 1969. Telex from Milo D. Nordyke, Lawrence Radiation Laboratory, to Bill A. Smith, March 10. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-074.
- Nordyke, Milo D., 1969. "Meeting with ESSO Personnel." Memo from M. D. Nordyke, Lawrence Radiation Laboratory, to G. C. Werth, March 17. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-074.
- Hammond, R. E., 1969. Letter from R. E. Hammond, Rear Admiral, U.S. Coast Guard, to Charles C. Bates, March 20. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-074.
- Bates, Charles C., 1969. Letter from Charles C. Bates to R. E. Hammond ("Bob"), March 28. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-074.
- Bates, Charles C., 1969. Letter with encls. (letter from R. W. Sexton, Southeastern Drilling, Inc., to C. C. Bates, March 21, letter from Harold James, U.S. Department of the Interior, to C. C. Bates, March 11) from Charles C. Bates, U.S. Coast Guard, to James H. Tormey, March 28. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-074.
- Bates, Charles C., 1969. "North Commission Briefing." Memo from Charles C. Bates, U.S. Coast Guard, to Colonel Tormey and Thomas McCarvill, April 8. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-074.
- McCool, W. B., 1969. "Meeting with Humble Oil Re Alaskan Harbor." Memo with encl. (memo with Attached Map from Donald C. Kull, U.S. Atomic Energy Commission, to Distribution, April 8) from W. B. McCool, U.S. Atomic Energy Commission, to Distribution, April 8. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-074.
- Nordyke, Milo D., 1969. Letter from Milo D. Nordyke, Lawrence Radiation Laboratory, to Stanley B. Hass, April 11. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-074.
- McCarvill, Thomas J., 1969. "Officials Contacted Re Alaskan Harbor." Memo from Thomas J. McCarvill, U.S. Atomic Energy Commission, Division of Peaceful Nuclear Explosives, to Files, April 14. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-074.
- Kelly, John S., 1969. Telex from John S. Kelly, U.S. Atomic Energy Commission, to Multiple Recipients, April 16. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-074.

- Kelly, John S., 1969. Letter from John S. Kelly, U.S. Atomic Energy Commission, Division of Peaceful Nuclear Explosives, to Charles C. Bates, April 18. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-074.
- U.S. Atomic Energy Commission, 1969. "Hearings Before the Joint Committee on Atomic Energy, Congress of the United States, Ninety-First Congress, First Session on General, Physical, Research Program, Space Nuclear Program, and Plowshare, April 17 and 18, Part I." Hearings, April 18. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-074.
- Nordyke, Milo D., 1969. "Meeting with Humble Oil and Refining Company in Houston, Texas, April 9, 1969." Memo from Milo D. Nordyke, Lawrence Radiation Laboratory, to Glenn C. Werth, April 21. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-074.
- U.S. Atomic Energy Commission, 1969. "Agreement for North Slope Harbor Feasibility Study." Agreement, U.S. Atomic Energy Commission and Humble Oil and Refining Company, April 21. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-074.
- Kelly, John S., 1969. Telex from John S. Kelly, U.S. Atomic Energy Commission, to Robert Miller, April 23. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-074 [OUO].
- Sterrett, T. S., 1969. "Summary of Meeting with Humble Oil and Refining Corporation, April 30, 1969, in Los Angeles." Memo from F. S. Sterrett, Lawrence Radiation Laboratory, to Distribution, May 2. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-074.
- Nordyke, Milo D., 1969. "Various Configurations for an Alaskan Off-Shore Terminal." Memo from Milo D. Nordyke, Lawrence Radiation Laboratory, to Distribution, May 3. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-074.
- Sterrett, T. S., 1969. "Proposed Logging Program - Humble Oil, Arctic Evaluation Program." Memo from T. S. Sterrett, Lawrence Radiation Laboratory, to Distribution, May 6. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-074.
- Nordyke, Milo D., 1969. Telex from Milo D. Nordyke, Lawrence Radiation Laboratory, to John S. Kelly, May 7.
- Kelly, John S., 1969. Telex from John S. Kelly, U.S. Atomic Energy Commission, to Michael May, May 12. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-074.

- Crawford, Todd V., 1969. "Alaskan Harbor and the LTBT." Memo from Todd V. Crawford, Lawrence Radiation Laboratory, to Distribution, June 25. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-074 [OUO].
- Lewis, A. E., 1969. "Meeting with Humble Oil Company Representatives in Houston June 17, 1969." Memo from A. E. Lewis, Lawrence Radiation Laboratory, to Distribution, June 30. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-074.
- Lewis, A. E., 1969. "Contacts between LRL and Humble Oil Company Prior to July 1, Regarding Construction of a Nuclear Harbor in Alaska." Memo from A. E. Lewis, Lawrence Radiation Laboratory, to File, July 9. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, July 9.
- Venn, R. H., 1969. Letter from R. H. Venn, Vice President, Humble Oil & Refining Company, to Seaborg, August 12. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-074.
- Collins, Albert T., 1969. Alaska Harbor Created by N-Blast Being Studied. *Houston Chronicle*, Section 4, p. 2, September 24. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-074.
- Drummond, Jim, 1969. Nuclear Harbor Project Advanced for Prudhoe Bay. *The Oil Daily*, No. 4587, September 25. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-074.
- Peacock, Darnell, 1969. Teller Stresses Nuclear Safety. *The Houston Post*, Section 2, p. 4, September 25. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-074.
- Wall Street Journal, 1969. Harbor on North Slope Dug by Nuclear Blast is Mulled, Teller Says. *Wall Street Journal*, September 25. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-074.
- Oil and Gas Journal, 1969. Atom Blasts for North Slope Harbor Proposed. *Oil and Gas Journal*, September 29. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-074.
- Frank, G. W., 1969. Letter from G. W. Frank, Austral Oil Company, Inc., to Glenn Werth, September 30. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-074.
- Harbor at Prudhoe Bay, [1969]. Harbor at Prudhoe Bay. Handwritten notes and drawings. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-074.

Surveyor, 2005. The First Arctic Tanker. *Surveyor*, pp. 18-22, Summer. American Bureau of Shipping, Houston, TX.

Lawrence Livermore National Laboratory, n.d. Cold environment harbor drawing -05-B1. Negative No. GLC-697-4013. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA.

**THIS PAGE INTENTIONALLY LEFT BLANK**

## **4.28 OLD RELIABLE MINE**

### **Plowshare Program High Explosives Seismic Study Arizona**

The Old Reliable Mine is in the Galiuro Mountains, 39.5 miles north of Tucson, Arizona (Figures 4.28-1 and 4.28-2). The mine sits at an elevation of 3,740 ft and it can be reached by driving 9.3 miles up Copper Creek Road from Mammoth, Arizona to coordinates 32°45.11' North latitude and 110°29.36' West longitude. Originally discovered in 1890, the mine operated from 1890 to 1919 and again between 1953 and 1954. During the life of the mine, only limited amounts of copper were obtained and eventually the mine proved to be economically unproductive with conventional mining techniques.

Ranchers Exploration and Development Corporation decided to experiment with a new copper extraction technique. Instead of mining the ore and then hauling it to a processing locality, the new method focused on breaking up the ore deposits and leaching the copper in place with a solution of acid and water, this substantially reducing costs. With explosive technical assistance from E. I. DuPont de Nemours and Company, they developed a plan to break up the copper ore body with one large explosion. Four million pounds of pelletized ammonium nitrate and fuel oil would be detonated in three tunnel complexes (Figure 4.28-3). The two lower tunnels were excavated during the conventional copper mining operations many years before, while the upper tunnel was constructed specifically for the blast. After the blast, the mountainside would be terraced and injected with leaching fluids. These fluids would pick up the copper as they percolated through the broken ore. Then the liquids could be collected at the bottom of the ore body and processed to remove the copper. In August 1971, a 2-ton calibration blast was conducted at the mine.

On January 27, 1972, there was a meeting to discuss the possibility of a mutual effort between the government and industry to make seismic and related measurements on this exceptionally large nonnuclear explosion. Present at the meeting were representatives from E. I. DuPont de Nemours and Company, Ranchers Development Corporation, Lawrence Livermore Laboratory, U.S. Atomic Energy Commission, U.S. Geodetic Survey, U.S. Army Engineers Explosive Engineering Research Organization, John A. Blume and Associates, Sandia Laboratories, Earth Sciences Laboratory, Las Vegas, the National Oceanic and Atmospheric Administration, Environmental Research Laboratories, and Environmental Research Corporation. Measurements discussed included earth-motion at surface zero, on ranch structures near the mine, structures at the Magma Mine facility, and several locations along a line between the Old Reliable Mine and Tucson. Also of interest were pressure measurements in water wells in the San Pedro River basin and air-blast measurements. The meeting was held less than two months before the date scheduled for the explosion. In order to expedite the research associated with this explosion, the interested parties divided up the work effort with each financing a

different effort. The U.S. Atomic Energy Commission approved the use of Plowshare funding for this research on February 16, 1972.

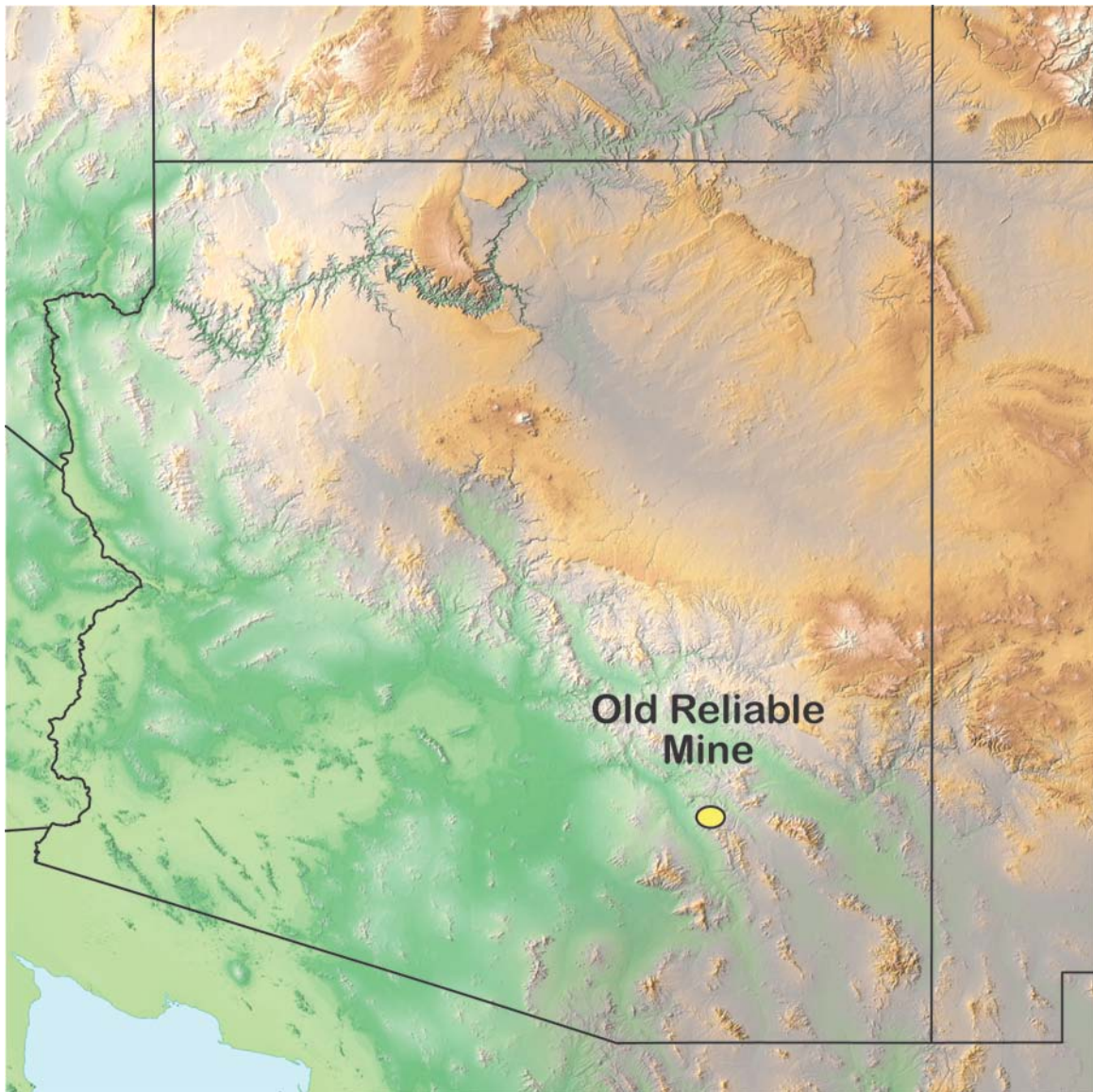


Figure 4.28-1. Location of Old Reliable Mine in southeastern Arizona (adapted from USA Relief Maps 2004).

E.I. DuPont de Nemours and Ranchers Corporation representatives wanted to obtain earth motion data for analysis of the performance of the explosive and for any possible future litigation for damage claims. For Lawrence Livermore Laboratory, the seismic data would help understand long-range seismic motions and the response of key structures at the mine to the blast. The U.S. Atomic Energy Commission was interested because the detonation was in an area where the likelihood of future high explosives or



nuclear explosions for industrial purposes were great. In fact, there were on-going discussions with Newmont Mining Company regarding a nuclear explosives copper leaching project for the nearby Zonia Mine. Lawrence Livermore Laboratory also saw the detonation at Old Reliable Mine as an opportunity to derive data for planned and future Plowshare projects because potential seismic damage was a limiting factor on gas stimulation and Plowshare applications in general and this was a rare opportunity to record a 2 kt explosion in a different geologic regime. DuPont was interested in the solution mining method of copper recovery but hesitant to proceed with the U.S. Atomic Energy Commission on such a Plowshare project because of the difficulties of working with government agencies. DuPont requested the government's participation and this involvement was viewed as an opportunity to show the company that Plowshare personnel could work efficiently and effectively with industry.

The overall goal of the seismic study was to derive a ground motion attenuation curve of the area near the detonation, to record the structural response effects near ground zero, and record the response effects at the base of a supporting beam inside the mine. The Nevada Special Projects Party of the Environmental Sciences Laboratories instrumented 12 temporary seismograph stations ranging from 1.2 to 39.5 miles away from the detonation, the last being in north Tucson. Additional data was obtained from nine permanent stations in Arizona, New Mexico, Nevada, and Utah. Sandia Laboratories involvement focused on instrumentation for the associated air-blast measurements.

The detonation at the Old Reliable Mine occurred on March 9, 1972. The ammonium nitrate was placed in three working levels of the mine: 600,000 lbs at elevation 3,995 ft, 2,000,000 lbs at 3,835 ft, and 1,400,000 lbs at 3,735 ft. The seismic study was not as successful as expected, with only two of the twelve stations able to obtain readings satisfactorily. The compressional wave generated by the detonation produced a body wave of magnitude 4.5 as calculated from distant stations. The attenuation rate and propagational velocities were successfully determined. Due to low ground-motion predictions, most data channels were saturated on the peak amplitudes and the data were lost. The other readings were inaccurate because of improper calibrations from an earlier detonation and from different methods of recording. Consequently, the primary objective for developing a capability to predict ground motion was not realized. Only the air blast measurement program was successful in obtaining useful data.

Project Old Reliable Mine was a Level 4 activity because the U.S. Atomic Energy Commission's involvement was confined to instrumentation and data readings.

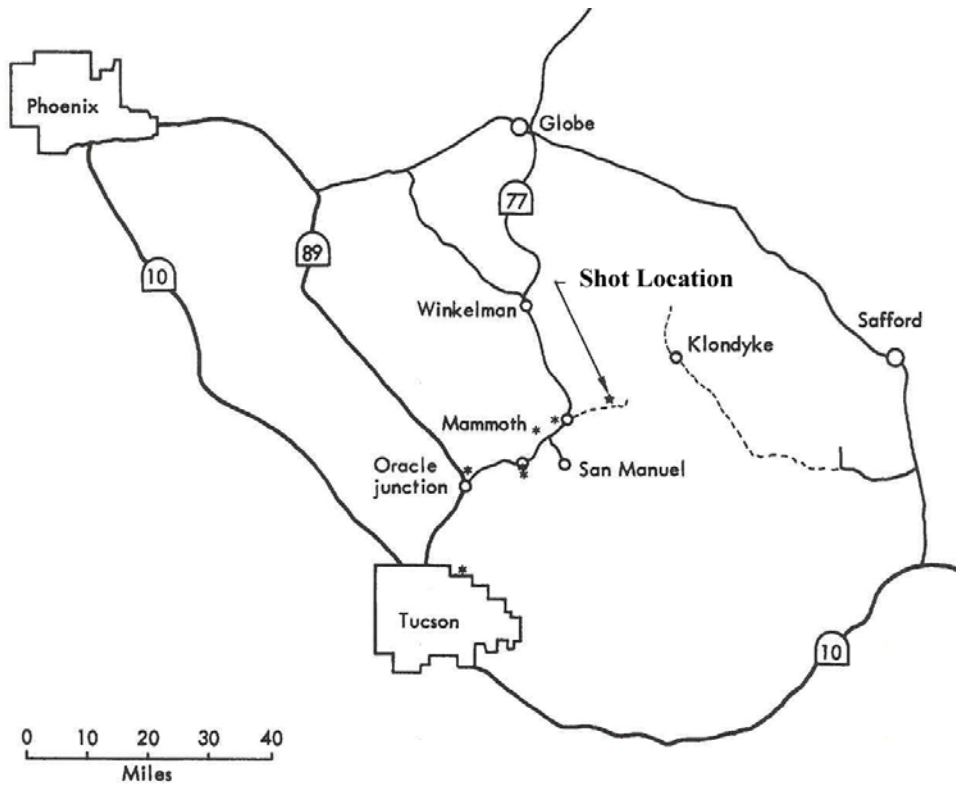


Figure 4.28-2. Shot location for Old Reliable Mine (Sisemore 1973, Figure 1).

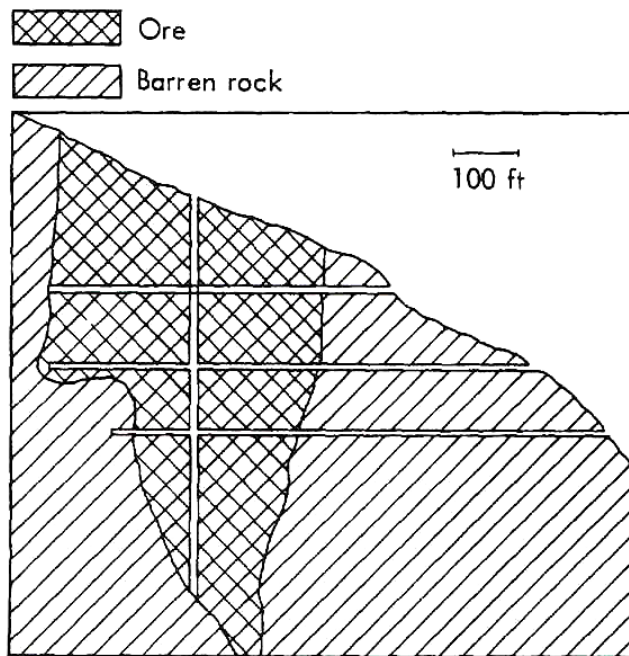


Figure 4.28-3. Tunnels in ore body at Old Reliable Mine (Sisemore 1973, Figure 2).

## CHRONOLOGICAL BIBLIOGRAPHY

- Werth, Glenn C., [between 1966 and 1973], Handwritten notes on Plowshare program meetings from Glenn C. Werth, U.S. Atomic Energy Commission, Division of Peaceful Nuclear Explosives, 1966-1973. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-118.
- Holzer, Fred, 1972. "Du Pont, in cooperation with Ranchers Mining Company..." Telex from Fred Holzer, Lawrence Livermore Laboratory, to E. M. Douthett, January 28. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-087.
- Todd, James A., 1972. Letter from James A. Todd, E. I. Du Pont De Nemours & Co., to Glenn C. Werth, February 3.
- Holzer, Fred, 1972. "Outline of Arizona Work." Memo from Fred Holzer, Lawrence Radiation Laboratory, to Glenn C. Werth, February 8.
- Werth, Glenn C., 1972. "On February 17 We Received a Letter from DuPont." Telex from Glenn C. Werth, Lawrence Radiation Laboratory, to John S. Kelly, February 15. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-087.
- Kelly, John S., 1972. "Plowshare Program Funding Support." Telex from John S. Kelly, U.S. Atomic Energy Commission, to Glenn C. Werth, February 16. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-087.
- Randolph, Philip L., 1972. Letter from Philip L. Randolph, El Paso Natural Gas Company, El Paso, TX, to Glenn C. Werth, February 24. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-087.
- Navarro, Richard, 1972. Old Reliable Mine Project: Seismic Measurements. National Oceanic and Atmospheric Administration, *Technical Memorandum* ERL ESL-19, July. U.S. Department of Commerce, Washington, D.C. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0330827.
- Vortman, L. J., 1972. Airblast from Sequenced Explosions of Charges Horizontally Dispersed in Three Vertical Layers. Sandia Laboratories, Report No. SC-RR-72 0517, October. Albuquerque, NM. On file at: Archives and Research Center, Lawrence Livermore National Laboratories, Livermore, CA, File PLO-092.

- Ranchers Exploration & Development Corporation, 1972. The Old Reliable Project. Manuscript, Ranchers Exploration and Development Corporation, Albuquerque, NM. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-087.
- Springer, D. L., 1973. "Comments on the HE Detonations in Arizona." Memo from D. L. Springer, Lawrence Livermore Laboratory, to H. C. Rodean, June 27. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-100.
- Sisemore, Clyde, 1973. Analyzing of Surface-Motion Data from Old Reliable Mine Blast. University of California, Lawrence Livermore Laboratory, *Report UCID-16314*, July 19. Livermore, CA. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0330830.
- Shafer, David S., William. C. Beck, Dwight Treadwell, and Stephen. A. Mellington, 1995. Inventory of Potential Environmental Restoration Liabilities Associated with Plowshare And Vela Uniform Program Sites. Manuscript, U.S. Department of Energy, Office of Environmental Restoration. On file at: Desert Research Institute, Las Vegas, NV.
- U.S. Department of Energy. Nevada Operations Office, 1997. Plowshare Program Executive Summary. Report from U.S. Department of Energy, December 22.
- U.S. Department of Energy. Nevada Operations Office, n.d. The Plowshare Program (Draft). Report from U.S. Department of Energy.

## **4.29 PHAETON**

### **Plowshare Program Nuclear Excavation Nevada, California, and Alaska**

The concept for Project Phaeton was well-developed by 1962 and was described in a July 10, 1962 U.S. Atomic Energy Commission Report as a one megaton scaling experiment tentatively considered for FY 1965. The initial purpose of the project was to extend data on cratering and on radioactivity containment to the megaton range. It was hoped this experiment could be conducted as a useful or quasi-useful project. A July 1962 preliminary estimate placed the cost at 10 million dollars. In the U.S. Atomic Energy Commission's 1963 Long Range Plan for the Plowshare Program, Project Phaeton is listed as part of the experimental, nuclear excavation program slated for completion by the end of FY 1967 in support of the Isthmian Canal project. This program consisted of at least eight nuclear detonations to study the characteristics of craters produced in various geological settings in relation to the depth of burial and yield of the device. Phaeton was one of the projects to be conducted in hard rock. Site selection was expected to begin in FY 1963 and this was a joint U.S. Atomic Energy Commission and U.S Army Engineer Nuclear Cratering Group project. A September 20, 1963 memorandum by the U.S. Atomic Energy Commission's Nuclear Cratering Group shows a design deadline for Phaeton of July 1966 and detonation date of March 1967. However, by late FY 1964, no potential locations had been identified. Due to its magnitude, Project Phaeton was slated for the later stages of the Plowshare experimental excavation program.

Between 1964 and 1968, there is a lack of information on Project Phaeton. In September 1968, Phaeton is listed on the Tentative Schedule for the Plowshare Program. Under Alternate #1, the fabrication for Phaeton was to begin in the fourth quarter of FY 1970 followed by a reduced yield detonation in the second quarter of FY 1971. According to Alternate #2, the fabrication for Phaeton would be initiated in the first quarter of FY 1970 with the test executed in the third quarter of FY 1970 at a reduced yield. Both scenarios placed the detonation on the Nevada Test Site.

Lawrence Radiation Laboratory identified a possible location for Phaeton on Pahute Mesa in Area 20 of the Nevada Test Site in late October 1968. This choice was questioned because the geology of this area, composed of dry and porous rock, was considered unrepresentative of most places in the world and extending the results to a wet or non-porous situation would not be valid. It was pointed out that conducting the project on the Nevada Test Site in an unsaturated zone would not provide data regarding seismic damage from nuclear cratering, the effect of water saturation on cratering physics, fallout, and cavity growth. The U. S. Geological Survey, Special Project Branch suggested the possibility of locations with more common geology in the Central Nevada Supplemental Test Site (now the Central Nevada Test Area) in Hot Creek Valley, in the Monitor Valley, and in Gold Flat or Kawich Valley north of Pahute Mesa on the Nellis Bombing Range. Locations listed in a summary table for Phaeton and Yawl (another proposed

Plowshare project) were UCe-1 and UCe-3 at the Central Nevada Supplemental Test Site, and Gold Flat and the Cactus Range on the Nellis Bombing Range. A memorandum from late January 1969 summarized an initial search for sites for Yawl and Phaeton with the following criteria: less than 10 percent topographic relief, silicate rock with high dry strength, saturation to within 50 ft or less below surface, and low population density. It lists Amchitka Island in Alaska as the best possible site, but also mentioned are secondary sites on the Nellis Range just north of the Nevada Test Site, Monitor Valley in central Nevada, the Black Rock Desert in northern Nevada, and Cima Dome in the Ivanpah Mountains of southern California (Figure 4.29-1). This memorandum concluded with the recommendation that the problem of operational constraints should be solved before devoting more effort to siting the project. Information on Phaeton after January 1969 has not been found and, apparently, the project was put on hold indefinitely.

Project Phaeton category of activity was a Level 5 as it never progressed beyond the conceptual stage and may have involved limited field visits to proposed locations.

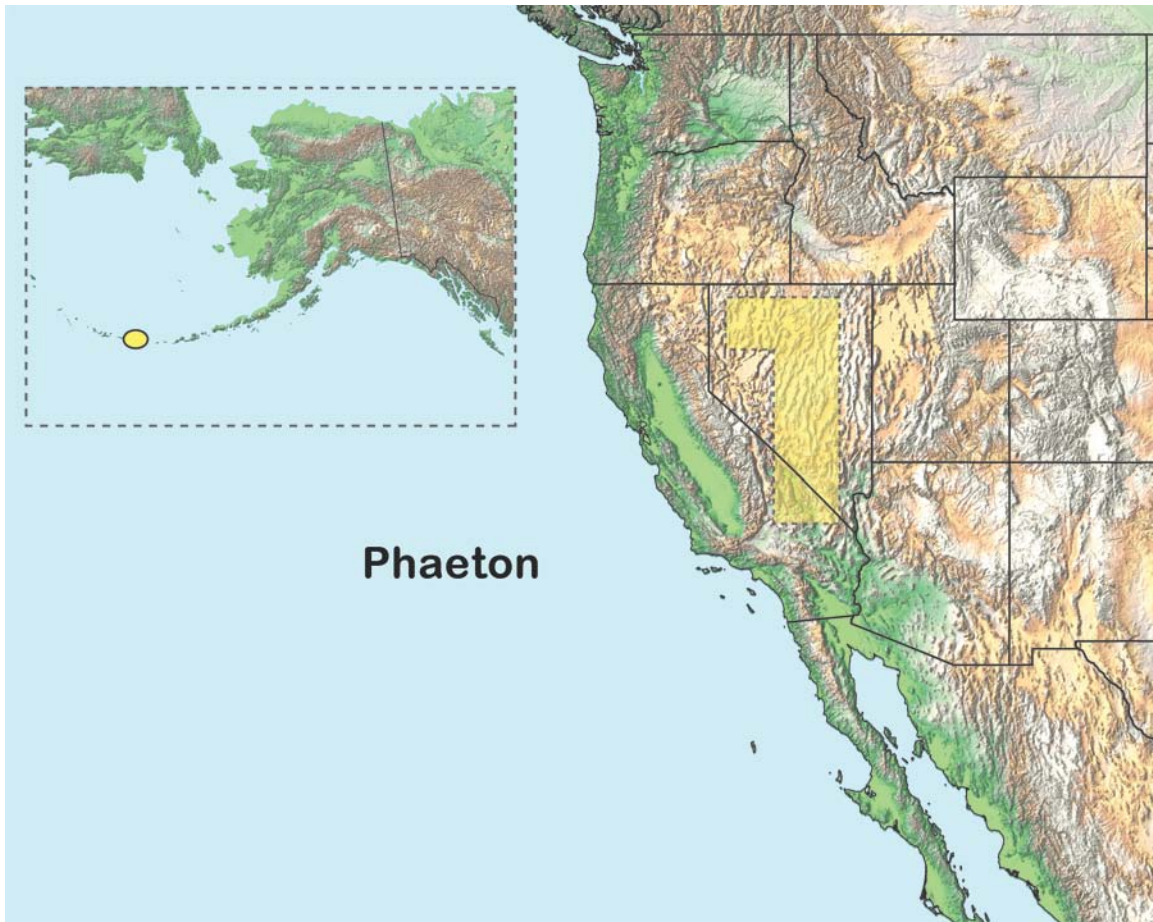


Figure 4.29-1. Possible locations for Phaeton (adapted from USA Relief Maps 2004).

## CHRONOLOGICAL BIBLIOGRAPHY

- McCool, W. B., 1962. "Atomic Energy Commission, Plowshare Excavation Program." Note with encl. (Plowshare Program, Nuclear Excavation Application, manuscript) from W. B. McCool, U.S. Atomic Energy Commission, Report 811/105, July 10. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0075573.
- U.S. Atomic Energy Commission, 1963. Plowshare Program. In *Annual Report to Congress of the Atomic Energy Commission*, pp. 2241-252, January. Government Printing Office, Washington, D. C.
- Science News, 1963. Dig Ditches with Atoms. *Science News Letter*, February 9. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.
- U.S. Atomic Energy Commission, 1963. Long Range Plan, 1964-1973, Peaceful Uses of Nuclear Explosives Program (Plowshare). Report from U.S. Atomic Energy Commission, March 20. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV.
- Defense Atomic Support Agency, 1963, Peaceful Uses of Nuclear Explosives: Project Plowshare. Report from Defense Atomic Support Agency, Sandia Base, Albuquerque, NM, September 1. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV [OUO].
- Graves, Ernest, 1963. "Program and Budget Justification, Nuclear Explosives Studies." Letter with encl. ("FY 1964 Program") from Ernest Graves, Lawrence Radiation Laboratory, U.S. Army Engineer Nuclear Cratering Group, to Chief of Engineers, Department of the Army, September 20. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029 [OUO].
- Johnson, Walter, 1963. Project Plowshare - Opportunity for the Drilling Industry. University of California, Lawrence Radiation Laboratory, *Report UCRL-7615*, December 6. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV.
- Defense Atomic Support Agency, 1964. Peaceful Uses of Nuclear Explosives: Project Plowshare. Report From Defense Atomic Support Agency, Sandia Base, Albuquerque, NM, September 1. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV [OUO].

- Kelly, John S., 1968. Letter with encl. ("U.S. Atomic Energy Commission Plowshare Program Projections – Estimated Cost in Thousands and Number of Nuclear Detonations") from John S. Kelly, U.S. Atomic Energy Commission, Division of Peaceful Nuclear Explosives, to Charles C. Noble, April. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-065.
- Werth, Glenn C., 1968. "Alternate #1, Tentative Schedule – Plowshare Program – LRL Related." Schedule from Lawrence Radiation Laboratory, September 10. On file at: Archives and Records Office, Lawrence Berkeley National Laboratory, Berkeley, CA, File 434-900205, 28/48.
- Werth, Glenn C., 1968. "Alternate #2, Tentative Schedule - Plowshare Program - LRL Related." Schedule from Lawrence Radiation Laboratory, September 10. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-118.
- Ramspott, L. D., 1968. Possible Sites for Cratering Experiments, Area 20, NTS. Memo from L. D. Ramspott, Lawrence Radiation Laboratory, to C. E. Williams, October 29. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-072.
- Ramspott, L. D., 1968. "Yawl and Phaeton Location: Technical Considerations." Memo from L. D. Ramspott, Lawrence Livermore National Laboratory, to Distribution, November 18. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-072.
- Ide, Roger H., 1968. Letter from Roger H. Ide, Lawrence Radiation Laboratory, to W. R. Cooper, November 25. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession Nos. NV0308620 and NV0309997.
- Connell, Richard P., 1968. Letter with encl. ("U.S. Atomic Energy Commission, Fiscal Year 1969 Midyear Review, Schedule A, Plowshare Program") from Richard P. Connell, Lawrence Radiation Laboratory, to John S. Kelly, December 19. On file at: Lawrence Berkeley National Laboratory, University of California, Berkeley, CA, File 434-900205, 28/48.
- Ramspott, L. D., 1969. Potential Saturated-Rock Sites for Yawl and Phaeton. Memo from L. D. Ramspott, Lawrence Radiation Laboratory, to J. A. Krover, January 24. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-072.



- U.S. Atomic Energy Commission, 1969. "United States Atomic Energy Commission, Plowshare Program Statement, JCAE FY 1970 Authorization Hearings." Statement from U.S. Atomic Energy Commission, April 18. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-028.
- Korver, John A., 1969. Operational Considerations for the Sturtevant/Yawl Sites. Memo from J. A. Korver, Lawrence Radiation Laboratory, to Distribution, June 2. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-072 [OUO].
- Connell, Richard P., 1970. "Request for FY70 Plowshare Financial Plan Change." Telex from Richard P. Connell, Lawrence Radiation Laboratory, to John S. Kelly, May 27. On file at: Archives and Records Office, Lawrence Berkeley National Laboratory, Berkeley, CA, File Director's Office, Budget, A&GS, Plowshare Program, DC 1968, File 434-900205, 28/48.
- Shafer, David S., William. C. Beck, Dwight Treadwell, and Stephen. A. Mellington, 1995. Inventory of Potential Environmental Restoration Liabilities Associated with Plowshare And Vela Uniform Program Sites. Manuscript, U.S. Department of Energy, Office of Environmental Restoration. On file at: Desert Research Institute, Las Vegas, NV.
- U.S. Department of Energy. Nevada Operations Office, 1997. Plowshare Program Executive Summary. Report from U.S. Department of Energy, December 22.
- Summary of Data, Possible Yawl-Phaeton Sites, n.d. Summary of Data, Possible Yawl-Phaeton Sites. Table. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-072.
- U.S. Department of Energy. Nevada Operations Office, n.d. The Plowshare Program (Draft). Report from U.S. Department of Energy.

**THIS PAGE INTENTIONALLY LEFT BLANK**

## 4.30 POINT BARROW HARBOR

### Plowshare Program Nuclear Excavation of a Harbor Alaska

As early as 1956, the Lawrence Radiation Laboratory was exploring the feasibility of conducting a nuclear excavation project to create a deep water harbor. In February 1958, the E. J. Longyear Company from Minneapolis, Minnesota was subcontracted by Lawrence Radiation Laboratory to prepare a report on the mineral potential and proposed deep water harbor locations in northwestern Alaska. Point Barrow was one of the locations suggested for a possible nuclear excavated harbor (Figure 4.30-1) (see also Cape Darby Harbor – Chapter 4.6 and Nome Harbor – Chapter 4.26). The Longyear Company delivered their report in April 1958, and the analysis could find no justification for a deep water harbor either near Point Barrow or along the entire northern coast of Alaska. They argued that a shipping season would last only one month and possibly less depending on the extent of the Arctic ice pack. In addition, the North Slope of Alaska was characterized by a tundra belt with permafrost and overland travel to Point Barrow would be restricted to the winter months. Finally, the report concluded that there was no mineral development in progress and a harbor at Point Barrow would not provide any economic benefit in the foreseeable future.



Figure 4.30-1. Location of proposed Point Barrow Harbor at Point Barrow, Alaska (adapted from USA Relief Maps 2004).

In July 1958, at meetings in Anchorage, Juneau, and Fairbanks, Alaska, a team of scientists from the U.S. Atomic Energy Commission and the Lawrence Radiation Laboratory discussed the possibility of a demonstration project in Alaska to excavate a harbor using nuclear explosives. Business representatives, civic leaders, and state officials who attended the meeting suggested a number of projects including a harbor near Umiat. Umiat is approximately 200 miles inland from Point Barrow and Alaskan representatives at the meeting suggested that a harbor on the northern coast near Umiat would assist in the development of oil in that area.

Shortly after the meetings Lawrence Radiation Laboratory began developing plans to conduct a harbor demonstration project at Cape Thompson (Project Chariot). However, in a July 1964 document prepared by the U.S. Atomic Energy Commission Division of Peaceful Nuclear Explosives, a harbor at Point Barrow is listed as a “possible” nuclear excavation project.

Commercial exploration for oil on Alaska’s North Slope began in the 1960s and a major oil field was discovered in 1968. With the need to transport oil to market, the idea of a harbor or loading facility somewhere along the northern coast of Alaska was re-examined. The proposed location, however, was well east of Point Barrow in the vicinity of Prudhoe Bay (see North Slope Harbor – Chapter 4.27).

Point Barrow Harbor was a Level 5 activity. The project did not progress beyond the conceptual stage.

## **CHRONOLOGICAL BIBLIOGRAPHY**

E. J. Longyear Company, 1958. The Mineral Potential and Proposed Harbor Locations in Northwestern Alaska. Report to University of California Radiation Laboratory from E. J. Longyear Company, April 18. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.

Anchorage Daily News, 1958. Atom Scientists Here Tell Plans to Blast Harbor. *Anchorage Daily News*, July 15. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.

## 4.31 PORT MOLLER CANAL

### Plowshare Project Nuclear Explosives for Canal Construction Alaska

During July 1958, scientists from the Atomic Energy Commission and Lawrence Radiation Laboratory held meetings in Alaska to discuss the possibility of undertaking a nuclear explosive construction project in Alaska as a demonstration of the peaceful use of nuclear explosives. A number of projects were discussed, including a harbor on either the Arctic Coast, Norton Sound, or the Gulf of Alaska; a dam on the Susitna, Copper, or Yukon Rivers; or a channel through the Alaskan Peninsula. The latter was recommended by representatives of the Governor of Alaska and was referred to variously as Port Moller Canal or the Aleutian Canal (Figure 4.31-1). Alaska officials argued that construction of this canal would demonstrate the ability to construct a deep-water channel using nuclear explosives. By connecting a bay at Port Moller on the Bering Sea with Stepovak Bay on the Pacific Ocean, a canal would provide a protected passage for fishing boats from the Gulf of Alaska to Bristol Bay and/or assist with the development of mineral resources in the Bristol Bay area. The project had been considered by the U.S. Army Corps of Engineers, Alaska District using conventional methods, but was not considered feasible.



Figure 4.31-1. Location of proposed Port Moller Canal on the Alaskan Peninsula (adapted from USA Relief Maps 2004).

After the meetings, in August 1958, a scientist from Lawrence Radiation Laboratory distributed a preliminary operational concept for the Port Moller Canal. This document

outlined two phases of study: 1) field survey, and 2) construction and detonation. In the preliminary plan, the field survey phase was scheduled from May to September 1959. It was to consist of a number of activities including surface and subsurface geological characterization studies, hydrological investigations, detailed charting of off-shore currents and silting patterns, aerial photography, contour mapping, and the construction of a pre-fabricated housing, office and workshop complex, as well as a docking facility. Preliminary high explosive studies to predict crater sizes were also planned as part of the field study. The construction and detonation phase was scheduled between November 1959 and December 1960. Activities proposed for this phase were drilling the device emplacement holes, construction of scientific stations, establishment of a radiological control area and a firing control point, and a post-shot survey of the project area. The planned canal site extended from Herendeen Bay through Deer Valley into Kagayan Flats terminating either in Beaver Bay or Left Hand Bay (Figure 4.31-2). The completed canal would be approximately 12.5 miles long by 1,200 ft wide with a minimum depth of 40 ft.

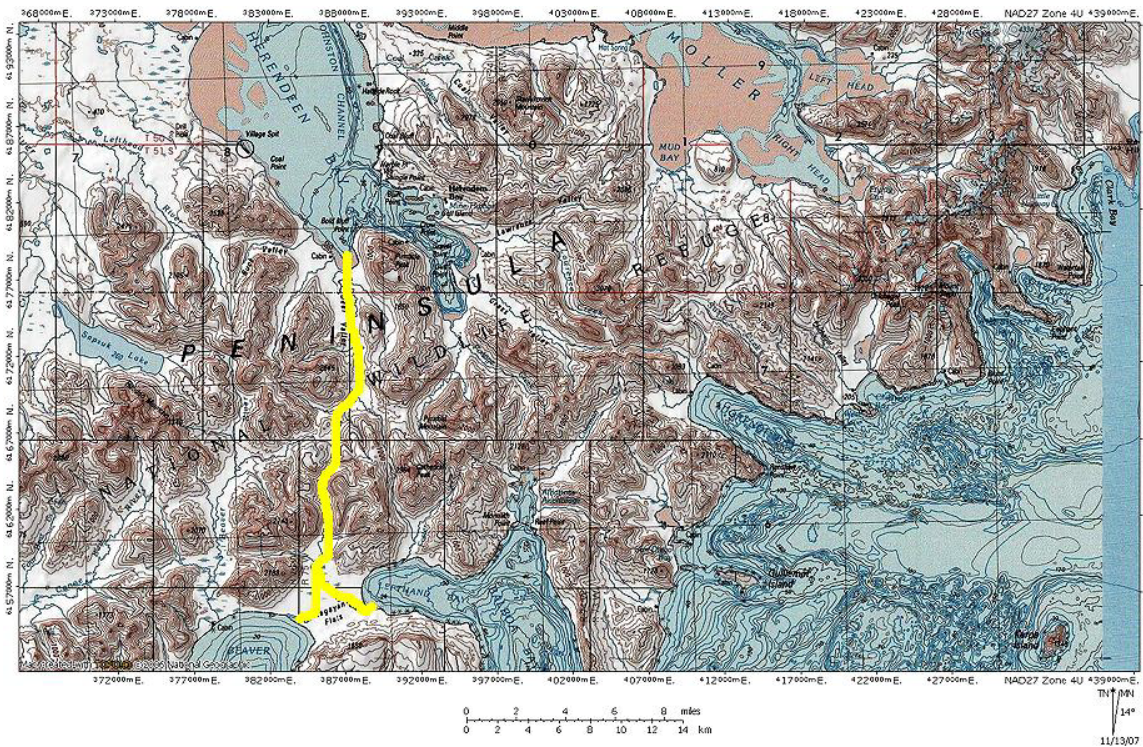


Figure 4.31-2. Proposed route (in yellow) for a canal across the Alaskan Peninsula (adapted from National Geographic Topographic Maps 2006).

The preliminary operational concept had limited distribution and there is no documentation to suggest what guidance, if any, was given by participating agencies or individuals, or if the project was considered for approval. There is also no documentation to suggest that any field activities were undertaken for the project. However, a University of California, Lawrence Radiation Laboratory report and an article in *Nuclear News*, both dating to 1963, briefly mention Port Moller as a sea-level canal project suitable for the Plowshare Program. Port Moller is also included in a list compiled by the U.S. Atomic

Energy Commission, Division of Peaceful Nuclear Explosives in 1964 as a “possible” nuclear excavation projects.

Port Moller Canal was a Level 5 activity. No known field activities were conducted.

## **CHRONOLOGICAL BIBLIOGRAPHY**

Anchorage Daily News, 1958. Atom Scientists Here Tell Plans to Blast Harbor. *Anchorage Daily News*, July 15. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.

Daily News Miner, 1958. Physicists Here for Discussion: Dam at Rampart, Harbors Along Arctic Possible. *Daily News Miner*, Vol. 36, July 16. Fairbanks, AK. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.

Daily News Miner, 1958. Alaska Can Have Massive Nuclear Engineering Job. *Daily News Miner*, July 17. Fairbanks, AK. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.

Jessen’s Weekly, 1958. Alaska Given First Chance on Nuclear Construction for Economic Development. *Jessen’s Weekly*, Vol. 17, No. 29, July 17. Fairbanks, AK. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.

Bacigalupi, C. M., 1958. “Preliminary Concept of Operation, Port Moller Canal.” Memo with encl. (Preliminary Operational Concept of the Test Director, manuscript) from C. M. Bacigalupi, Lawrence Radiation Laboratory, to Distribution, August 25. On file at: Archives and Records Office, Lawrence Berkeley National Laboratory, Berkeley, CA, File 434-900157, 2/18 [OUO].

Teller, Edward, 1963. Plowshare. University of California, Lawrence Radiation Laboratory, *Report UCRL-7222*, February 4. Livermore, CA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, file PLO-029.

Teller, Edward, 1963. Plowshare. *Nuclear News*, Vol. 6, No. 3, pp. 4-12, March. American Nuclear Society.

U.S. Atomic Energy Commission, 1964. Suggested Nuclear Excavation Projects and Possible Nuclear Excavation Projects, manuscript, Division of Peaceful Nuclear Explosives, July. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.

**THIS PAGE INTENTIONALLY LEFT BLANK**



## 4.32 RAMPART CANYON DAM

### **Plowshare Program Nuclear Excavation for Dam Construction and Quarry Alaska**

At a conference held at the University of Alaska in July 1958, Dr. Edward Teller from the Lawrence Radiation Laboratory discussed the opportunities of using nuclear energy for earth moving projects and the search by scientists from the Laboratory for a practical demonstration project in Alaska. One of the suggested projects, reported in a July 17, 1958 edition of the *Daily New Miner* and *Jessen's Weekly*, was to use nuclear explosives in the construction of a dam across the Yukon River at Rampart Canyon, a project that was already under consideration, using conventional means, by the U.S. Army Corps of Engineers, Alaska District. Five years later, the possibility of a nuclear explosive construction project at Rampart Canyon was mentioned in a February 1963 report published by the Lawrence Radiation Laboratory and again in a March 1963 *Nuclear News* publication by the American Nuclear Society. By 1964, the project was listed as a suggested nuclear excavation project on a document from the U.S. Atomic Energy Commission, and site selection for the project was underway.

Rampart Canyon, the proposed location for the Rampart Canyon Dam, is in the central plateau region of Alaska, 100 miles northwest of Fairbanks (Figure 4.32-1). The canyon is downriver from the Yukon Flats, a physiographic region characterized by extensive lowlands with meandering river channels. At Rampart Canyon the Yukon River flows through a more confined channel approximately 2,000 ft wide, narrowing to a channel 1,200 ft wide in the vicinity of the proposed dam. The general plan for using nuclear explosives to construct the dam was twofold. First, nuclear excavation techniques would be used to divert the river at the dam site and/or to excavate the spillway. Second, a nuclear excavated quarry would provide a source of material for the concrete aggregate, rock-fill, and riprap needed for construction of the dam. Available documentation is not clear concerning the excavation component for the project. In 1963, Teller proposed that nuclear explosives could be used to divert the Yukon River to an older river channel, south of and parallel to the current river channel. However, a 1964 document from the U.S. Atomic Energy Commission suggests that nuclear explosives would be used for excavation of the spillway through an abutment with an elevation of 635 ft. A feasibility study on the Rampart Canyon Dam and reservoir was completed by the U.S. Army Corps of Engineers, Alaska District, in 1965 but had limited distribution and a copy of the document has not been located.

In 1967, a student from University of Alaska used data from the 1965 Alaska District report as part of a Master's Degree Research Project for the University of Alaska. The research was a study of aggregate production methods for a dam at Rampart Canyon and compared the use of conventional versus nuclear quarrying methods to obtain aggregate and rip-rap for the dam. In the unpublished Alaska District report the site selected for the dam was at a narrowing of the canyon, approximately 25 miles southwest of the town of

Rampart, below the confluence of the Yukon River with Texas Creek (Figure 4.32-2). The nuclear quarry site was planned for a steep slope approximately four miles southwest of the dam site, a location where sloping terrain would facilitate post-shot downhill rock movement and subsequent operations of the quarry (Figure 4.32-3). The scheme called for detonation of a 100 kt nuclear device producing an estimated 43 million tons of rock aggregate, a quantity considered sufficient for the estimated 16,262,000 cubic yards required for construction of the dam. A cost analysis suggested that nuclear quarrying would save more than 26 million dollars over conventional methods. An updated version of the nuclear quarry study was issued in May 1967 as a feasibility study by the U.S. Army Corps of Engineers, Alaska District. According to a 1969 report by Bernard Hughes, the feasibility study (not available) recommended that production of aggregate by nuclear means be considered once Rampart Canyon Dam was authorized.



Figure 4.32-1. Proposed location for the Rampart Canyon project on the Yukon River in the Alaskan interior (adapted from USA Relief Maps 2004).

Once completed, the proposed Rampart Canyon Dam would inundate the Yukon Flats and create a reservoir 280 miles long with a shoreline of approximately 3,700 miles. The surface area of the reservoir would be about 10,500 square miles, an area slightly larger than Lake Erie. The dam was projected to have an installed capacity of 5 million kilowatts of power, twice the hydroelectric power generated at the Grand Coulee Dam in Washington. However, during the 1960s, the idea of building a dam at Rampart Canyon by any method was controversial. Building the dam was viewed by some as a reclamation project that would serve the energy needs for the economic development of the new state; however, there was strong opposition from conservationists and environmentalists concerned with the protection of wilderness area and habitat. The dam would also cause flooding of a number of villages of the region's indigenous populations and their primary

subsistence areas in the Yukon Flats. In a 1964 report, the U.S. Department of Fish and Wildlife stated their opposition to the project and by 1967 the U.S. Department of the Interior, Bureau of Reclamation, recommended that construction of a dam at Rampart Canyon be dropped from further consideration.

Rampart Canyon was a Level 5 activity. Activity was limited to conceptual design, background research, and possibly field visits.

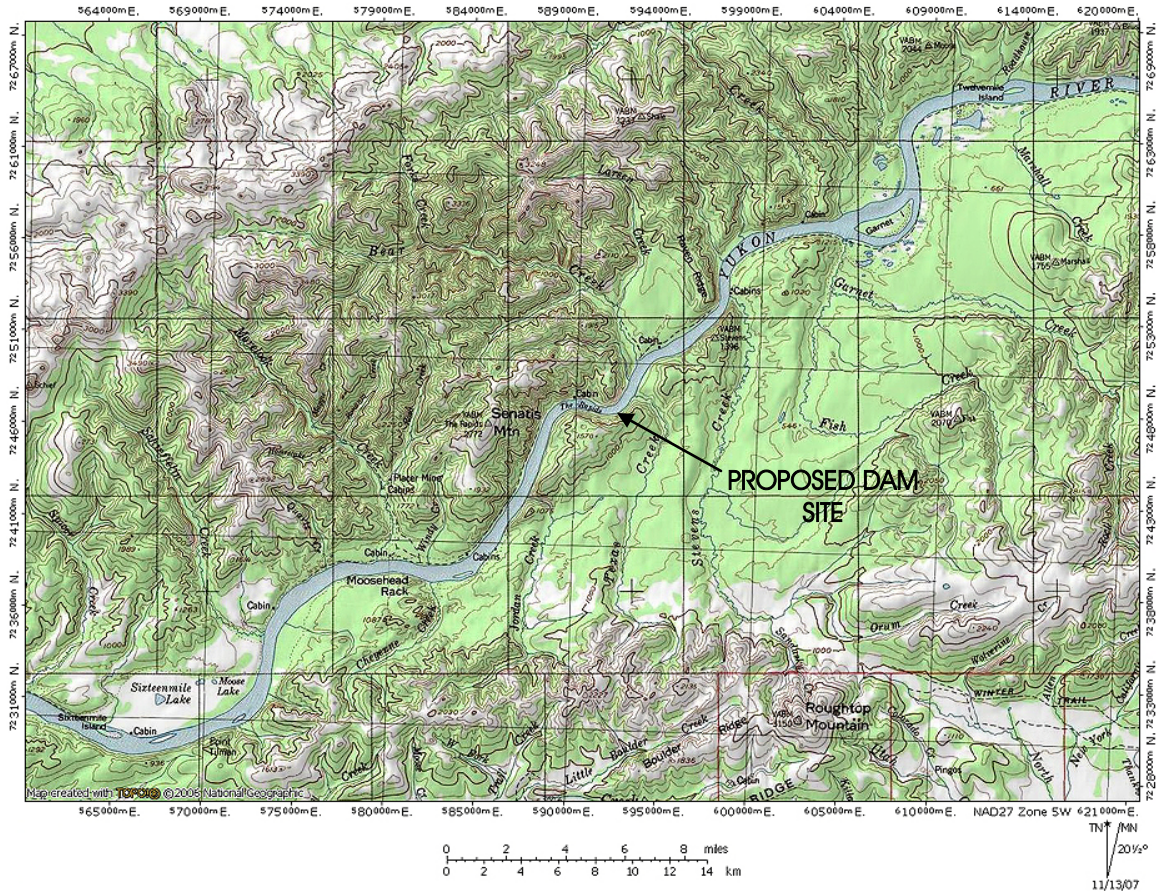


Figure 4.32-2. Location of the proposed Rampart Canyon Dam on the Yukon River (adapted from National Geographic Topographic Maps 2006).

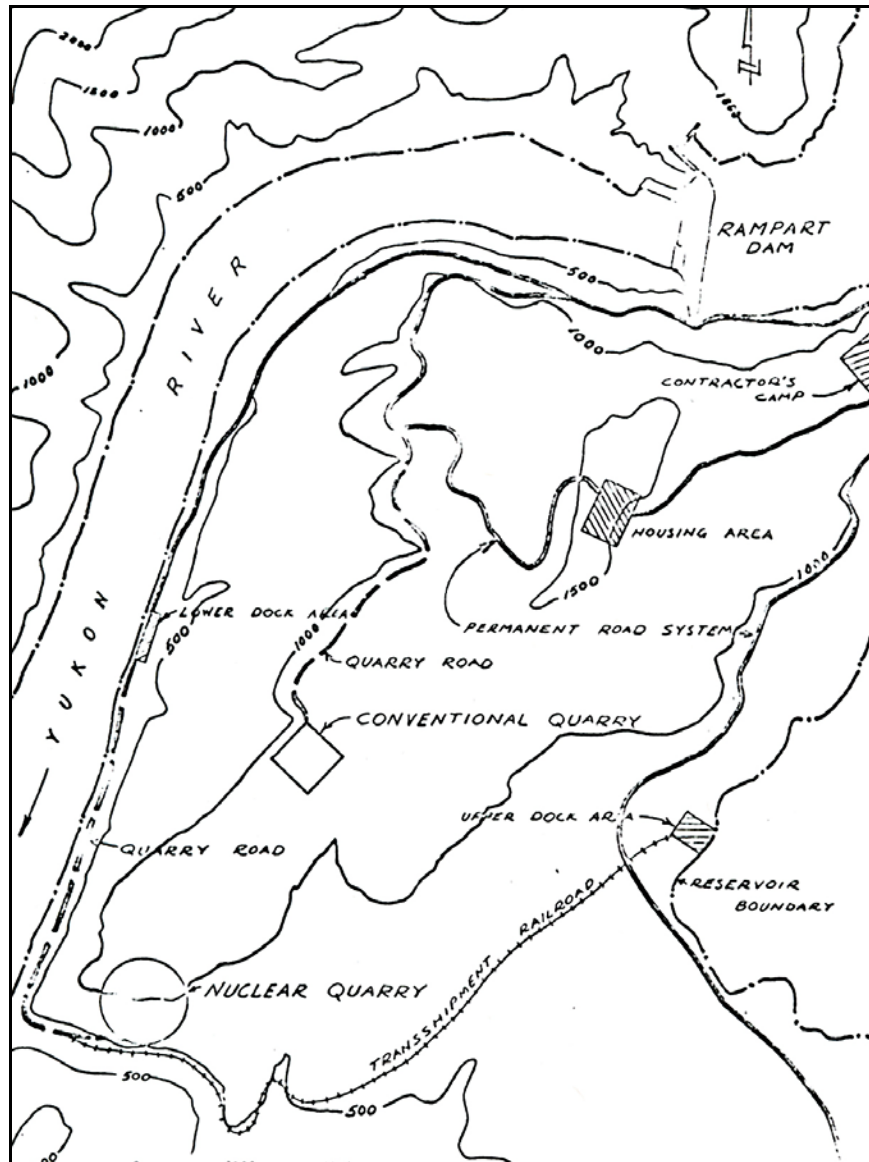


Figure 4.32-3. Proposed site plan for the dam and quarry area at Rampart Canyon (Ellis 1965, Figure B).

## CHRONOLOGICAL BIBLIOGRAPHY

Daily News Miner, 1958. Physicists Here For Discussion: Dam at Rampart, Harbors Along Arctic Possible. *Daily News Miner*, Vol. 36, July 16. Fairbanks, AK. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.

Daily News Miner, 1958. Alaska Can Have Massive Nuclear Engineering Job. *Daily News Miner*, July 17. Fairbanks, AK. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.

- Jessen's Weekly, 1958. Alaska Given First Chance on Nuclear Construction for Economic Development. *Jessen's Weekly*, Vol. 17, No. 29, July 17. Fairbanks, AK. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.
- Teller, Edward, 1963. Plowshare. University of California, Lawrence Radiation Laboratory *Report UCRL-7222*, February 4. Livermore, CA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.
- Teller, Edward, 1963. Plowshare. *Nuclear News*, Vol. 6, No. 3, pp. 4-12, March. American Nuclear Society.
- U.S. Atomic Energy Commission, 1964. Suggested Nuclear Excavation Projects and Possible Nuclear Excavation Projects. Manuscript, Division of Peaceful Nuclear Explosives, July. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, file PLO-030.
- Ellis, Earl P., 1965. Comparative Analysis of Aggregate Production Methods for Rampart Canyon Dam, Alaska. Manuscript, April. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-084.
- Kurtz, Maurice K., 1967. Letter from Maurice K. Kurtz, Jr., Lawrence Radiation Laboratory, U.S. Army Engineer Nuclear Cratering Group, to Glenn Werth, August 2. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029 [OUO].
- Lawrence Radiation Laboratory. U.S. Army Engineer Nuclear Cratering Group, 1968. Engineering Applications of Nuclear Explosives, Bi-Monthly Statistics of NCG Technical Reports, Memoranda, and Studies. Manuscript, February 15. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV.
- Hughes, Bernard C., 1969. History of the U.S. Army Engineer Nuclear Cratering Group, January. Lawrence Radiation Laboratory, January. Livermore, CA.
- Vortman, L. J., 1969. Nuclear Excavation. Report, SC-DC-69-1716, Underground Physics Division, Sandia Laboratories, Albuquerque, NM, March. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-104.
- Yanity, Brian, 2007. Alaska's Megaproject Mentality, part two; insurgent 49. <[http://www.insurgent49.com/yanity\\_megaproject\\_two.html](http://www.insurgent49.com/yanity_megaproject_two.html)>.

**THIS PAGE INTENTIONALLY LEFT BLANK**

## **4.33 RED LAKE GAS STORAGE**

### **Plowshare Program Nuclear Excavation for Underground Gas Storage Arizona**

Red Lake Gas Storage was a project concept initiated by the El Paso Natural Gas Company to use nuclear explosives to create underground storage for gas in northwestern Arizona (Figure 4.33-1). Beginning in the mid-1960s, the El Paso Natural Gas Company began investigating ideas for the economical storage of gas that would enhance supply in the vicinity of a crossover of two major east-west interstate transmission systems in Arizona, near the California boarder (Figure 4.33-2). Developing a storage facility in this area was economically attractive based on projections of future gas supply deficiency in relation to pipeline transmission capacity. Beginning in 1967, El Paso began conducting geologic investigations for an aquifer that could provide suitable underground storage; however, the effort was not successful and ended during 1968. During the winter of 1968-1969, El Paso conducted an economic study of gas storage alternatives and reached the conclusion that the use of nuclear explosives to create an underground storage cavity was economically favorable compared to constructing additional transmission facilities. The idea of constructing underground storage with nuclear explosives was a project concept that had received considerable attention by the U.S. Atomic Energy Commission's Division of Peaceful Nuclear Explosives, and had been explored for Project Ketch in Pennsylvania during the mid-1960s (see Chapter 4.22).

Concurrent with El Paso's economic studies for a gas storage project in Arizona, a geological formation outside of Phoenix was drilled for a brine well. Halite was encountered at 850 ft below the surface and, with financial assistance from El Paso, continued drilling revealed that the halite deposit extended beyond 4500 ft. The occurrence of a massive halite deposit suggested that similar salt formations might exist in the region. Geology was a key issue for the selection of a site for an underground gas storage facility, and a salt cavern of sufficient size and depth would provide a suitable formation for a gas storage project. By late 1969, El Paso had begun geophysical studies to locate a salt deposit for their project. The search included an investigation of valleys in the transmission crossover areas and eliminated population centers that would possibly be impacted by ground motion from nuclear detonations (Figure 4.33-3). By the end of the year, El Paso had selected four locations for additional study. These areas were Red Lake, Buck Mountain Wash, Bullard Wash, and Butler Valley (Figure 4.33-4).

On December 10, 1969, El Paso Natural Gas Company held a meeting with representatives from El Paso's Nuclear Group, Lawrence Radiation Laboratory, Sandia Laboratory, and the U.S. Atomic Energy Commission's Nevada Operations Office. El Paso participants presented their plan to proceed with developing a project that would use nuclear explosives to create an underground gas storage facility, a project that had management approval and budget commitment from El Paso. The plan called for a gas storage project that would create 150 million cubic ft of void space capable of storing 10

billion cubic ft at a pressure of about 1500 psi. The initial plan was to conduct geophysical exploration including drilling exploratory holes during the winter of 1969-1970 to provide data for finding a suitable site. A tentative schedule called for site selection by the summer of 1970. The first detonation was planned for early 1971, and completion of the project was scheduled for early 1972. El Paso's management had approved making formal contact with the U.S. Atomic Energy Commission in the near future and announced plans to submit a formal proposal once the site selection phase was completed.

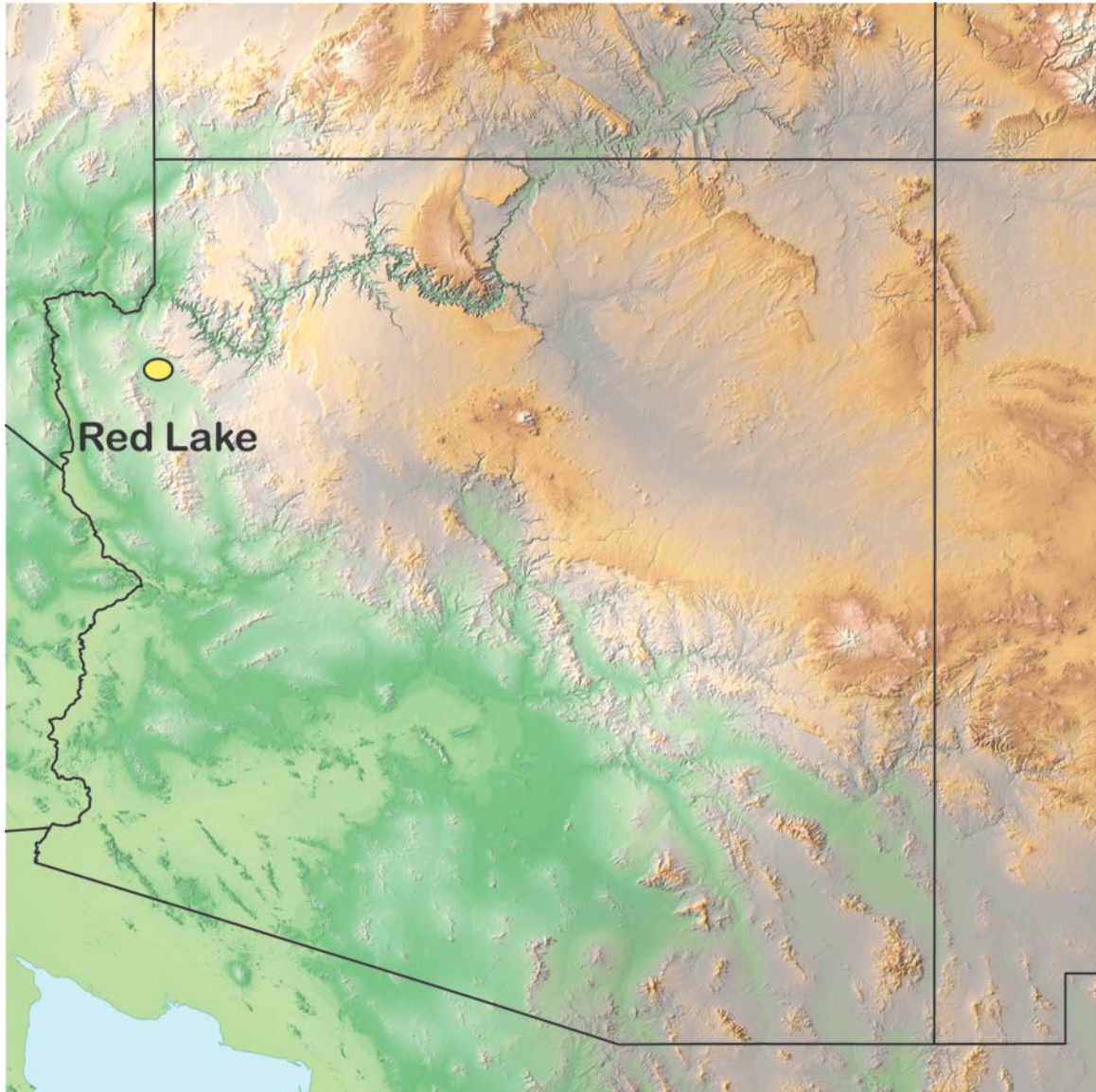


Figure 4.33-1. Map showing the general location of the proposed Red Lake Gas Storage project in northwestern Arizona (adapted from USA Relief Maps 2004).



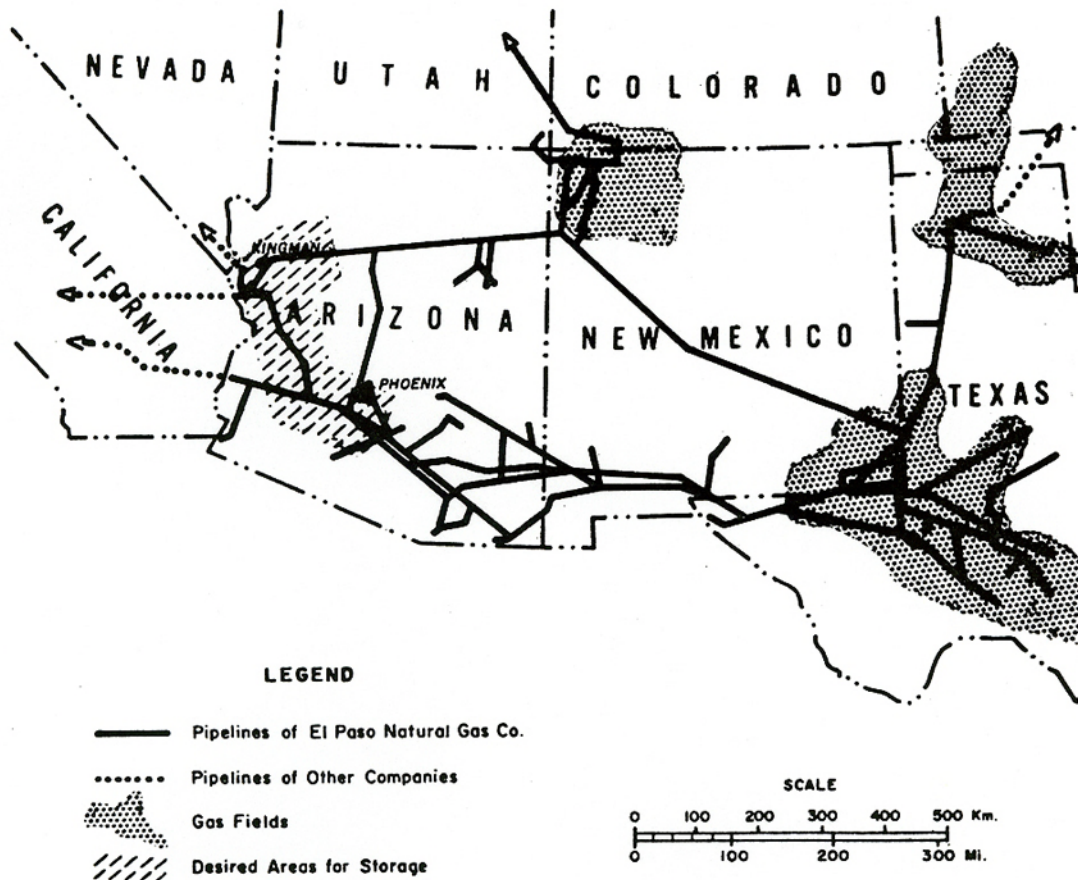


Figure 4.33-2. El Paso Natural Gas Company's interstate transmission system showing desired areas for underground gas storage (from Randolph 1970, Figure 1).

A November 1970 paper provides an overview of the gas storage project. The paper was prepared by the manager of El Paso's Nuclear Group, Philip Randolph, for presentation at meetings on the Peaceful Uses of Nuclear Explosives scheduled for January 1971. According to Randolph, results of the geophysical survey showed that only Bullard Wash and Red Lake had gravity minima that would suggest the occurrence of a salt deposit. Stratigraphic test wells were drilled at the two locations. The test well in Bullard Wash was located in Sec. 4, T10N R11N, in Yavapai County. Low density Tertiary deposits were encountered to a depth of 4,000 ft. The test well at Red Lake, Sec. 21, T26N R16W, in Hualapai Valley, north of Kingman, Arizona, revealed massive halite deposits at a depth of 1,786 ft continuing past 5,984 ft. Red Lake appeared to provide a suitable geologic medium and was considered an attractive location for a gas storage facility, a facility that would provide reliable service to an economic market in the southwest. The El Paso Natural Gas Company considered the project to be economically feasible if it could be completed in the desired time frame. Determining the precise location for the Red Lake project was contingent on seismic studies to evaluate the lateral extent of the deposit and negotiations to procure mineral and surface rights.

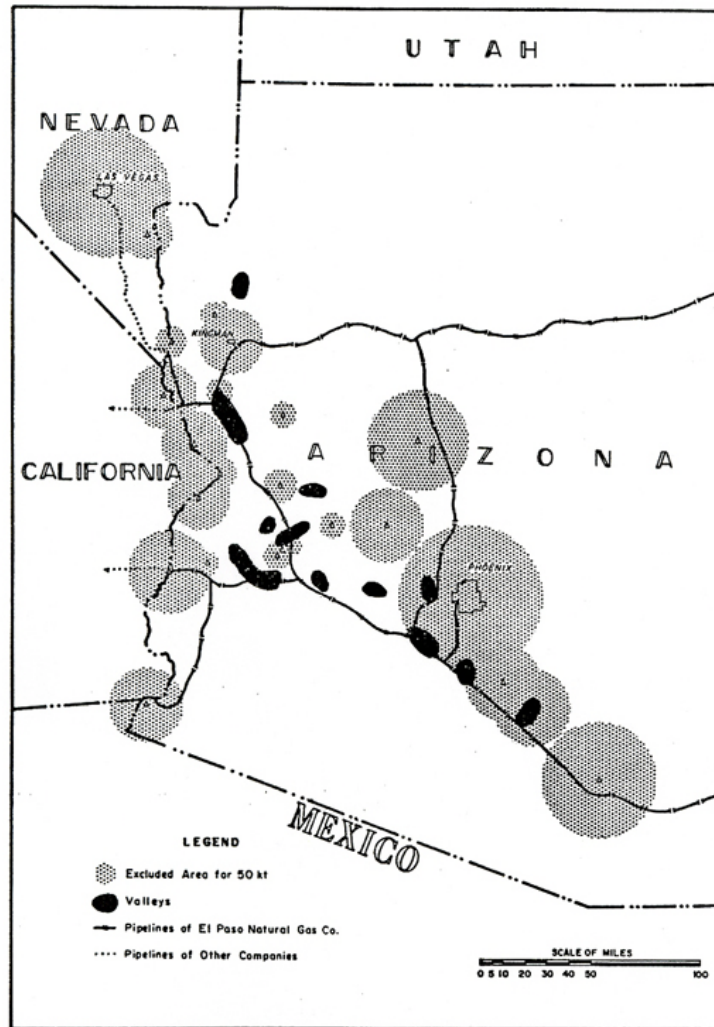


Figure 4.33-3. Map showing valleys investigated for gas storage project and populated areas excluded from consideration because of potential ground motion effects of a 50 kt detonation (Randolph 1970, Figure 3).

By December 1970, scientists from Lawrence Radiation Laboratory had completed an evaluation concerning residual elements (in particular levels of tritium and sulfur) that would occur in a cavity created by a nuclear explosion in the Red Lake salt formation. The analysis was based on data from the Red Lake test core from 4,000- -5,100 ft. This analysis recommended that the cost of flushing the cavity to remove gaseous radioactivity should be included in an economic feasibility study for the project. A June 1971 paper titled "Status of Contained Nuclear Explosive Applications" mentions that El Paso was undergoing negotiations for acquiring land rights and once obtained the project would proceed. However, there is no documentation available to indicate what became of El Paso's gas storage plan, and it appears that a formal request for the project was never submitted to the U.S. Atomic Energy Commission. Yet, the Red Lake location continued

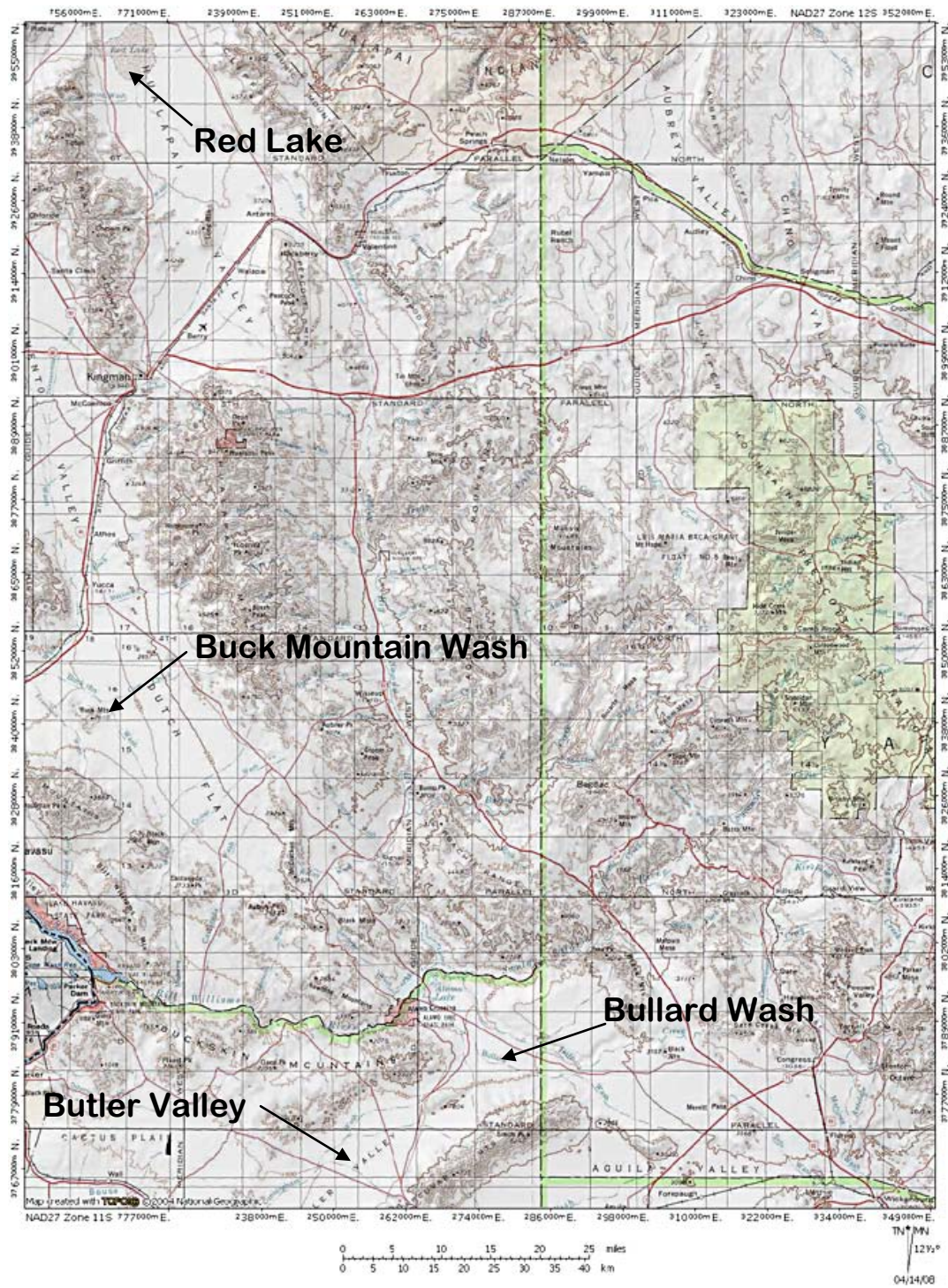


Figure 4.33-4. Four locations selected by El Paso Natural Gas Company for additional study for an underground gas storage project (adapted from National Geographic Topographic Maps 2006).

to be studied for underground natural gas storage, but formed by solution mining rather than nuclear detonation. In 2002, Aquila, Inc. based in Kansas City, Missouri, purchased the Red Lake Gas Storage Project from Southwest Gas Corporation in Las Vegas, Nevada, including the rights to develop a salt cavern facility. However, the project failed in 2004 after the Federal Energy Regulatory Commission denied the project market-based rate authority.

Red Lake Gas Storage was a Level 4 activity. Research by Lawrence Radiation Laboratory was confined to existing data from a test well drilled by El Paso Natural Gas Company in the Red Lake salt formation.

### **CHRONOLOGICAL BIBLIOGRAPHY**

Cohen, Gerald D., and Francis M. Sand, 1967. Water Resource Applications, Underground Storage of Natural Gas, and Waste Disposal Using Underground Nuclear Explosions. *Mathematica*, August 31. Princeton, New Jersey. U.S. Atomic Energy Commission, Report PNE 3008. Washington, D.C. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV and Defense Threat Reduction Information Center, Albuquerque, NM.

Holzer, Fred, 1969. "El Paso Natural Gas Company Plans for a Nuclear Gas Storage Project." Memo from Fred Holzer, Lawrence Radiation Laboratory, to Glenn C. Werth, December 11. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-093.

Evans, Roy B., and David E. Bernhardt, 1970. "Probable Scheduling of Plowshare Events." Memo from Roy B. Evans and David E. Bernhardt, U.S. Department of Health, Education, and Welfare, Southwestern Radiological Health Laboratory, to Francis N. Buck, May 8. On file at Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0173142 [OUO].

Randolph, Philip L., 1970. Gas Storage Application of Peaceful Nuclear Explosions. Paper for presentation at the IAEA Panel on the Peaceful Uses of Nuclear Explosives, January 18-21, 1971. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-095.

Bedford, R. G., 1970. "Estimation of the Disposition of Tritium and Sulfur ( $S^{35}$ ) in a Cavity Created By a Nuclear Explosion in Salt." Memo from R. G. Bedford to R. W. Taylor, December 1. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-107.

Werth, Glenn C., 1971. Status of Contained Nuclear Explosive Applications. University of California, Lawrence Radiation Laboratory, *Report UCRL-51074*, June 21. Livermore, CA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-103.

Federal Energy Regulatory Commission, 2004. Current State of and Issues Concerning Underground Natural Gas Storage. Staff Report, Docket No. AD04-11-000, September 30.

**THIS PAGE INTENTIONALLY LEFT BLANK**

## **4.34 SAN CLEMENTE ISLAND**

### **Plowshare Program Development of Underground Aquifer Using Nuclear Explosives California**

The application of nuclear explosive technology for water conservation projects was an early area of inquiry by scientists from the Plowshare Program. In 1958, the Lawrence Radiation Laboratory began considering San Clemente Island as a possible site for a nuclear experiment to develop an underground aquifer (Figure 4.34-1). The island had intermittent water sources, and the water supply was dependent on precipitation and the water balance of selected watersheds, sources that were inadequate for water needs.

A memo dating to January 1959 shows that Lawrence Radiation Laboratory subcontracted Stanford Research Institute to investigate the feasibility of establishing a fresh water supply utilizing rainfall on San Clemente Island. While the study of the hydrology of San Clemente Island was ongoing, meetings were held at the Lawrence Radiation Laboratory on March 4 and June 12, 1959, to discuss possible experimental aquifer projects using nuclear excavation technology. Attendees included representatives from Lawrence Radiation Laboratory, U.S. Geological Survey, California Department of Water Resources, Stanford Research Institute, Stanford University. Four potential sites for an aquifer experiment were identified. These were San Clemente and San Nicholas Islands, California; the Dakota Sandstone formation in the eastern Great Plains; Wendover Air Force Base, Utah; and the Hunter-Liggett Reservation, California. A July 1959 memo shows that a project agreement (Project Agreement No. 14) was being considered for Stanford Research Institute to undertake a site selection study for a Plowshare aquifer study. The proposal called for a comprehensive literature search to obtain data on the geology and hydrology of the above mentioned sites. However, there is no documentation indicating that the site selection study was conducted.

On August 1, 1959, the Stanford Research Institute issued a report on the hydrology of San Clemente Island based on data collected from December 1958 to May 1959. The objectives of the study were to learn about the hydrological cycle of the island and to obtain geologic data to augment the hydrological findings in order to provide information to evaluate San Clemente Island for a Plowshare aquifer experiment. Two drainage basins on the island were selected for study (Figure 4.34-2). Hydrological measurements were made of precipitation, evaporation, and runoff to provide baseline data about the water balance of the selected watersheds. Data were also collected on soil moisture and infiltration rates as well as geology of the island. Over the duration of the study precipitation was below normal; thus, the report suggested that hydrologic measurements continue over the wet season of 1959-1960. More data were also needed about surface and subsurface geology if San Clemente was to be considered for an aquifer experiment. To this end, the report recommended a comprehensive drilling program.



Figure 4.34-1. Location of the proposed San Clemente Island aquifer project (adapted from USA Relief Maps 2004).

In October 1959 Lawrence Radiation Laboratory published a report on the hydroclimatology and surface hydrology of San Clemente Island with a focus on evaluating San Clemente Island for a Plowshare aquifer project. The study was based on data collected during the 1958 through 1959 wet season and data from neighboring weather stations in a similar geographic context with a long record. The project concept for San Clemente Island was to use nuclear explosives to create an underground reservoir to capture and store rainwater to make available a supply of fresh water on the island. In addition, the experiment would generate basic data pertaining to 1) the effect of nuclear explosions on porosity and permeability in andesite, 2) the crushing and caving characteristics of this medium in response to a nuclear explosion, and 3) potential



radioactive contamination of andesite. An aquifer experiment on San Clemente would also provide baseline data for other aquifer development projects throughout the U.S. and abroad. San Clemente Island was favorable from a safety standpoint as the island was sufficiently isolated, controlled by the military, and government owned. The report concluded that hydrologic conditions on San Clemente were appropriate for construction of a local water supply and if the subsurface conditions were favorable the island would be an appropriate site for a nuclear experiment. However, additional geologic data would be needed to conduct studies of geohydrologic models to determine the technological feasibility of the project.

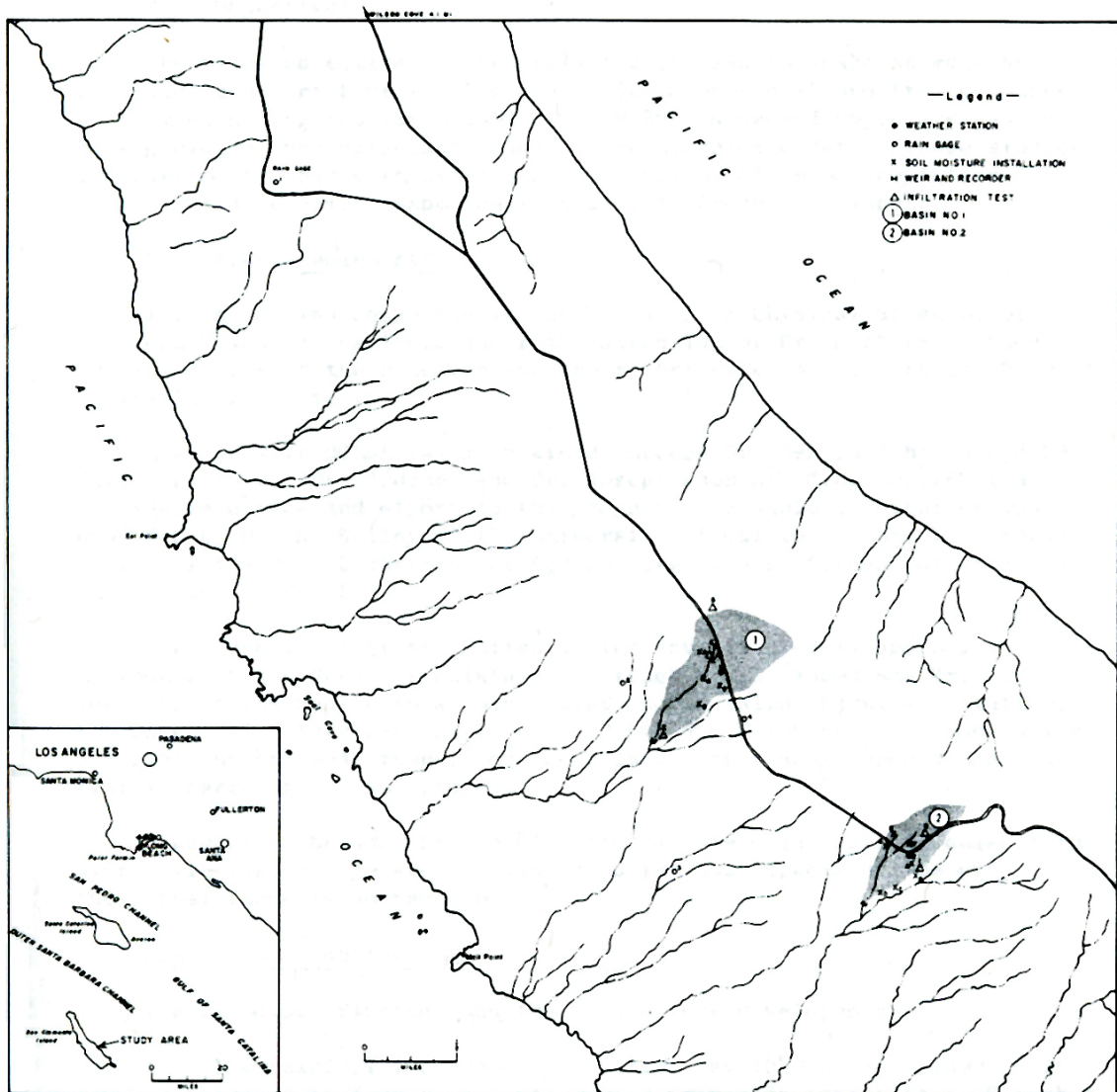


Figure 4.34-2. Map showing the location of two basins selected to study the island hydrology (Hall 1959, Figure 1).

During 1959, Stanford Research Institute conducted supplementary geological studies. Specifically, under Project Agreement No. 19, a study was undertaken from September to November 1959, to determine what geologic and hydrologic information would be necessary to make an evaluation for San Clemente Island as a potential site for development of an underground aquifer using nuclear construction techniques. Recommendations from a December 1959 report were similar to previous reports suggesting the need for a detailed geological mapping program to identify rock types and fault zones, and a comprehensive drilling program to investigate subsurface geology. However, it is unknown if any of these additional studies were ever undertaken. The final document available that discusses an aquifer experiment on the island, dated February 1960, is a request to approve an extension for the initial hydrologic measurement program through August 1959, a request for work that had already been completed.

San Clemente was a Level 5 or Level 4 activity. Most of the activity for this project was based on the collection of geological and hydrological data that likely involved minimal ground disturbing activity. There is no documentation to suggest that the proposed drilling program was implemented.

#### **CHRONOLOGICAL BIBLIOGRAPHY**

Blue, C. L., 1959. "Stanford Research Institute - Subcontract 122, Project Agreement No. 5." Letter with encls. (letter from James H. Banistar, Stanford Research Institute, to C. L. Blue, January 9; letter from Richard M. Foose to Gerald Johnson, January 8) from C. L. Blue, Lawrence Radiation Laboratory, to W. B. Reynolds, January 14. On file at: Archives and Records Office, Lawrence Berkeley National Laboratory, Berkeley, CA, File 434-900157, 4/18.

Douglass, W. D., 1959. "Project Agreement No. 5 to Subcontract 122 with SRI." Memo from W. D. Douglass to C. L. Blue, January 19. On file at: Archives and Records Office, Lawrence Berkeley National Laboratory, Berkeley, CA, File 434-900157, 4/18.

Blue, C. L., 1959. "Subcontract 122 - Stanford Research Institute, Proposed Project Agreement No. 14, Aquifer Site Selection Study." Memo with encl. (letter from Richard M. Foose, Stanford Research Institute, to Gerald W. Johnson, July 6; letter from A. Pohlmeyer, Stanford Research Institute, to Gerald W. Johnson, July 6) from C. L. Blue to W. B. Reynolds, July 29. On file at: Archives and Records Office, Lawrence Berkeley National Laboratory, Berkeley, CA, File 434-900157, 4/18, 40285.

Hall, Francis R., 1959. Hydrology of Selected Areas on San Clemente Island, California. Report to University of California, Lawrence Radiation Laboratory, Livermore, CA, from Stanford Research Institute (SRI Project No. SD-2775), Menlo Park, CA, August 1.

Regents of the University of California, 1959. "Subcontract 122, Project Agreement No. 19." Contract between Regents of the University of California and Stanford Research Institute, August 21. On file at: Archives and Records Office, Lawrence Berkeley National Laboratory, Berkeley, CA, File 434-900157, 4/18.

Knox, Joseph, B., and Harlan Zodtner, 1959. Hydroclimatology and Surface Hydrology of San Clemente Island. University of California, Lawrence Radiation Laboratory, *Report UCRL-5709*, October 12. Livermore, CA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-109.

Hall, Francis R., and Bernard J. O'Neill, Jr., 1959. Geohydrologic and Geologic Observations of a Portion of San Clemente Island, California. Report to University of California, Lawrence Radiation Laboratory, from Stanford Research Institute (SRI Project No. SD-3005), Menlo Park, CA, December 15. On file at: Technical Reports Library, Lawrence Livermore National Laboratory, Livermore, CA.

Blue, C. L., 1960. "Project Agreement No. 5, Subcontract 122." Memo from C. L. Blue, Lawrence Radiation Laboratory, to W. B. Reynolds, February 3. On file at: Archives and Records Office, Lawrence Berkeley National Laboratory, Berkeley, CA, File 434-900157, 7/18.

**THIS PAGE INTENTIONALLY LEFT BLANK**

## 4.35 SAND

### **Vela Uniform Program Nuclear Explosive Seismic Monitoring Experiment Mississippi and Texas**

Sand was a nuclear explosive seismic experiment planned under the Dribble Program. The experiment was initially planned for the Tatum Salt Dome in Mississippi, but after engineering difficulties were encountered a different location, the Hockley Salt Dome in Texas, was considered (Figure 4.35-1).

The Dribble program, or Project Dribble (originally named Ripple), was established in early 1960 as a joint Advanced Research Projects Agency and U.S. Atomic Energy Commission program to study decoupling using nuclear explosives. Decoupling was based on the theory that a detonation in a large underground cavity would decrease the seismic force of an underground explosion. Previously, there had been success testing this theory with high explosive experiments (see Cowboy – Chapter 3.1); however, several questions could not be addressed by the high explosive program alone and the nuclear explosive program was initiated. A salt dome was selected as a suitable geologic medium for the Dribble program because of a number of favorable attributes, namely, relatively homogenous and massive formations, elasticity, and soft consistency for construction of underground cavities. The selection of the Tatum Salt Dome was based on a U.S. Bureau of Mines survey in 1959 of all possible suitable salt domes, salt beds, and operating salt mines in Colorado, Utah, and the Gulf Coast. Tatum Salt Dome is in Lamar County, Mississippi, 130 miles northeast of New Orleans, Louisiana, and 33 miles southwest of Hattiesburg, Mississippi.

A series of six nuclear tests were planned in the original program for Dribble and outlined in a November 1960 program concept document, but the project was suspended after the exploratory drilling phase when nuclear weapons testing resumed in September 1961. Later Project Dribble was reactivated and a revised technical concept was issued by the Lawrence Radiation Laboratory on September 10, 1962. The revised concept had significant changes that simplified the program. The primary objectives of the program were to infer the significance of decoupling at the 5 kt level and to study seismic wave propagation in the earth's mantle as a result of a nuclear explosion. With a decoupled emplacement a nuclear device would be set apart from the surrounding earth. In this case, the device would be emplaced in the center of a cavity mined in salt. Previously, underground nuclear explosions were in tamped (coupled) emplacements in tunnels and drill holes and fired in as small a shot chamber as possible.

To meet the objectives of Project Dribble, the 1962 technical concept outlined the specific objectives for three seismic experiments. The experiments were: 1) a 100 ton decoupled explosion, 2) a 5 kt tamped explosion, and 3) a 100 ton tamped explosion. In a March 1963 University of California *UCRL Report* on the status of Project Dribble, the three planned explosions are referred to as Salmon (5 kt tamped), Sand (100 ton

decoupled), and Tar (100 ton tamped) and the locations shown on a plan map (Figure 4.35-2).

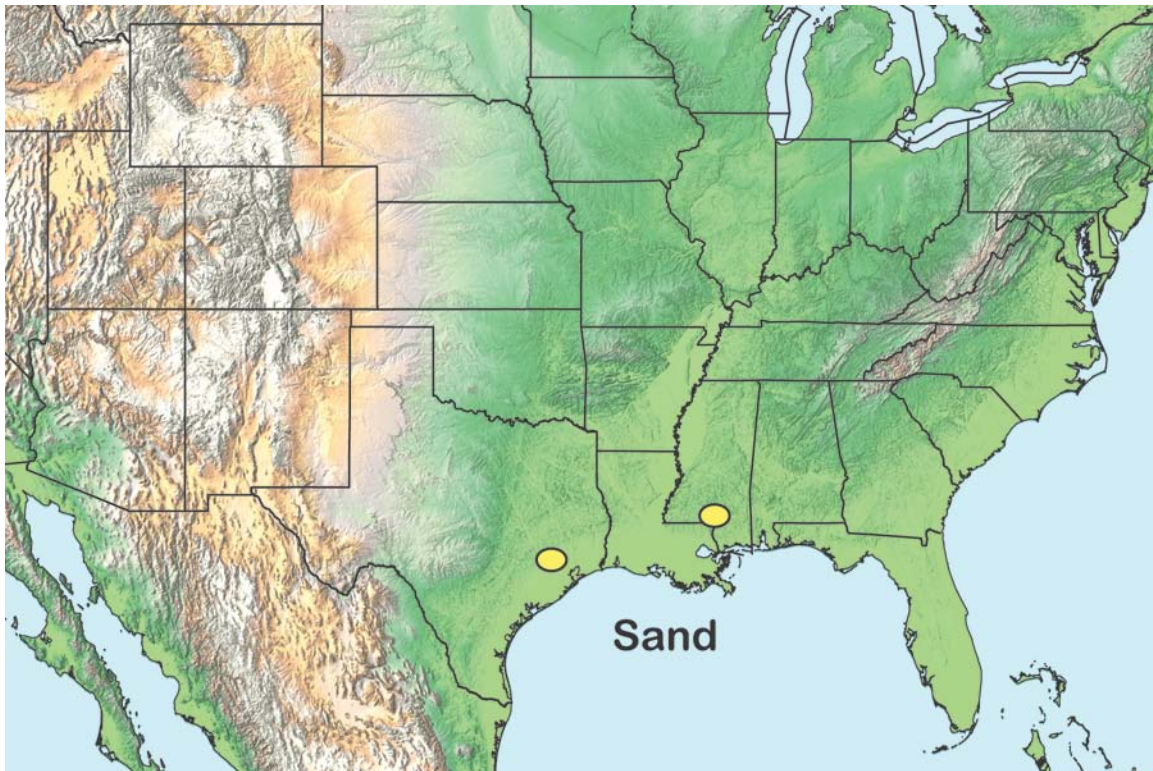


Figure 4.35-1. Two proposed locations for the Sand nuclear explosive seismic monitoring experiment (adapted from USA Relief Maps 2004).

Sand, the second task of Project Dribble, was planned as a decoupling experiment in the center of a large excavated spherical cavity. The proposal called for detonation of a 100 ton device in a 95 ft diameter cavity. Conducting the experiment at a 100 ton yield rather than some larger yield was considered more straightforward from a construction standpoint as it did not require as massive of a cavity. Construction of the underground cavity for Sand would require excavation of 18,000 cubic yards with a geometric center point at approximately 2,000 ft below the surface (Figure 4.35-3). By extrapolation, data from Sand would be used to deduce the probable decoupling or seismic signal reduction for a 5 kt device. By late 1963, drilling for Sand was underway at Station 3 on the Tatum Salt Dome when technical problems were encountered. The problem was that underground water was flowing into the shafts drilled into the salt deposit, and efforts to seal the shafts with cement grout failed. At the request of the U.S. Atomic Energy Commission, Nevada Operations Office a report was prepared by Fenix & Scisson summarizing the drilling operation. The report was submitted in January 1964. The Sand project was postponed because Station 3 was abandoned due to flooding and the cost of completing facilities for Sand at the Tatum location was substantially more than originally estimated.

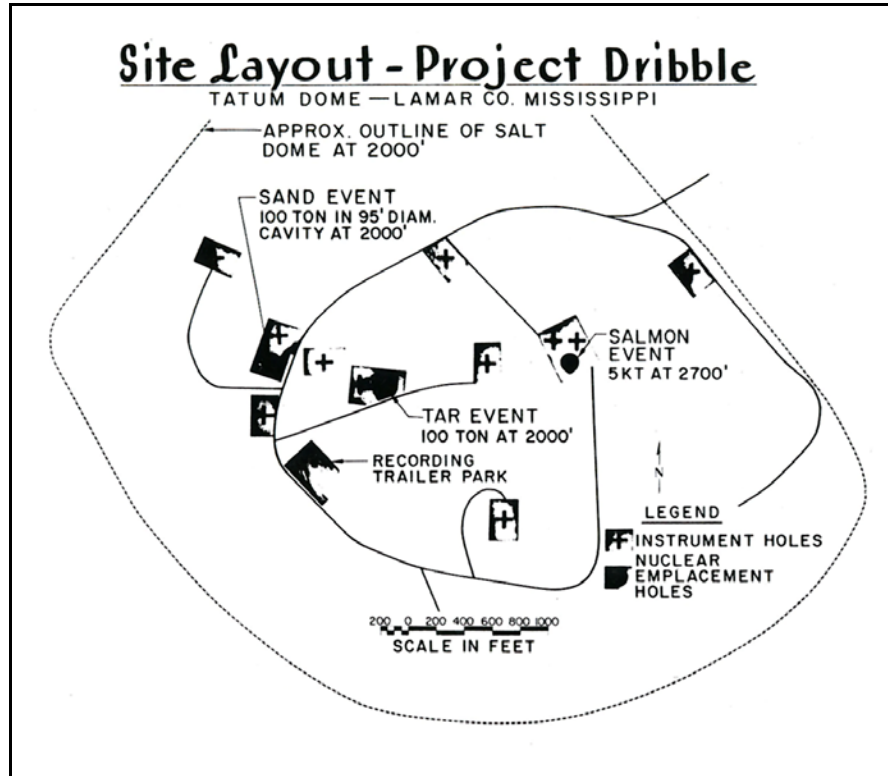


Figure 4.35-2. Project Dribble site plan showing location for Sand, Tar and Salmon at the Tatum Dome (Werth and Randolph 1963, no figure number).

Authorization was given by the Director of the Division of Military Applications to study the Hockley Mine in the Hockley Salt Dome as an alternate location for Sand during December 1963. The Hockley Salt Dome was a formation previously reviewed by the U.S. Bureau of Mines and is located south of Hockley in Harris County, Texas, approximately 35 miles northwest of Houston. The United Salt Company owned a mine in the north central portion of the dome, and the existing mine shaft provided access to the salt core.

In May 1964, a conceptual engineering and construction plan was issued by the U.S. Atomic Energy Commission, Nevada Operations Office, as well as a report entitled "Re-Evaluation of the Hockley Site, Project Dribble." Construction for Sand at the Hockley site required building a cavity 95 ft in diameter, 2,050 ft below ground level. Use of the mine shaft was planned as an entry point for drilling the cavity (Figure 4.35-4). A new shaft from the 1,650 ft level in the existing mine shaft would be drilled for the emplacement at 2,050 ft. The plan also called for drilling a post-shot hole 2,000 ft deep. Additional drill holes were needed for instruments, ventilation, and hydrology studies. Engineering services and drilling and mining for Sand would be accomplished by Fenix & Scisson and Petroleum Consultants, Holmes & Narver would be responsible for the

engineering services for surface facilities. Ground water safety would be evaluated by the U.S. Geological Survey and Hazleton-Nuclear Services. The Lawrence Radiation Laboratory concluded that the criteria for the technical objectives of Project Dribble could be met at the Hockley location and the salt mine was an acceptable alternative to the Tatum Salt Dome (see also Tar – Chapter 4.42).

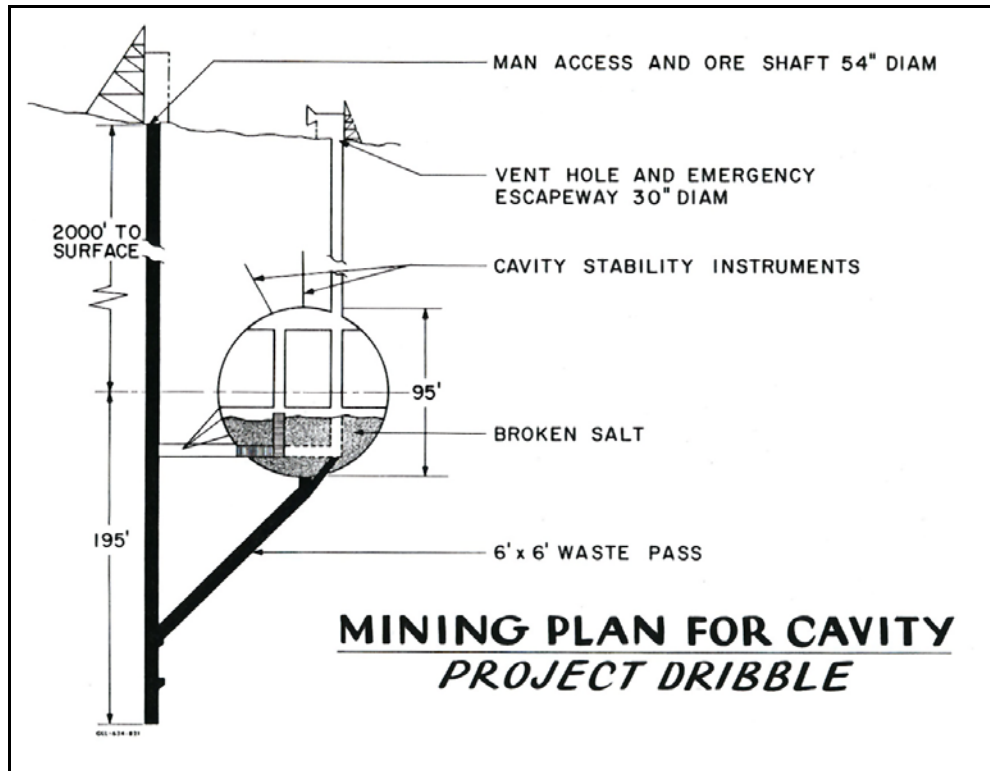


Figure 4.35-3. Diagram of the mining plan for the Sand decoupling study at the Tatum Salt Dome (Werth and Randolph 1963, no figure number).

Concurrent with the evaluation of the Hockley site for the Sand seismic study, engineering studies were underway at the Tatum Dome to investigate drilling strategies for the emplacement location for Sand at Station 3A, after Station 3 had been abandoned due to flooding. According to a report issued on May 13, 1964, to the U.S. Atomic Energy Commission, Nevada Operations Office, a major problem for construction of acceptable emplacement facilities was sealing against water entry. The drilling plan recommended using conventional drilling methods to drill two 54-inch holes for the access and ventilations shafts (Figure 4.35-5). The holes would be cased to a depth of 1,930 ft, beyond which the holes would be drilled with a 53 inch bit to a depth of 2,150 ft. Once the shafts were completed a cavity with a diameter of 47.5 ft would be mined. To prevent water entry into the shaft and cavity, the shafts would need a barrier of at least 100 ft from any unsealed drill hole.



After the revised drilling plan for Sand at the Tatum Salt Dome was submitted there is little mention of conducting the decoupling study. Documentation that is available suggests that the three planned tests for Project Dribble would take place at the Tatum Salt Dome; however, an August 1, 1964, report on Project Dribble states that construction of facilities for Sand had not been authorized. Of the documents available, those with a date later than August 1964 do not mention the proposed Sand or Tar detonations.

The Project Dribble Salmon nuclear test was conducted on October 22, 1964, at the Tatum Salt Dome. On December 3, 1966, Project Sterling, a 380 ton decoupled nuclear detonation, was conducted in the Salmon cavity. The non-nuclear Miracle Play Program (detonable gas explosions) was conducted in the Salmon cavity in 1969 and 1970. The Tatum Dome, also referred to as the Salmon Site, is one of the nine nuclear off-site locations currently monitored as part of the U.S. Department of Energy's Long-Term Stewardship Program.

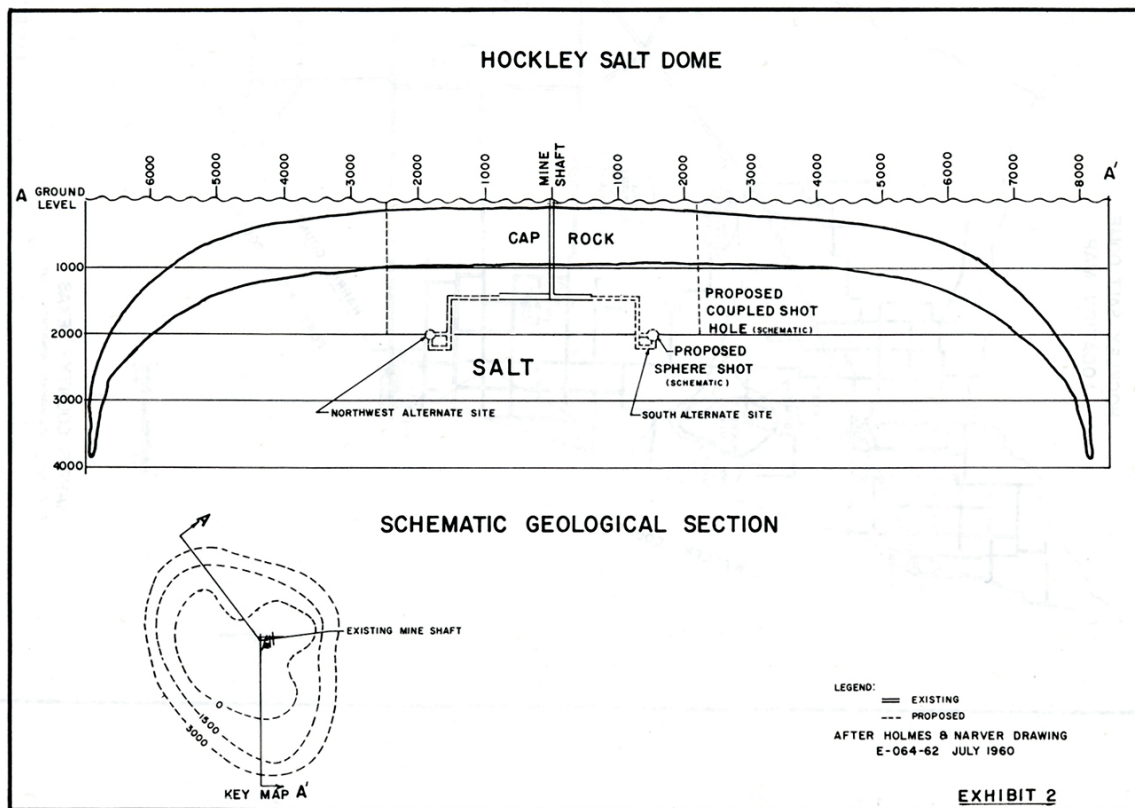


Figure 4.35-4. Schematic section showing the alternate locations for the Sand decoupled experiment (sphere shot) and the Tar coupled experiment at the Hockley Salt Dome (U.S. Atomic Energy Commission. Nevada Operations Office 1964b).

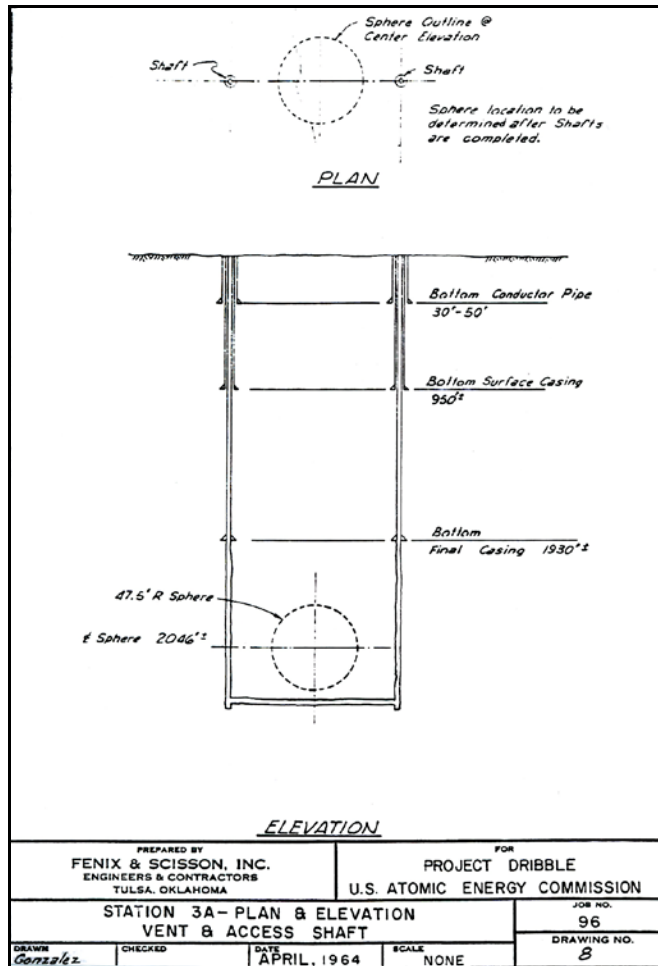


Figure 4.35-5. Revised drilling plan for the Sand drill hole at the Tatum Salt Dome (Fenix & Scisson, Inc. 1964, Drawing No. 8).

The Tatum Salt Dome is monitored by the Department of Energy. The project was a Level 4 activity for the Hockley Salt Mine, where a pre-existing mine shaft was planned for access to construct the Sand cavity and for geological studies.

### CHRONOLOGICAL BIBLIOGRAPHY

Lawrence Radiation Laboratory, 1962. LRL Technical Concept, Project Dribble, September 10, 1962. Manuscript, Lawrence Radiation Laboratory, September 10. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-013.

- Werth, Glenn C., and Phillip Randolph, 1963. Prepared Statement on the Theory of Decoupling and the Status of Project Dribble, for the Joint Committee on Atomic Energy, Congress of the United States. University of California, Lawrence Radiation Laboratory, *Report UCRL-7323*, March 6. Livermore, CA. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV.
- Fenix & Scisson, Inc., and Petroleum Consultants, 1964. Project Dribble, Critical Hole Summary, Tatum Dome, Lamar County, Mississippi. Report to U.S. Atomic Energy Commission, Nevada Operations Office, from Fenix & Scisson, Inc. and Petroleum Consultants, Tulsa, OK and Houston, TX, January. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV.
- U.S. Atomic Energy Commission, 1964. "AEC Seeks Bids on Drilling for Project Dribble in Mississippi." Press Release from U.S. Atomic Energy Commission, January 16. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.
- Lawrence Radiation Laboratory, 1964. "Unclassified TWX MA: 358-1, Betts to Reeves, Info R. E. Batzel, dated 12/24/63." Letter from Lawrence Radiation Laboratory to Brigadier General Delmar Crowson, February 24. On file at: Lawrence Berkeley National Laboratory, Berkeley, CA, File 434-900205, 5/48.
- Holmes & Narver, Inc., 1964. Dribble Composite Plan. Report to U.S. Atomic Energy Commission, Nevada Operations Office, from Holmes & Narver, Inc., Las Vegas, NV, May. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV.
- U.S. Atomic Energy Commission. Nevada Operations Office, 1964a. Conceptual Engineering and Construction Plan for Tar and Sand Events at Hockley Salt Dome, Project Dribble. Manuscript, U.S. Atomic Energy Commission, May. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV.
- U.S. Atomic Energy Commission. Nevada Operations Office, 1964b. Re-Evaluation of the Hockley Site, Project Dribble. Manuscript, U.S. Department of Energy, May. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV.
- Fenix & Scisson, Inc., 1964. A Report on Engineering Studies to Provide Station 3A, Project Dribble. Report to U.S. Atomic Energy Commission from Fenix & Scisson, Inc. Tulsa, OK; and Petroleum Consultants, Houston, TX, May 13. On file at: Technical Reports Library, Lawrence Livermore National Laboratory, Livermore, CA.

- Seaborg, Glenn T., 1964. Letter from Glenn T. Seaborg, U.S. Atomic Energy Commission, to The President (Lyndon B. Johnson), May 30. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Las Vegas, NV, Accession No. 0075430.
- Patterson, Dan W., 1964. Theory of Nuclear Explosion in a Cavity Including the Effects of Shock and Nonelastic Effects on the Wall and Comparison with Tamped Explosions - Project Dribble. University of California, Lawrence Radiation Laboratory, *Report UCRL-7916*, June 8. Livermore, CA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-012 and PLO-029.
- Lawrence Radiation Laboratory, 1964. Technical Director's Operations Plan, Project Dribble, Salmon Event, July 1964. Manuscript, Lawrence Radiation Laboratory, Livermore, CA.
- U.S. Atomic Energy Commission. Nevada Operations Office, 1964c. Project Dribble Facilities and Support Execution. Manuscript, U.S. Department of Energy, Las Vegas, NV, July. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV.
- U.S. Department of Defense and U.S. Atomic Energy Commission, 1964. Project Dribble. Manuscript, U.S. Department of Defense, Hattiesburg, MS; and U.S. Atomic Energy Commission, Las Vegas, NV, August 1. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas NV; and Technical Reports Library, Lawrence Livermore National Laboratory, Livermore, CA.
- Gardner, M. C., and C. E. Downs, 1971. Evaluation of the Project Dribble Site, Hattiesburg, Mississippi, for Disposition, Including Identification of Restrictions, Part I. Report to U.S. Atomic Energy Commission, Nevada Operations Office, from Earth Sciences and Engineering, Teledyne Isotopes, Palo Alto, CA, March. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV00067650 and Technical Reports Library, Lawrence Livermore National Laboratory, Livermore, CA.

## 4.36 SHEMYA ISLAND

### Plowshare Program Nuclear Harbor Excavation Alaska

Shemya Island was a proposal to use nuclear explosives to construct a harbor in the Semichi Islands on the western end of the Aleutian Island chain (Figure 4.36-1). In 1960, a preliminary feasibility study for the project was issued by the Lawrence Radiation Laboratory. Three possible locations for the harbor were identified, two on Shemya Island (Alcan Harbor and Skoot Cove) and one at the southwest tip of Nizki Island (Figure 4.36-2). Two of the locations were excluded early in the study: Alcan Harbor due to a history of severe storm damage and changing water depths, and the Nizki location based on weather considerations. Skoot Cove on Shemya Island was selected as the best site for the harbor project.



Figure 4.36-1. Location of a proposed harbor project on Shemya Island in the Semichi Islands in Alaska (adapted from USA Relief Maps 2004).

In the 1960s, Shemya Island was under the jurisdiction of the U.S. Air Force and home of the Shemya Air Force Base. Shemya Island is small (approximately 3.8 miles by 1.8 miles) and seaward approaches are available only through small beaches with reefs, rocks, and shallow water. A usable harbor was considered to be beneficial for the U.S. Government as well as for others in the area. The project concept called for constructing an offshore harbor by detonating a 20 kt nuclear explosive placed at a depth of 400 ft (Figure 4.36-3). A pile or floating platform would be required to conduct drilling and

emplacement. According to estimates in the study, the detonation would produce a crater 800 ft in diameter with a maximum depth of 190 ft with the beach line at Skoot Cove marking the landward edge of the crater. All personnel were to be evacuated from the Semichi Islands at the time of the detonation and on Shemya Island for several weeks afterward. The cost estimate for the device and the emplacement was \$2,000,000. The report concluded that the project was technically feasible.

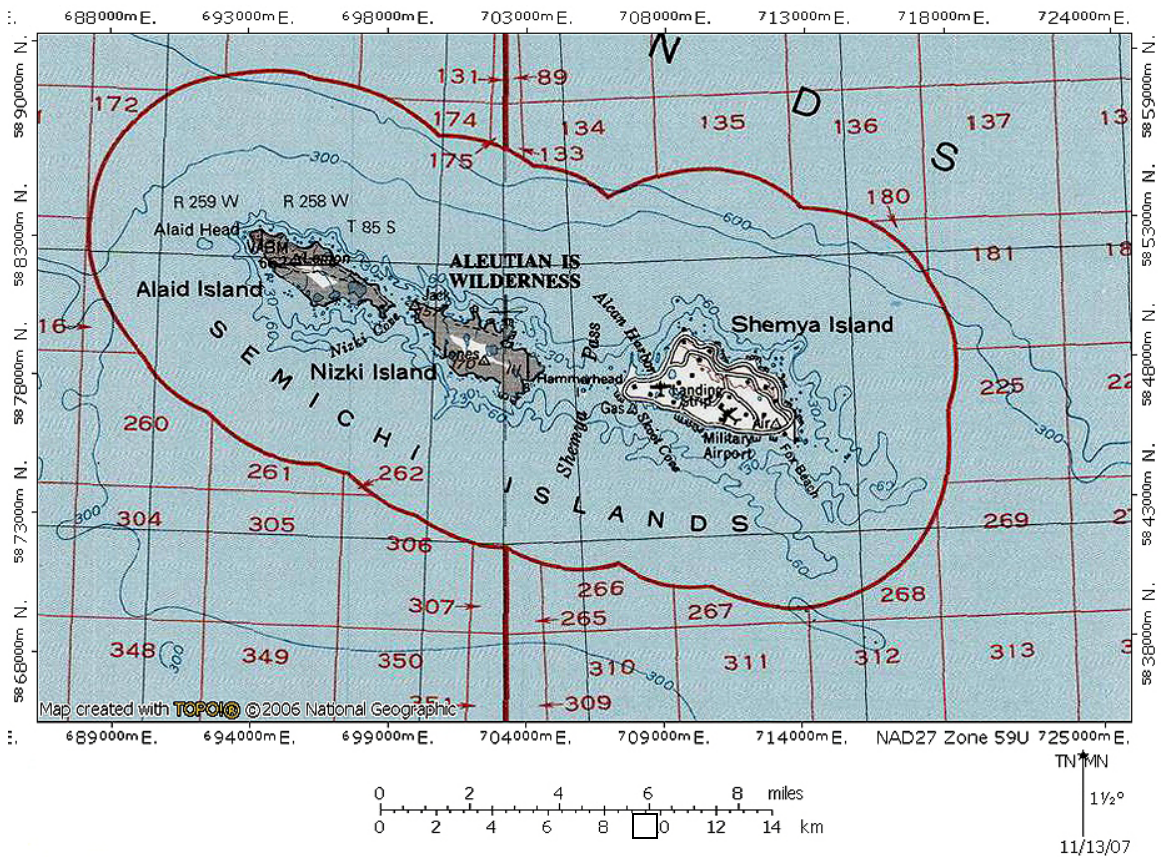


Figure 4.36-2. Map of the Semichi Islands showing Skoot Cove and Alcan Harbor on Shemya Island and Nizki Island (National Geographic Topographic Maps 2006)

There is no documentation to indicate how the preliminary study was received. However, a harbor at Shemya Island is included in a July 1964 list of suggested nuclear excavation projects compiled by the U.S. Atomic Energy Commission, Division of Peaceful Nuclear Explosives. The project name is also found in a series of tables from summary documents on nuclear excavation that date to 1969 and 1970. The tables list projects that had been previously suggested, but were no longer under consideration.

In 1960, Shemya Island was under the jurisdiction of the U.S. Air Force with Shemya Air Force Base occupying the area. This base was later known as Shemya Air Station and currently Eareckson Air Force Station. Today the island continues to be under the

primary control of the U.S. Air Force with U.S. Department of the Interior having secondary jurisdiction because the island is part of the Alaska Maritime National Wildlife Refuge and the National Wildlife Refuge System.

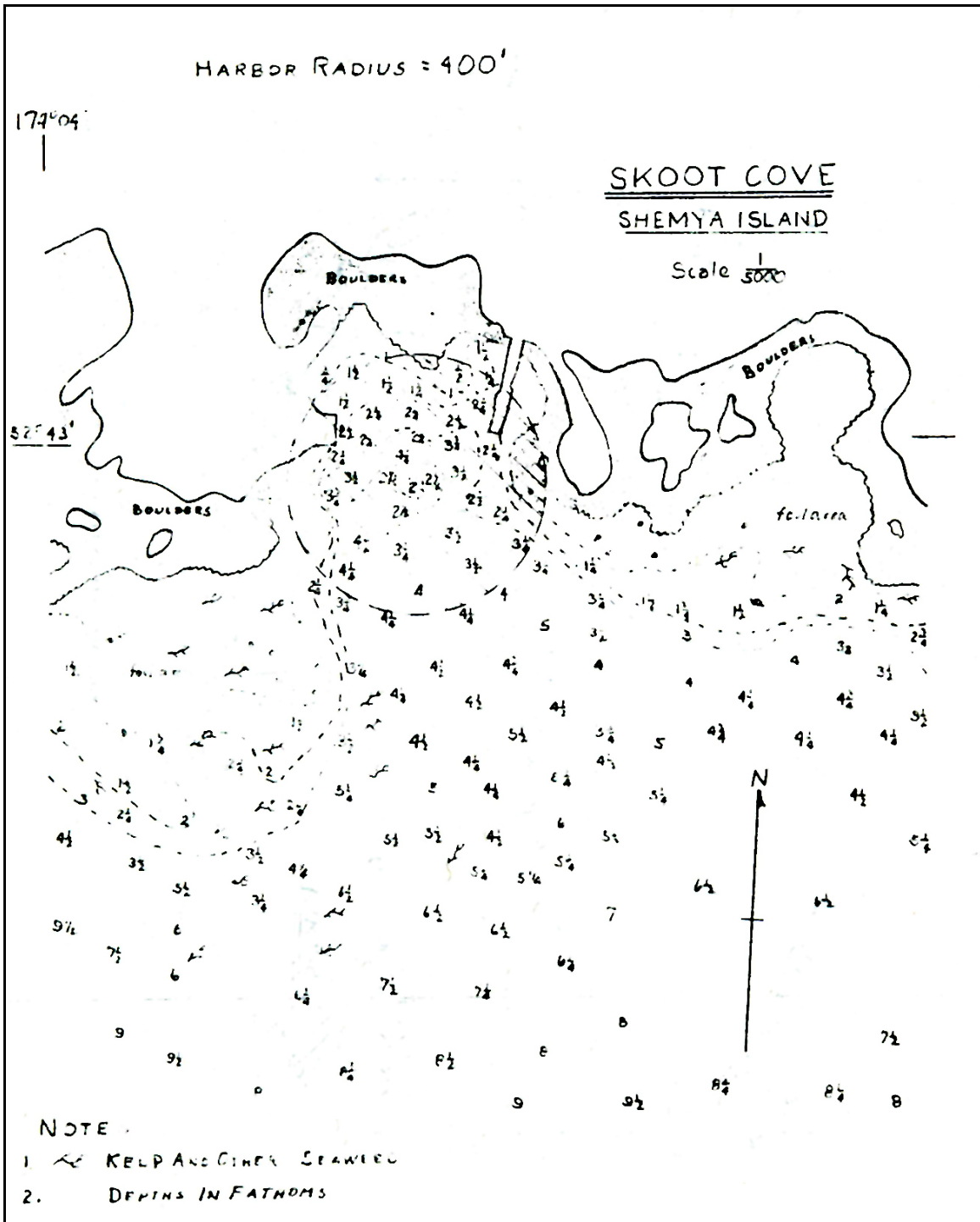


Figure 4.36-3. Diagram of Skoot Cove showing location for proposed harbor [best copy available] (Bacigalupi 1960, no figure number).

Shemya Island was a Level 5 activity. Activity was confined to conceptual design and background research.

## **CHRONOLOGICAL BIBLIOGRAPHY**

Bacigalupi, C. M., 1960. Preliminary Feasibility Study on the Use of Nuclear Explosives to Create a Harbor on Shemya Island. Manuscript, Lawrence Radiation Laboratory, Livermore, CA, October 10. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV.

U.S. Atomic Energy Commission, 1964. Suggested Nuclear Excavation Projects and Possible Nuclear Excavation Projects. Manuscript, Division of Peaceful Nuclear Explosives, July. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.

Vortman, L. J., 1969. Nuclear Excavation. Report, SC-DC-69-1716, Underground Physics Division, Sandia Laboratories, Albuquerque, NM, March. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-104.

Ross, James L., 1969. Construction and Operation of a World War II Army Air Force Forward Base: Shemya, Alaska, May 1943 – December 1945. Manuscript, Office of History, Alaskan Air Command, August.

Toman, John, 1970. Summary of Nuclear-Excavation Applications. Paper prepared for Proceedings of the ANS Topical Meeting, Engineering with Nuclear Explosives, Las Vegas, Nevada, January 14-16, 1970. University of California, Lawrence Radiation Laboratory, *Preprint UCRL-72220*, January 29. Livermore, CA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-104.

Toman, John, 1970, Summary of Nuclear-Excavation Applications. In *Symposium on Engineering with Nuclear Explosives: Proceedings*, Report CONF-700101, Vol. 1, pp. 245-279, May. American Nuclear Society, Hinsdale, IL.



## 4.37 SLOOP

### **Plowshare Program Nuclear Cratering Experiment for Leaching Copper Ore Arizona**

Results from the 1957 Rainier Test at the Nevada Test Site suggested that a contained subsurface nuclear explosion could be used in mining operations to fracture as much as a million tons of ore. In 1962, the U.S. Geological Survey and U.S. Bureau of Mines, at the request of the U.S. Atomic Energy Commission, compiled a list of mining properties that might be suitable for a Plowshare application. Subsequently, the Bureau of Mines contacted major mining companies in the west concerning a possible Plowshare application for mineral recovery. By September 1963, Project Hansom was identified formally by Lawrence Radiation Laboratory with the following technical objectives 1) to demonstrate the capabilities of nuclear explosives in a rock breaking situation of commercial interest, 2) to demonstrate the feasibility of the use of the broken rock, and 3) to establish experience that could be used for practical economic and engineering analyses of a similar project of larger magnitude. As such, Project Hansom had an overarching program goal versus a specific application per se and was considered a key program in the establishment of rock breaking as a useful Plowshare application. Eventually, the recovery of copper was viewed as having the most promising potential for a successful demonstration and became the focus of investigation by scientists from the Lawrence Radiation Laboratory, who convened under the heading of the Hansom Committee (see Copper Recovery – Chapter 4.12). It is in this context that the Kennecott Copper Corporation, in cooperation with the U.S. Atomic Energy Commission, developed plans for an in situ copper ore leaching experiment, named Project Sloop (Figure 4.37-1).

As early as 1957, the Kennecott Copper Corporation had considered performing a mining experiment using nuclear explosives to fracture a large, low-grade copper deposit near Safford, Arizona, but this early proposal was rejected by members of the Board of Directors due to lack of information about the effects of nuclear explosions in rock breaking applications. Yet, in 1959, the Kennecott Copper Corporation went ahead with the purchase of the property after initial geological explorations by Bear Creek Mining Company, a subsidiary of Kennecott, documented the extent and depth of the ore deposit. In 1963, Kennecott began studies regarding the feasibility of fracturing this low-grade copper deposit in order to prepare it for in situ leaching and copper recovery, and in June 1963, approached the U.S. Atomic Energy Commission, San Francisco Operations Office and the Lawrence Radiation Laboratory regarding the potential for using nuclear explosives to accomplish their objectives.

The Safford deposit was located in the Lone Star Mining District, Graham County, Arizona (Figure 4.37-2). The deposit had already been characterized by drilling in a grid pattern. The core analyses showed that the ore deposit was dry and no ground water was ever encountered during the drilling. In 1961, Kennecott constructed an 800 ft deep shaft

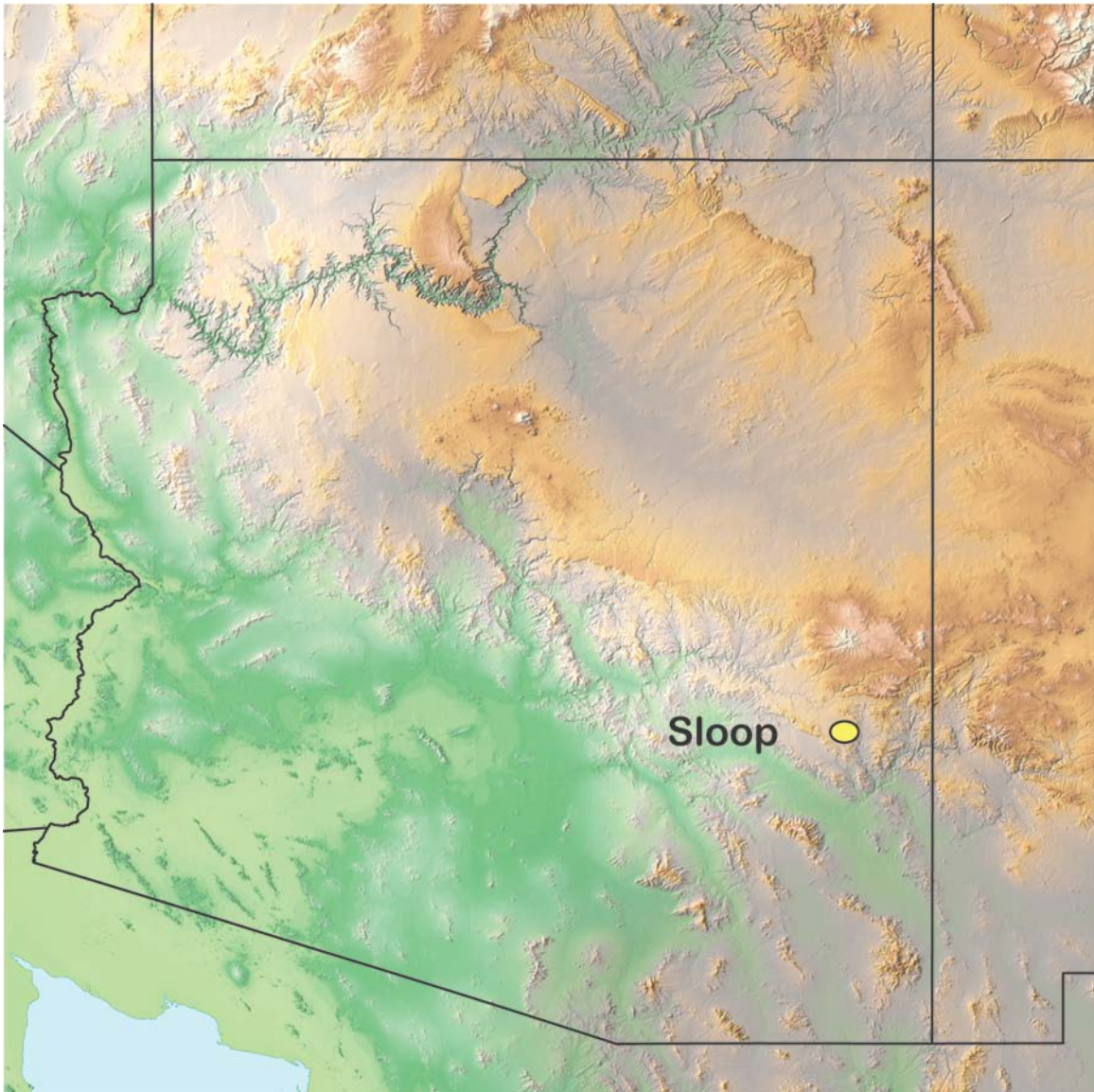


Figure 4.37-1. Location of Project Sloop in Arizona (adapted from USA Relief Maps 2004).

and 3,000 ft of underground mine workings. In addition, a pilot leaching plant was constructed near the shaft site. This plant was designed to process copper ores from the area and could handle one ton of ore per day. However, financial analyses of capital and operating costs showed that mining of even the higher-grade copper ore was uneconomical under conventional open-pit or underground mining techniques. A February 3, 1964, memo to the Hansom Committee at the Lawrence Radiation Laboratory states that the Kennecott Copper Corporation had disclosed that, given current market conditions, it would not go ahead with mining the deposit using conventional methods.

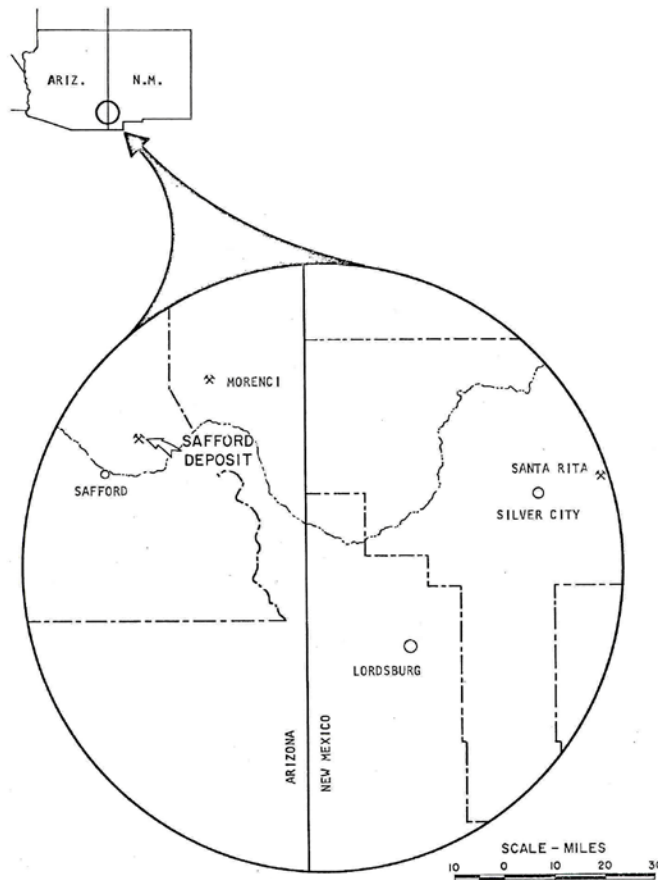


Figure 4.37-2. Location of the Safford Copper Ore for Project Sloop (Kennecott Copper Corporation 1967, no figure number).

In October 1964, after consideration by Kennecott management, Kennecott engineers proceeded with plans for a detailed study of the use of nuclear explosives to fracture the ore body and in situ leaching for recovery of copper, a study that would be undertaken in cooperation with the U.S. Atomic Energy Commission. A report on the status of discussions and activities between the Kennecott Copper Corporation and the San Francisco Operations Office was distributed in February 1965, under the name of Project Sloop. Shortly thereafter, on March 11, 1965, an organizational meeting was held at the U.S. Atomic Energy Commission, San Francisco Operations Office, to discuss planning for a feasibility study. Participants were given tasks that would contribute to a preliminary project report. The Nevada Operations Office was asked to determine the weather information for Safford, Arizona. This office submitted a weather proposal on April 21, 1965. The weather information was prepared by the U.S. Weather Bureau. On June 7, 1965, a second meeting was held with preliminary information shared by the participants. Lawrence Radiation Laboratory had reviewed the Kennecott proposal and

felt the proposal was technically feasible. However, Lawrence Radiation Laboratory and the other participants decided that the 100 kt yield that Kennecott thought would make the experiment the most economical was too large for an initial experiment and recommended a yield of 15 to 25 kts.

Kennecott needed to get formal approval to expend funds for this project from its Board of Directors, a process expected to take until at least the end of September. Kennecott anticipated submitting a formal proposal to the U.S. Atomic Energy Commission in January 1966. Kennecott also asked the Nevada Operations Office and others present to supply their information to the company by early August for the budget submittal. The Nevada Operations Office was responsible for a conceptual description of the scope of work for the program, including preliminary cost and support needs. Another meeting was scheduled for the end of July at the Nevada Operations Office in order to accommodate Kennecott's timetable and information request. The conceptual time frame for Project Sloop included a March 1967 date for detonation in the ore body with leaching operations beginning in January 1968.

In June 1965, the U.S. Public Health Service, Southwestern Radiological Health Laboratory submitted an estimate to conduct a preliminary site survey for Project Sloop, confirming a previous conversation with the Nevada Operations Office. On August 27, 1965, the Nevada Operations Office approved expenditures for John A. Blume & Associates; Roland F. Beers, Incorporated; Holmes & Narver, Incorporated; Reynolds Electrical & Engineering Company; and the U.S. Public Health Service. Work also was authorized for the U.S. Coast and Geodetic Survey, to be conducted under existing funding.

Also in 1965, authorization was given for a study to evaluate the feasibility of conducting an experiment to fracture copper ore with a nuclear explosive, followed by large scale leaching tests in order to develop a low cost commercial process for extracting copper from low-grade deposits. The Sloop study was a joint effort by the U.S. Atomic Energy Commission, the U.S. Bureau of Mines, and the Kennecott Copper Corporation. The objectives, besides evaluating the feasibility of the experiment, included identifying a suitable deposit site and developing criteria to design, conduct and evaluate the test results, upon receipt of authorization for the project. The work for the feasibility study was divided among different entities. Kennecott Copper Corporation was responsible for the geological evaluations and environmental studies of the proposed copper deposit. The U.S. Bureau of Mines examined the copper reserves appropriate for this type of mining and leaching process, and projected the effect of this recovery technique on the nation's resources, if developed successfully. Lawrence Radiation Laboratory and Oak Ridge National Laboratory were in charge of determining the effects of the explosion, contamination of the copper ore, and radiation safety for the leaching process. The U.S. Atomic Energy Commission was responsible for developing the appropriate criteria and investigations required for the fracturing aspects of the test program.

On June 26, 1965, Blume & Associates issued a report on structures that identified and described the residential and commercial structures in Safford and several of the surrounding communities. It also evaluated the Coolidge Dam, two bridges over rivers, and the Phelps Dodge Smelter stack. Several potential problems were identified, most

notably there was concern that aging concrete at Coolidge Dam, about 70 miles from the shot, could suffer from the Sloop detonation. On July 30, 1965, Holmes & Narver submitted a conceptual task plan for a pre- and post-shot structural survey for Project Sloop. The plan argued that detailed structural surveys were essential for quick assessment and settlement of any possible damage claims arising from the ground motion effects of the explosive experiment. The company provided cost estimates to conduct structural surveys of selected structures, mines, and other facilities based on the expected ground motion from 10 kt, 20 kt, 50 kt, and 100 kt explosions.

The Project Sloop feasibility study was issued on June 1, 1967. The stated purpose of the experiment was to determine whether copper could be commercially produced from the rubble chimney created by an underground nuclear explosion. The study focused on the Safford deposit in the Lone Star Mining District, about 9 miles northeast of Safford, Arizona, and 30 miles west of the New Mexico border. The deposit was situated in the Gila Mountains at an elevation of 4,500 to 5,500 ft on land owned by the Kennecott Corporation. The copper sulfide ore deposit was overlain by basalt with interbedded tuff and within a deposit of andesites, tuffs and agglomerates (Figure 4.37-3)

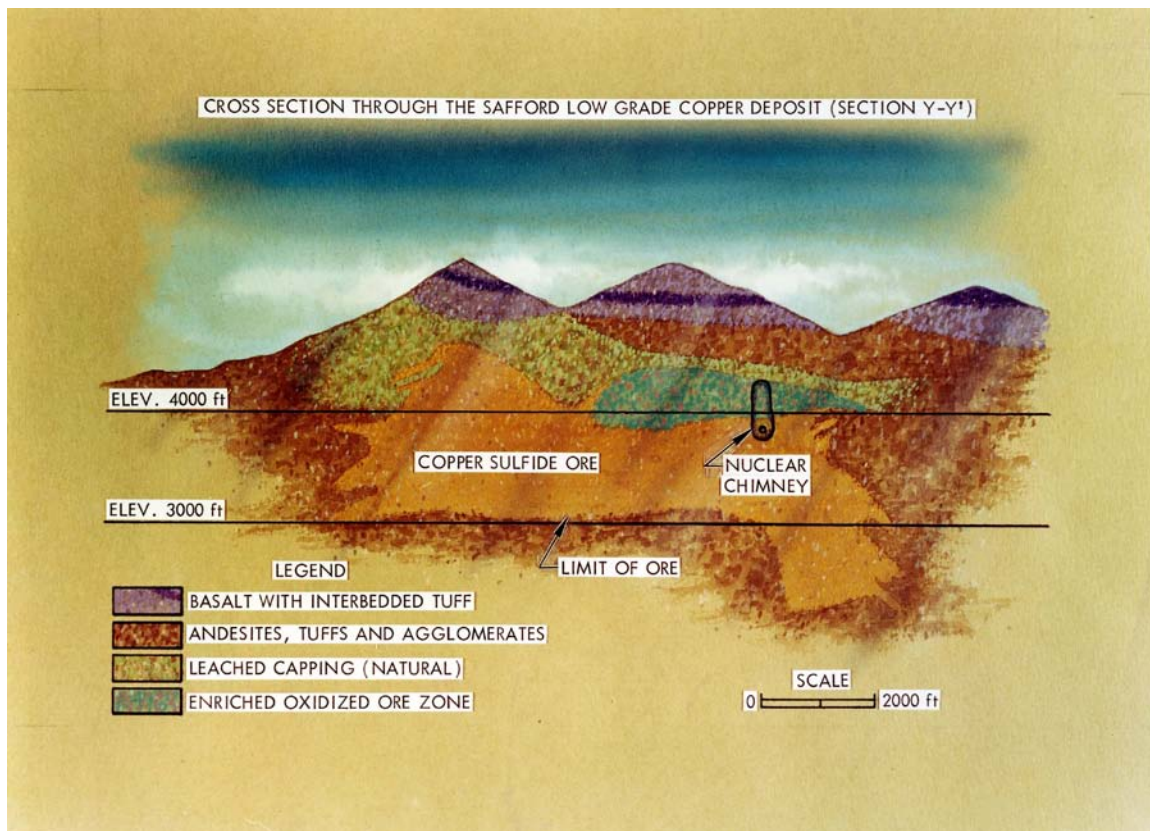


Figure 4.37-3. Schematic of a geological section through the Safford Deposit showing the location of oxidized ore zone (Lawrence Livermore National Laboratory n.d.).

The Project Sloop objectives were: 1) to determine what percentage of the copper in a nuclear explosion chimney could be recovered by leaching, 2) to study the way

radionuclides from the explosion behave during the leaching process to determine what measures, if any, would be needed for radiation control and decontamination of the copper, and 3) to test and show the capability to predict the physical effects of a nuclear explosion in a new medium at a new location. The project was proposed in three phases. Phase I consisted of site investigation and confirmation of the suitability of the location. Phase II was the pre-shot preparation and construction, the nuclear detonation, and post-shot drilling to define the rubble chimney characteristics. Phase III was the construction and operation of the in situ copper leaching and recovery plant. The Project Sloop objectives could be attained only if all three phases were conducted. Phases I and II would be done by the U.S. Atomic Energy Commission with Lawrence Radiation Laboratory, U.S. Bureau of Mines, and Kennecott. These two phases would take about 15 months and cost 6.5 million dollars. Kennecott would be the lead on Phase III with assistance from the U.S. Atomic Energy Commission, Lawrence Radiation Laboratory, and the U.S. Bureau of Mines.

The pre-shot effort would consist of four pre-shot holes, drilled near the proposed emplacement hole, each 200 ft below the shot depth (Figure 4.37-4). Cores, photography and pressure tests would be conducted to study the geology in detail. For the emplacement of the explosive, a hole would be drilled to a depth of 1,200 ft. This hole would be placed near the Kennecott exploration hole G-13 in the N1/2, Sec. 8, T6S R27E, Graham County, Arizona. The hole would be 20 inches in diameter and would not be reentered after the detonation. The hole would be stemmed with grout plugs and pea gravel. A nearby shaft also would be stemmed with 50 ft of sand, charcoal, and asphalt. All drill holes located up to 1,000 ft from the emplacement hole would be stemmed. Physical effects measurements would be taken in the emplacement hole and a nearby hole. Seismic information would be recorded at various locations nearby and at different distances from the ground zero.

The cavity radius that would be created by the nuclear detonation was calculated to be 100 ft with a chimney height about 440 ft. Fracturing was expected to extend from 250 to 373 ft beyond the side of the chimney. The chimney was expected to contain about 1.3 million tons of fragmented rock with more than 8 million pounds of copper. No radioactivity would be vented after the explosion nor were any damages from the associated seismic activity expected. After detonation, hole S-7 would be drilled near the emplacement hole and would be used for characterizing the chimney. Two other post-shot holes, S-8 and S-9, would be drilled to 1,400 ft just outside the chimney perimeter and two holes would be drilled from these two holes to cross the chimney edge and cavity bottom. The holes would be studied through cores, photography, and film.

A final design for the leaching system would have to be prepared, although the basic concept was theoretically workable. An acid solution would be injected into the chimney at the top of the rubble pile and percolate through the broken ore body dissolving the copper. The solution would be concentrated in a pool at the bottom of the cavity. The liquid could then be pumped out via wells drilled into the base of the rubble. It was expected that sampling for radioactivity would continue for at least one year. The study tentatively concluded that possible problems with radioactivity reaching the leaching system were not a major obstacle to the use of nuclear explosives for copper processing (Figures 4.37-5 and 4.37-6). It was known that ruthenium would contaminate the copper, but

### SUMMARY OF DRILL HOLES

**Pre-Shot:**

- Two — 12" to 1,400 ft.
- Three — NC (= 4.7") to 1,400 ft.
- One — 20" emplacement hole to 1,280 ft.\*

**Post-Shot:**

- One — 8¾" diameter post-shot chimney re-entry hole.

Two — 8" to 1,400 ft.

**Leaching:**

- Three — 6" to about 800 ft. (may use the above post-shot holes).

\* If the exploratory hole proves the rock unsuitable for an uncased emplacement hole, it will be drilled at 24" with a standard 20" casing.

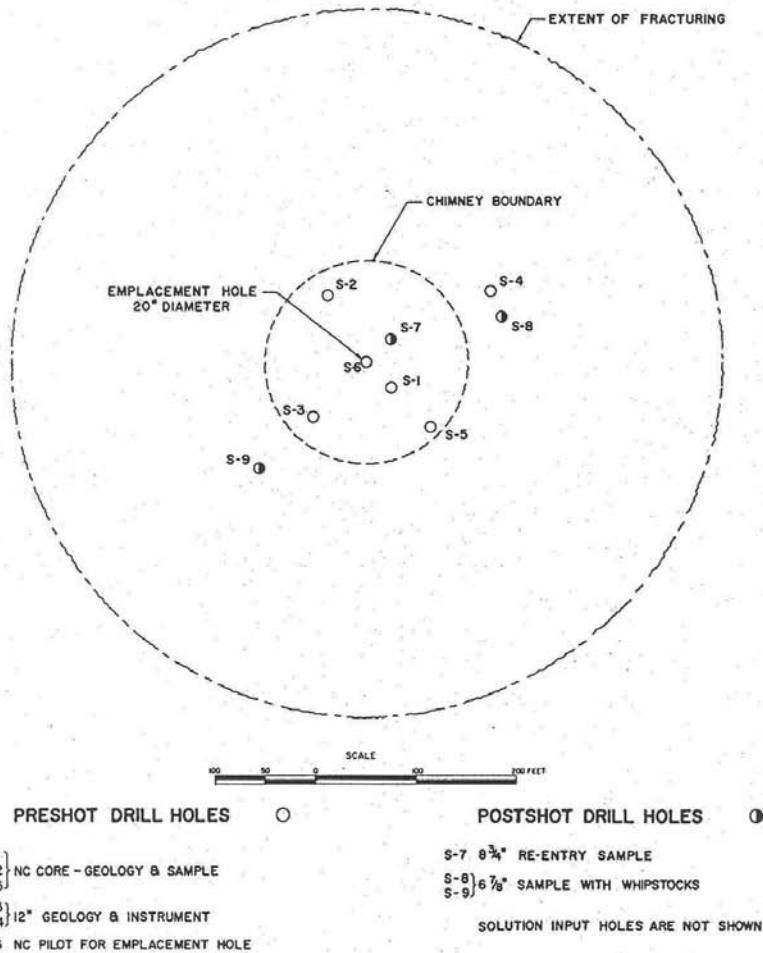


Figure 4.37-4. Drill hole plan for Project Sloop (Zimmer and Lekas 1967, Figure 4).

the radionuclides would be low enough that shielding the processing equipment would not be necessary. Therefore, the facility should be built so that spillage of leach solutions would be minimized and have little contact with the personnel working at the processor. The refining process would eliminate most of the ruthenium and the contamination of the final product would not be hazardous to the consumer. The feasibility study recommended that Project Sloop be executed as long as the site had the expected characteristics. The cost for all three phases was estimated at over 13 million dollars. For the public announcement scheduled for Project Sloop, the Kennecott Corporation prepared a memorandum on October 4, 1967, detailing events and individuals involved in the process. On October 6, 1967, the Governor would be briefed by Kennecott. An "Off-

the-Record” briefing for key state and county Arizona officials was scheduled for October 10, 1967, followed by a similar briefing for the Governor of New Mexico on the same day. A summary report indicates that questions at the briefings focused on procedures for public announcements to keep people informed of progress on the project. In addition, Arizona state officials asked what they could do to facilitate the project and the schedule. On October 11, 1967, a public meeting was held in Safford, Arizona. It was well attended by local residents and the press with concerns raised regarding structural damage from the ground shock and contamination of the groundwater.

Articles on Project Sloop followed these announcements. In November 1967, the journal *Mining Engineer* published an article on the Sloop project, with another article appearing in *World Mining* in January. On January 8, 1968, the *Ely Nevada Daily Times* printed an article detailing the Steel Union Workers Association’s threats to delay or stop Project Sloop. The Steel Union had labor problems with Kennecott regarding salaries, labor practices, and concerns about health and safety issues for Project Sloop. The group vehemently objected to the use of tax money for projects for private profit without the public receiving a benefit. The union also objected to the government partnering with a firm that ignored national labor laws.

In a January 24, 1968 letter, the U.S. Atomic Energy Commission mentioned five Plowshare projects that were currently under consideration. These were Rulison, Dragon Trail, Bronco, Ketch, and Sloop. Schedules for the projects could not be planned until funding was approved by the Commission and Congress. The U.S. Atomic Energy Commission assigned technical direction for projects Sloop and Rulison to Los Alamos Scientific Laboratory on March 8, 1968. As a result of a meeting held at the Nevada Operations Office a month later, the Nevada Operations Office was given primary responsibility for the development of Sloop and designated as the principal field contact. Two weeks later, the Nevada Operations Office was formally requested and authorized by the U.S. Atomic Energy Commission to define Project Sloop technically and operationally. However, the U.S. Bureau of Mines had responsibility for the government’s review and design participation for the recovery of copper from Project Sloop. In response to a letter from the Anaconda Company that discussed issues related to in situ copper leaching, an August 1968 Lawrence Radiation Laboratory letter described in situ leaching in general and included a reference to Sloop and the plans to mine back through a nuclear rubble pile.

Kennecott Copper Company submitted a technical proposal for Project Sloop to the Nevada Operations Office Sloop Advisory Board for review on October 1, 1968. The U.S. Bureau of Mines, Salt Lake City Office completed its review in November and pointed out that the hydrological studies were critical, especially the study of pre-shot holes and the results of this research. The U.S. Bureau of Mines also clearly stated its roll in Project Sloop in its review. The U.S. Bureau of Mines was responsible for utilizing the Project Sloop results in the assessment of the country’s copper resource potential and to use the Sloop results as a basis for evaluating the applicability and economic feasibility of nuclear fracturing for in situ leaching for other minerals and metals. Lawrence Radiation Laboratory completed its review in December and made a set of technical recommendations to improve the experiment.



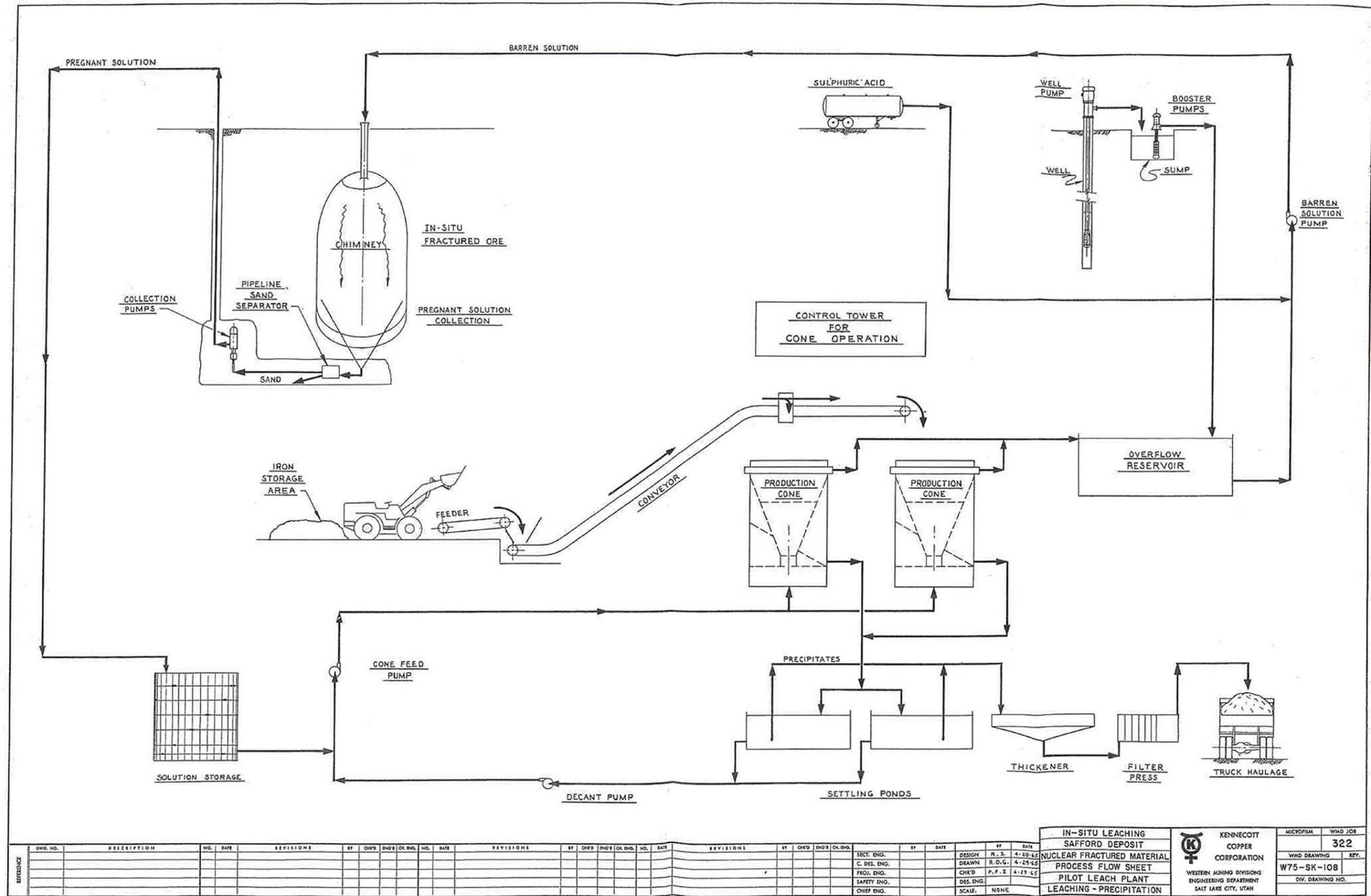


Figure 4.37-5. Proposed plan for a leaching plant for Project Sloop (Kennecott Copper Corporation 1967, Drawing No. W75-SK-108).

**THIS PAGE INTENTIONALLY LEFT BLANK**



Figure 4.37-6. Percolation leaching of copper waste (Rosenbaum and McKinney 1970, Figure 1).

On July 14, 1969, Kennecott Copper Corporation contacted the U.S. Atomic Energy Commission regarding the possibility of conducting more than one detonation in Project Sloop. A meeting at the Nevada Operations Office was held four days later with representatives of Kennecott, Los Alamos Scientific Laboratory, U.S. Bureau of Mines, and the Nevada Operations Office. The representative from Kennecott explained that the Salt Lake City Office was conducting a detailed comparison of nuclear versus conventional methods for the Safford deposit with the disadvantages of the nuclear approach being the high cost and length of time to determine its commercial viability. He also pointed out that at the conclusion of Sloop, at least one more detonation would be

needed to study the effects of leaching the fracture zones between chimneys. He asked about the feasibility of detonating more than one explosive so that it would be possible to determine if the nuclear approach would be feasible at the conclusion of Project Sloop. Kennecott preferred a three shot plan and discussion revolved around the issues involved in simultaneous and sequential detonations. In terms of yields, alternatives included firing two 10 kt explosives simultaneously, firing three 7 kt explosives simultaneously, and firing two 20 kt explosives with a delay between the shots. Multiple shots also brought up new considerations in regard to fracture development and the effect of multiple shots with lower yields. The Nevada Operations Office committed to fully evaluating multiple detonations for Project Sloop. In March 1970, a Project Sloop meeting was held in Denver, Colorado and there were several recommended actions. Concerns related to the subsurface hydrologic regime continued and to address these issues the Nevada Operations Office made recommendations for changes in the technical specifications for the drill hole for the pre-shot exploratory hole, and planned a site visit to investigate the suitability of Kennecott's GS-13 core hole for the detonation. It was proposed that the U.S. Geological Survey, with assistance from the Nevada Operations Office, take a lead in developing a work scope for the exploratory drilling and testing program with work on this beginning immediately. In addition, the Nevada Operations Office with the U.S. Bureau of Mines was to arrange a meeting with Kennecott in Salt Lake City when the work scope was completed in order to reach a joint government-Kennecott agreement that would allow the exploratory program to start as soon as possible. A memorandum, dated May 8, 1970, estimated Project Sloop at 2.5 to 3 years away from detonation; however, the memo also noted that Kennecott had denied funds for additional drilling that were recommended to address concerns about the site hydrology.

Kennecott Copper Corporation and the U.S. Atomic Energy Commission were to share costs of the project, with Kennecott already approving funds to conduct the Sloop experiment. However, federal budget restrictions did not allow the U.S. Atomic Energy Commission to fully participate. Therefore, Kennecott decided to re-evaluate the added costs and determine if the company wanted to proceed. Based on cost estimates, in lieu of rising copper prices, it appeared that use of nuclear explosions for mining were comparable to conventional methods, that is, there was no economic benefit to the use of nuclear explosives.

Project Sloop was a Level 4 activity. An exploratory hole was drilled in 1961 and data were used for evaluation of the project feasibility and design of the proposed experiment.

## **CHRONOLOGICAL BIBLIOGRAPHY**

Flangas, W. G., and L. E. Shaffer, 1960. An Application of Nuclear Explosives to Block Caving Mining. University of California, Lawrence Radiation Laboratory, *Report UCRL-5949*, June 2. Livermore, CA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore CA, File PLO-102.

- Smith, Fred L., and Thomas R. Young, 1960. Nuclear Explosives and Mining Costs. University of California, Lawrence Radiation Laboratory, *Report UCRL-5928*, July. Livermore, CA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA.
- University of California. Office of Public Information, 1960. Press Release, Subject: Nuclear explosions with "block-caving" mining for recovery of ore, from University of California, September 15. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-085.
- Flangas, William G., and David D. Rabb, 1961. Nuclear Explosives in Mining. University of California, Lawrence Radiation Laboratory, *Report UCRL-6636*, September 26. Livermore, CA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-102.
- Hasler, J. W., and A. S. Konselman, 1963. Mineral Deposits Suitable for Plowshare Mining Experiments. U.S. Department of the Interior. Geological Survey and Bureau of Mines, Technical Letter Special Projects-7, May 29. Denver, CO. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV.
- Philip, John F., 1963. "Meeting with Kennecott Corporation on October 23, 1963." Memo with encl. ("SAN-LRL-Kennecott Meeting," from Mitchell A. Lekas to Files) from John F. Philip, U.S. Atomic Energy Commission, San Francisco Operations Office, to Distribution, November 1. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-085 [OUO].
- Rabb, David D., 1964. "Plowshare Mining Prospect - Kennecott Copper Corporation." Memo from David D. Rabb, Lawrence Radiation Laboratory, to Hansom Committee, February 3. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-085.
- Rabb, David D., 1964. "Tour of Copper Mining Leaching-In-Place Sites." Memo from David D. Rabb, Lawrence Radiation Laboratory, to Distribution, February 25. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-085.
- Hansen, Spenst M., 1964. "Trip Report - Tour of Southwest Copper Leaching Operations." Memo from S. M. Hansen, Lawrence Radiation Laboratory, to Hansom Committee, April 15. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-086.
- Shaffer, Lysle E., 1964. "In-Situ Leaching of Copper (Safford)." Memo from Lysle Shaffer, Lawrence Radiation Laboratory, to Plowshare Physics K Division - Dr. Gary Higgins, July 22. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-086.

- Philip, John F., 1965. Letter with encl. (Project Sloop Status Report, February 25, 1965, manuscript and draft outline of Project Sloop study) from John F. Philip, U.S. Atomic Energy Commission, San Francisco Operations Office, to Gerald W. Johnson, February 26. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-087 [OUO].
- Lombard, David B., 1965. "Kennecott Safford Experiment: Preliminary Design." Memo from D. B. Lombard, Lawrence Radiation Laboratory, to Hansom Committee, April 20. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-087.
- Philip, John F., 1965. Letter from John F. Philip, U.S. Atomic Energy Commission, San Francisco Operations Office, to Multiple Recipients, May 27. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-060.
- Placak, Oliver R., 1965. Letter from Oliver R. Placak, U.S. Public Health Service, Las Vegas, NV, to R. H. Thalgott, June 15. On file at: National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0162674.
- Holmes, Ray L., 1965. Report on Structures: Structural Response Reconnaissance Survey, Project Sloop. Manuscript, John A. Blume & Associates Research Division, San Francisco, CA, June 26. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV.
- Holmes & Narver, Inc., 1965. Project Sloop – Safety: Pre-Shot and Post-Shot Structural Survey, Conceptual Plan. Manuscript, Holmes & Narver, Inc., On-Continent Test Division, Las Vegas, NV, July 12. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV [OUO].
- Holmes & Narver, Inc., 1965. Project Sloop – Safety: Pre-Shot and Post-Shot Structural Survey and Engineering Support for Damage Claim Settlement, Conceptual Plan. Manuscript, Holmes & Narver, Inc., On-Continent Test Division, Las Vegas, NV, July 30. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV [OUO].
- Roehlk, Otto H., 1965. "DPNE (Plowshare Program) Work Authorization 66-3, Project Sloop." Memo from Otto H. Roehlk, U.S. Atomic Energy Commission, Nevada Operations Office, to List, August 27. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0162680.
- Bowyer, Ben, 1965. "Current Status of Project Sloop." Memo from Ben Bowyer, U.S. Atomic Energy Commission, Civil Use Branch, to Files. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0038601.

- U.S. Atomic Energy Commission, 1966. Chapter 12 - The Plowshare Program. In Annual Report to Congress of the Atomic Energy Commission for 1965, pp. 191-209, January. U.S. Atomic Energy Commission, U.S. Government Printing Office, Washington D.C.
- Rabb, David D., 1966. Plowshare Program, October 1, 1965 – July 15, 1966, Vol. II, No. 2. University of California, Lawrence Radiation Laboratory, Report UCRL-50008-66-1, July 15. Livermore, CA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.
- Hansen, Spenst M., 1966. "Sites for Copper Leach Application Projects." Memo from Spenst Hansen, Lawrence Radiation Laboratory, to Glenn Werth, August 2. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-087.
- Rabb, David D., 1966. Plowshare Program, July 16, 1966 – October 31, 1966, Vol. II, No. 3. University of California, Lawrence Radiation Laboratory, Report UCRL-50008-66-2, October 31. Livermore, CA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.
- Werth, Glenn C., [between 1966 and 1973], Handwritten notes on Plowshare program meetings from Glenn C. Werth, U.S. Atomic Energy Commission, Division of Peaceful Nuclear Explosives, 1966-1973. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-118.
- U.S. Atomic Energy Commission, 1967, Chapter 11 - Plowshare Program. In Annual Report to Congress of the Atomic Energy Commission for 1966, pp. 239-258, January. U.S. Atomic Energy Commission, U.S. Government Printing Office, Washington D.C.
- Kennecott Copper Corporation, 1967. Preliminary: Project Sloop – A Feasibility Study of the Use of Nuclear Explosives to Prepare a Copper Orebody for In-Situ Leaching. Manuscript, Kennecott Copper Corporation, U.S. Atomic Energy Commission, and U.S. Bureau of Mines, January 9. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV.
- U.S. Atomic Energy Commission, 1967. Report on Project Ketch Meeting, Nuclear Excavation for Underground Gas Storage. Notes from meeting with U.S. Atomic Energy Commission, Commonwealth, and Columbia Gas System Service Corporation, January 24. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0188125.

- Werth, Glenn C., 1967. Program Activities for Plowshare. University of California, Lawrence Livermore National Laboratory, Report UCRL-124785, February 3. Livermore, CA. On file at: Technical Reports Library, Lawrence Livermore National Laboratory, Livermore, CA.
- U.S. Atomic Energy Commission, 1967. Nuclear Underground Tests in Planning or Feasibility Stage. Table, March 6. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0188117.
- American Nuclear Society, 1967. Technical Program Engineering and Construction; Scope of Work - Sloop. Manuscript, March 13. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0162249.
- Werth, Glenn C., 1967. Plowshare Program Goals. University of California, Lawrence Livermore National Laboratory, Report UCRL-126674, March 13. Livermore, CA. On file at: Technical Reports Library, Lawrence Livermore National Laboratory, Livermore, CA.
- Nordyke, Milo D., 1967. "Status Review of Field Project Studies." Memo from Milo Nordyke, Lawrence Radiation Laboratory, to G. Higgins, April 14. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore CA, File PLO-026.
- U.S. Atomic Energy Commission, 1967, "Statement on the Civilian Applications of Nuclear Explosives (Plowshare) Program, U.S. Atomic Energy Commission FY 1968 Authorization Hearings Before the Joint Committee on Atomic Energy." Statement from U.S. Atomic Energy Commission, April 17. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-028.
- Rabb, David D., 1967. Plowshare Program February 1, 1967 – April 30, 1967, Vol. II, No. 5. University of California, Lawrence Radiation Laboratory, Report UCRL-50008-67-2, April 30. Livermore, CA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.
- Thalgott, Robert H., 1967. "DPNE (Plowshare) Work Authorization 67-30, Project Sloop Cost Estimate." Letter from Robert H. Thalgott, U.S. Atomic Energy Commission, Nevada Operations Office, to Oliver R. Placak, May 2. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0162230 and NV0165017.



- Zimmer, P. F., and M. A. Lekas, 1967. Sloop. U.S. Atomic Energy Commission, Report PNE 1300, June 1. Springfield, VA. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas NV, Accession No. NV0065733 and Technical Reports Library, Lawrence Livermore National Laboratory, Livermore, CA.
- Kase, K. S., 1967. "Projects Sloop and Ketch Operations Plans." Memo from K. R. Kase, Hazards Control, Off-Site Field Representative, to J. A. Button, June 12. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.
- Tewes, H. A., 1967. "Establishment of a Leaching Task Group." Memo from H. A. Tewes, Lawrence Radiation Laboratory, to J. S. Kahn, July 31. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-087.
- Renfro, H. B., 1967. "Plowshare Committee, Atomic Industrial Forum." Memo from H. B. Renfro to G. Werth, August 18.
- Dowell, Edwin E., 1967. "Sloop Public Announcement Status Summary." Memo from Edwin E. Dowell, Kennecott Copper Corporation, to Rodney L. Southwick, October 4. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0162254.
- Pickering, I. G., J. F. Philip, Gary H. Higgins, Peter F. Zimmer, and W. W. Allaire, 1967. "Sloop Report Announcement." Transcript: Kennecott Copper Cooperation; U.S. Atomic Energy Commission, San Francisco Operations Office; Lawrence Radiation Laboratory; U.S. Atomic Energy Commission, Nevada Operations Office, October 11. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV.
- Plowshare Advisory Committee, 1967. Plowshare Advisory Committee, Report of Sixteenth Meeting. Meeting held at Lawrence Radiation Laboratory, Livermore, CA, October 10-11. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029 [OUO].
- Southwick, Rodney L., 1967. "State of Arizona Reaction - Sloop." Memo with encls. (Press Release, Subject: "Statement Regarding Sloop," October 11, and letter from K. R. Geiser, Arizona Atomic Energy Commission, to Governor Jack Williams, October 11) from Rodney L. Southwick, U.S. Atomic Energy Commission, San Francisco Operations Office, to John A. Harris, October 12. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-061.

- Barth, Delbert S., 1967. "Trip to Phoenix, Arizona and Safford, Arizona October 10-11, 1967." Memo from Delbert S. Barth, Chief, Bioenvironmental Research, U.S. Public Health Service, to Files, October 13. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0162255.
- Russell, Paul L, 1967. Letter from Paul L. Russell, U.S. Department of the Interior, Bureau of Mines, to J. S. Kahn, October 13. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-061.
- U.S. Atomic Energy Commission, 1967. Proposal for a Joint Experiment (Project Sloop). Atomic Energy Clearing House, Vol. 13, No. 42, pp. 8-12, October 16. Washington, D.C. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0065739.
- Mining Engineering, 1967. Kennecott Proposes Nuclear Mining Experiments at Safford Deposit. Mining Engineering, pp. 66-67, November. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.
- NTS News, 1967. " Plowshare Program 'Sloop'." NTS News, Vol. 10, No. 22, p . 7, November 3. Reynolds Electrical & Engineering Company, Inc., Mercury, NV. On file at: Nuclear Testing Archives, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0112292.
- Kelly, John S., 1967. "Redirection of Plowshare Industrial Effort." Memo from John S. Kelly through General Manager, U.S. Atomic Energy Commission, to Seaborg et al., November 21. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-027.
- Jackson, Melvin W., 1967. Ten Years of Plowshare. Civil Engineering, December. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.
- Oil, Gas Projects, 1967. Oil, Gas Projects Perk Up AEC's Plowshare. Government, 1967. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.
- Project Sloop Notes, [1967]. Project Sloop Notes. Notes. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0162244.

- U.S. Atomic Energy Commission. San Francisco Operations Office, [1967]. Summary of the Sloop Feasibility Study. Manuscript, San Francisco Operations Office, Lawrence Radiation Laboratory, U.S. Bureau of Mines, Kennecott Copper, and Oak Ridge National Laboratory. On file at: Nuclear Testing Archives, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0162229.
- Applied Nuclear Company, [Post 1967]. Applied Nuclear Company and Plowshare. Report to U.S. Atomic Energy Commission from Applied Nuclear Company, La Jolla, CA. On file at: Technical Reports Library, Lawrence Livermore National Laboratory, Livermore, CA.
- Hansen, Spent M., and David D. Rabb, 1968. Seek Profitability Answer to Nuclear In-Situ Copper Leaching at Safford. World Mining, January. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.
- U.S. Atomic Energy Commission, 1968. Chapter 11 - The Plowshare Program. In Annual Report to Congress of the Atomic Energy Commission for 1967, pp. 199-208, January. U.S. Government Printing Office, Washington, D.C.
- Ely Daily Times, 1968. Steel Union Threatens U.S. Govt. Seek to Delay or Deny 'SLOOP.' Ely Daily Times, Vol. 51, No. 5, January 8. Ely, NV. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0189171.
- Vermillion, Henry G., 1968. Letter from H. G. Vermillion to G. K. Plumleigh, January 24. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0188360.
- U.S. Atomic Energy Commission, 1968. "Civilian Applications of Nuclear Explosives (Plowshare) Program – Operating Costs, FY 1969 Budget Estimates: Appropriation – Operating Costs." On file at: Archives and Records Office, Lawrence Berkeley National Laboratory, Berkeley, CA, File 434-900205, 28/48.
- Seaborg, Glenn T., 1968. The Progress of the Peaceful Atom. Paper presented at the Governor's Industrial Safety Conference, February 7, 1968, San Francisco, California. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Las Vegas, NV, Accession No. NV0148558.
- Werth, Glenn C., 1968. "Plowshare Reductions." Memo from G. C. Werth, Lawrence Radiation Laboratory, to Distribution, February 15. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.

- New York Times, 1968. A-Blasts Studied as Way to Expand U.S. Gold Output. New York Times, February 26.
- Rabb, David D., 1968. "Meeting with R. M. Stewart, Western Operations Manager for the Anaconda Company." Memo from D. Rabb, Lawrence Radiation Laboratory, to A. Holzer and M. Nordyke, April 8. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-098.
- Kelly, John S., 1968. "NVOO Responsibility for Project Sloop." Memo from John S. Kelly, U.S. Atomic Energy Commission, Division of Peaceful Nuclear Explosives, to James E. Reeves, April 20. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-061.
- McCool, W. B., 1968. "Atomic Energy Commission Status of Plowshare Industrial Projects." Memo with encl. ("Status of Plowshare Industrial Projects," memo from John S. Kelly, U.S. Atomic Energy Commission, Division of Peaceful Nuclear Explosives, to List) from W. B. McCool, U.S. Atomic Energy Commission to Distribution, April 26. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029 [OUO].
- Rabb, David D., 1968. Memo from David D. Rabb, Lawrence Radiation Laboratory, to Record / G. Higgins, April 26. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-061.
- Industrial Research, 1968. Preoccupied with Gold. Industrial Research, June. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-098.
- Niermeyer, K. E., 1968. Letter from K. E. Niermeyer, The Anaconda Company, Salt Lake City, UT, to David D. Rabb, July 17. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-061.
- Rabb, David D., 1968. Letter from David D. Rabb, Lawrence Radiation Laboratory, to K. E. Niermeyer, August 6. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-061.
- U.S. Atomic Energy Commission, 1968. Plowshare Program. Booklet. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.
- Reeves, James E., 1968. Letter from James E. Reeves, U.S. Atomic Energy Commission, Nevada Operations Office, to Michael M. May, October 18. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-061.

- Rosenbaum, Joe B., 1968. Letter from Joe B. Rosenbaum, U.S. Bureau of Mines, Salt Lake City Metallurgy Research Center, to James E. Reeves, November 15. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-061.
- Plowshare Advisory Committee, 1968. Plowshare Advisory Committee, Report on Eighteenth Meeting. Meeting held at Oak Ridge National Laboratory, Oak Ridge, TN, November 21-22. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029 [OUO].
- Toman, John, 1968. "Review of Project Sloop." Memo with encl. (Review of Project Sloop, manuscript) from John Toman, Lawrence Radiation Laboratory, to G. Werth and G. Higgins, December 6. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-061.
- Reeves, James E., 1968. "BuMines Sloop Comments." Memo with encl. (letter from Joe B Rosenbaum to James E. Reeves, November 15) from James E. Reeves, U.S. Atomic Energy Commission, Nevada Operations Office, to List, December 17. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-061.
- U.S. Atomic Energy Commission, 1969. Chapter 11 - Peaceful Nuclear Explosions. In Annual Report to Congress of the Atomic Energy Commission for 1968, pp.195-202, January. U.S. Government Printing Office, Washington, D.C.
- Plowshare Advisory Committee, 1969. Plowshare Advisory Committee, Report on Nineteenth Meeting. Meeting held at Lawrence Radiation Laboratory, Livermore, CA, November 4-5. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029 [OUO].
- U.S. Atomic Energy Commission. Division of Technical Information, 1969. Status of Nuclear Test Reports. U.S. Atomic Energy Commission, Report TID-9533. Washington, D.C. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0105641.
- Rabb, David D., 1969. Letter from David D. Rabb, Lawrence Radiation Laboratory, to Paul C. Trussell, February 3. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-061.
- May, Michael M., 1969. Letter with encl. (Review of Project Sloop, Manuscript, February 19) from Michael M. May, Lawrence Radiation Laboratory, to Robert E. Miller, February 19. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-061.

- Nordyke, Milo D., 1969. Underground Engineering Applications. Paper prepared for The Symposium on Public Health Aspects of Peaceful Uses of Nuclear Explosives, Las Vegas, April. University of California, Lawrence Radiation Laboratory, Preprint UCRL-71453, April. Livermore, CA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-103.
- U.S. Atomic Energy Commission, 1969. "United States Atomic Energy Commission, Plowshare Program Statement, JCAE FY 1970 Authorization Hearings." Statement from U.S. Atomic Energy Commission, April 18. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-028.
- May, Michael M., 1969. A Public Corporation for Plowshare. University of California, Lawrence Radiation Laboratory, Report UCRL -50693, June 24. Livermore, CA. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV.
- Bowyer, Ben, 1969. "Highlights of July 18, 1969 Sloop Meeting." Memo with encl. (List of Attendees) from Ben Bowyer, U.S. Atomic Energy Commission, Nevada Operations Office, to Plowshare Division Files, July 26. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-061.
- Coffer, H. F., and G. H. Higgins, 1970. Future Contained Nuclear Explosives Experiments. In Education for Peaceful Uses of Nuclear Explosives, Lynn E. Weaver, editor, pp. 45-63. University of Arizona Press, Tucson, AZ.
- U.S. Atomic Energy Commission, 1970. Plowshare Program During 1969: Based on the Annual Report to Congress for 1969 of the U.S. Atomic Energy Commission. U.S. Atomic Energy Commission, U.S. Government Printing Office, Washington, D.C. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV.
- U.S. Atomic Energy Commission, 1970. Chapter 11 - Peaceful Nuclear Explosives. In Annual Report to Congress of the Atomic Energy Commission for 1969, pp. 195-203, January. U.S. Government Printing Office, Washington D.C.
- U.S. Atomic Energy Commission, 1970. "Plowshare Program Statement, JCSE FY 1971 Authorization Hearings." Statement from U.S. Atomic Energy Commission, March 5. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-028.

- Bowyer, Ben, 1970. "Notes on March 6, 1970 S loop Meeting at Denver, Colorado." Memo from Ben Bowyer, U.S. Atomic Energy Commission, Nevada Operations Office, to Files thru A. Dean Thornbrough, March 16. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-061.
- Michaelson, S. D., 1970. A Summary Paper on Nuclear Mining. In Symposium on Engineering with Nuclear Explosives: Proceedings, Report CONF-700101, Vol. 1, pp.859-863, May. American Nuclear Society, Hinsdale, IL.
- Rosenbaum, J. B., and W. A. McKinney, 1970. In Situ Recovery of Copper from Sulfide Ore Bodies Following Nuclear Fracturing. In Symposium on Engineering with Nuclear Explosives: Proceedings, Report CONF-700101, Vol. 2, pp.877-887, May. American Nuclear Society, Hinsdale, IL.
- Evans, Roy B., and David E. Bernhardt, 1970. "Probable Scheduling of Plowshare Events." Memo from Roy B. Evans and David E. Bernhardt, U.S. Department of Health, Education, and Welfare, Southwestern Radiological Health Laboratory, to Francis N. Buck, May 8. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0173142 [OUO].
- Whan, Glenn A., 1973. Plowshare Technology Assessment, Final Report, Implications to State Governments. Report to the Western Interstate Nuclear Board, Lakewood, CO, from Glenn A. Whan, Chemical and Engineering Department, University of New Mexico. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV.
- Crump, Joseph R., 1975. PNE (Peaceful Nuclear Explosion) Activity Projections for Arms Control Planning, Vol. I. Report to the U.S. Arms Control and Disarmament Agency, Contract No. ACDE/PAB-253, from Gulf Universities Research Consortium, Galveston, TX, April 10.
- Ballou, L., M. Nordyke, and G. Werth, 1977. A Summary of U.S. PNE Experience. Report prepared for U.S. Energy Research & Development Administration from Lawrence Livermore Laboratory, Report UCID-17649, November 17. On file at: Defense Threat Reduction Information Analysis Center, Albuquerque, NM; and Technical Reports Library, Lawrence Livermore National Laboratory, Livermore, CA.
- Shafer, David S., William C. Beck, Dwight Treadwell, and Stephen A. Mellington, 1995. Inventory of Potential Environmental Restoration Liabilities Associated with Plowshare And Vela Uniform Program Sites. Manuscript, U.S. Department of Energy, Office of Environmental Restoration. On file at: Desert Research Institute, Las Vegas, NV.

U.S. Department of Energy. Nevada Operations Office, 1997. Plowshare Program Executive Summary. Report from U.S. Department of Energy, December 22.

Engineering and Mining Journal, no date. Behind the By-lines. Engineering and Mining Journal. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.

Plowshare Public Health Evaluation, no date. Plowshare Public Health Evaluation. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0316824.

U.S. Department of Energy. Nevada Operations Office, no date. The Plowshare Program (Draft). Report from U.S. Department of Energy.

Lawrence Livermore National Laboratory, n.d. "Cross Section through the Safford Low Grade Copper Deposit (Section Y-Y')." Safford copper deposit drawing. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-0882.



## **4.38 SOUTH POINT HARBOR**

### **Plowshare Program Nuclear Excavation of a Military Harbor Hawaii**

Status reports from the U.S. Army Engineer Nuclear Cratering Group document that beginning in 1963 and continuing into 1965 the U.S. Army Corps of Engineers, Honolulu District, was investigating the shorelines of the Hawaiian Islands for a location suitable for a nuclear excavated harbor. However, no exact site or project concept was specified. Three years later, during the spring of 1968, Frank Midkiff, the President of the Board of Trustees for the Bernice P. Bishop Estate in Hawaii, contacted the Honolulu District and expressed interest in using nuclear explosives to develop a small boat harbor at South Point on the Island of Hawaii (Figure 4.38-1). A telex dated May 22, 1968, from the Honolulu District to the Nuclear Cratering Group summarizes a number of points in regard to Midkiff's inquiry. First, Midkiff notified the Honolulu District that he would be meeting with the Secretary of the Department of Defense in Washington, D.C. on May 22 and was interested in discussing the nuclear excavated harbor idea with someone from either the Department of Defense or the U.S. Atomic Energy Commission. According to the telex, Mr. Midkiff was informed that a report was being prepared by the U.S. Army Engineer Nuclear Cratering Group on the nuclear excavation of a harbor, but as the information was classified it could not be discussed (see Kaunakakai Harbor – Chapter 4.21). Furthermore, while South Point had been one of the locations initially considered, it was no longer in the running. A small boat harbor at this location was deemed economically unjustified.

During the spring of 1968, Midkiff also wrote to the U.S. Atomic Energy Commission concerning his idea for an experimental Plowshare harbor project at South Point, mentioning that either the U.S. Atomic Energy Commission or the Department of Defense might be interested in developing the lagoon in the lava flows near South Point, an area used by the Department of Defense for target runs. In a memo to the Board of Trustees for the Bishop Estate, Midkiff mentioned that he met with Joe Foster, the Chief of Research of the Department of Defense, on May 24, 1968. According to the memo, Midkiff discussed with Foster the idea of a harbor at South Point as well as what he believed to be safety and economic benefits of the project, and Foster expressed interest in having the project studied. Meanwhile, the U.S. Atomic Energy Commission responded to Midkiff's initial inquiry thanking him for his interest in the Plowshare program, but mentioning that no decisions had been made regarding locations for cratering experiments.

Correspondence continued during the early summer of 1968 with Midkiff expressing his interest in a Plowshare demonstration at South Point and the U.S. Atomic Energy Commission and the U.S. Army Corps of Engineers, Honolulu District acknowledging his interest. However, the Honolulu District reiterated the position that while the feasibility of a nuclear excavated harbor in the Hawaiian Islands was being studied, South

Point was not, but would be considered if the demonstration did not require economic justification.



Figure 4.38-1. Proposed location for the South Point Harbor project in Hawaii (adapted from USA Relief Maps 2004).

After July 1968 there is no documentation of any additional correspondence about a nuclear excavated harbor at South Point. Yet, in March 1971, a feasibility study for constructing a military harbor at South Point was issued by the U.S. Army Engineer Nuclear Cratering Group. The feasibility study for South Point compares conventional and nuclear methods for construction of a harbor that would provide logistical support in a hypothetical Theater of Operations. In the study, criteria considered critical for expedient construction of a military harbor were time, personnel, and material requirements (not economic benefit). According to the study, conventional techniques for harbor construction would require 262 tons of high explosives to blast and dredge a basin and construct breakwater fills. Alternatively, nuclear excavation techniques could be used to construct a crater that would provide a berthing basin with the crater lip forming necessary breakwaters. The coast at South Point is characterized by basalt formations and data from the Buggy row charge detonation, an experimental detonation in a basalt medium at the Nevada Test Site, were used as a basis for the analysis. According to the plan, the detonation of a row configuration of five 10 kt explosive charges 287 ft apart

and emplaced 250 to 280 ft below ground surface would create a harbor of sufficient dimensions to accommodate four cargo ships or tankers of the T-2 class (Figure 4.38-2).

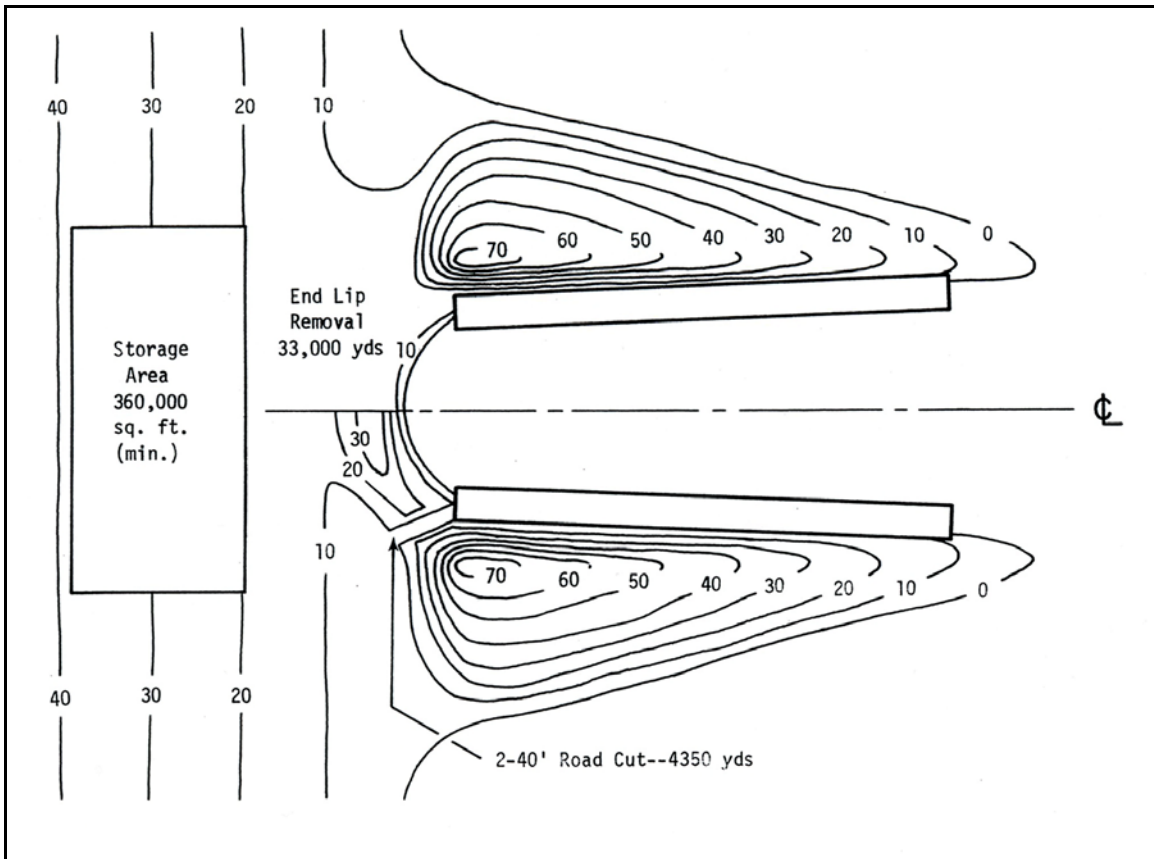


Figure 4.38-2. Plan diagram for the layout of a military harbor at South Point (Warden and Tami 1971, Figure 3).

For nuclear construction both Plowshare explosives and nuclear explosives of the hypothetical family of Atomic Demolition Munitions (ADM) were examined. According to the feasibility study, ADM explosives in the 10 kt range had the added advantage of being team portable and were designed to be used as a demolition munitions against military targets or, as envisioned here, for military construction (Figure 4.38-3). The study concluded that nuclear excavation using Plowshare nuclear explosives was technically feasible and had the advantage of construction time. Excavation time was the controlling factor in comparing nuclear versus conventional techniques and the report concluded that a harbor constructed with nuclear explosives would provide a time savings of 30 weeks. However, the study also concluded that the time advantage of nuclear construction would be lost if ADM explosives were used and that expedient construction for military use might benefit from a new version of the ADM family with low-fission suppressed radiation. The feasibility study for a military harbor at South Point is the final documentation available for the proposed project.

## Atomic Demoliton Munitions

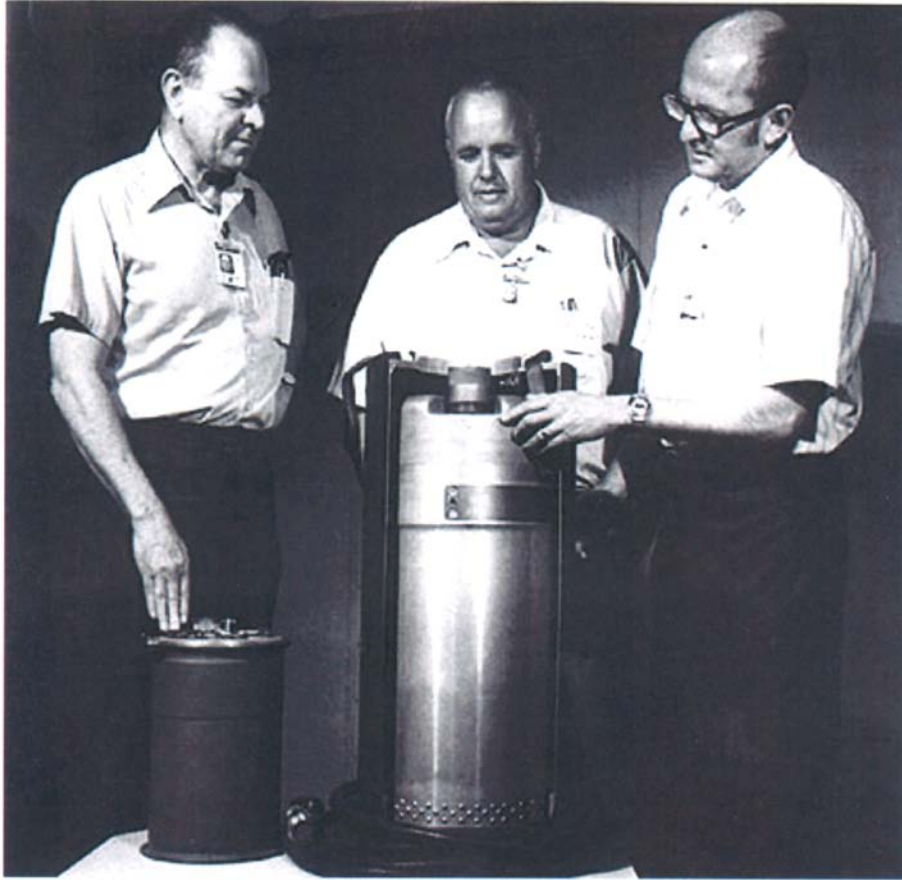


Figure 4.38-3. Photo of scientists displaying warhead (left) and packing container (right) for Atomic Demolition Munitions (<http://www.brook.edu/FP/projects/nucwcost/madm.html>, last accessed October 2007).

South Point Harbor was a Level 5 activity. Research of the South Point area for a harbor project was confined to conceptual design of the project and background research. The project was not executed.

## CHRONOLOGICAL BIBLIOGRAPHY

- McIntire, Elliot G., 1961. Hawaiian Islands: With Special Reference to Kaneohe Bay, Oahu, South Point, Hawaii Waimea District, Kauai. Library Brochure for Pacific Missile Range, Point Mugu, CA, from University of California, Riverside (William L. Thomas, Jr. editor), January 30. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV.
- Graves, Ernest, 1964. "Status Report - Nuclear Explosives Studies for Civil Construction (Reports Control Symbol ENGCE-E-9)." Letter with encl. ("Status Report, Effective Date: 31 December 1963 - ENGCE-E-9") from Ernest Graves, Lawrence Radiation Laboratory, U.S. Army Engineer Nuclear Cratering Group, to Chief of Engineers, Department of the Army, February 4. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.
- Graves, Ernest, 1964. "Status Report - Nuclear Explosives Studies for Civil Construction (Reports Control Symbol ENGCE-E-9)." Memo with Encl. ("Status Report, Effective Date: 31 March 1964 - ENGCE-E-9") from Ernest Graves, Lawrence Radiation Laboratory, U.S. Army Engineer Nuclear Cratering Group, to Chief of Engineers, Department of the Army, April 23. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.
- Slazak, Walter J., 1965. "Status Report - Nuclear Explosives Studies for Civil Construction (Reports Control Symbol ENGCE-E-9)." Memo with encl. ("Status Report, Effective Date: 31 December 1964 - ENGCE-E-9") from Walter J. Slazak, Lawrence Radiation Laboratory, U.S. Army Engineer Nuclear Cratering Group, to Chief of Engineers, Department of the Army, January 15. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.
- Hughes, Bernard C., 1965. "Status Report - Nuclear Explosives Studies for Civil Construction (Reports Control Symbol ENGCE-E-9)." Letter with ("Status Report, Effective Date: 31 March 1965 - ENCGW-P-6(R1)") from Bernard C. Hughes, U.S. Army Engineer Cratering Group, to Chief for Engineers, Department of the Army, April 13. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.
- Midkiff, Frank E., 1968. Letter from Frank E. Midkiff, Bernice P. Bishop Estate, Honolulu, HI, to Glenn T. Seaborg, May 21. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0075928; and Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-078.

- Roos, William F., 1968. Telex from William F. Roos, District Engineer, U.S. Army Corps of Engineers, Honolulu District, to Director, Nuclear Cratering Group, May 22. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-078 [OUO].
- Seaborg, Glenn T., 1968. Letter with encl. (FY 1969 Authorization Hearings before the Senate Commerce Committee, remarks by John S. Kelly) from Glenn T. Seaborg, Chairman, U.S. Atomic Energy Commission, to Frank E. Midkiff, June. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0075933; and Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, PLO-078.
- Midkiff, Frank E., 1968. Letter from Frank E. Midkiff, Bernice P. Bishop Estate, Honolulu, HI, to Glenn T. Seaborg, June 26. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0075934; and Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-078.
- Midkiff, Frank E., 1968. "Nuclear Cratering Project." Memo from Frank E. Midkiff, Bernice P. Bishop Estate, Honolulu, HI, to Trustees, June 26. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-078.
- Hamburger, Richard, 1968. Letter from Richard Hamburger, U.S. Atomic Energy Commission, Division of Peaceful Nuclear Explosives, to Frank E. Midkiff, July 16. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-078.
- Hughes, Bernard C., 1968. Memo with (letter from William F. Roos, U.S. Army Corps of Engineers, Honolulu District, to Frank E. Midkiff, July 25) from Bernard C. Hughes, U.S. Army Engineer Nuclear Cratering Group, to Glenn Werth. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-078.
- Warden, Fred F., and Thomas M. Tami, 1971. Feasibility of Constructing a Military Harbor Using Nuclear Explosives. Lawrence Radiation Laboratory, U.S. Army Engineer Nuclear Cratering Group, *NCG Technical Memorandum* No. NCG/TM 70-12. Livermore, CA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-092.

## 4.39 SPIRIDON LAKE

### Plowshare Program Nuclear Explosives to Construct a Slide Dam Alaska

The project concept for Spiridon Lake was to use nuclear explosives to redesign the drainage of a lake on Kodiak Island in Alaska (Figure 4.39-1). Spiridon Lake is the third largest lake on the island, measuring approximately six miles in length and one mile in width at a surface elevation of 446 ft above mean sea level (Figure 4.39-2). The outlet stream at the south end of the lake drops over a distance of 1.5 miles before reaching Spiridon Bay, crossing steep bluffs that create waterfalls impassable to salmon.



Figure 4.39-1. Location of the proposed Spiridon Lake project on Kodiak Island (adapted from USA Relief Maps 2004).

A discussion about using nuclear explosives to construct a dam at Spiridon Lake for developing salmon habitat was initiated by Karl Brunstad, a resident of the island. In May 1963, in a letter to the Alaska Department of Fish and Game, Brunstad proposed that nuclear explosives be used to construct a landslide dam that would block the outlet stream causing a rise in lake level and diverting the flow to a well established stream system at the north end of the lake. The new drainage system would have a mild gradient over a distance of nine miles before discharging into Shelikof Strait, providing a suitable migration route for salmon to reach the lake (Figure 4.39-3). This, he argued, would be more economical than building salmon ladders on the existing outlet. He also pointed out that the experiment, if successful, could be applied elsewhere. In his letter, Brunstad

suggested that the Alaska Department of Fish and Game put forth the idea to the U.S. Atomic Energy Commission. The letter was eventually forwarded to the U.S. Atomic Energy Commission's Division of Peaceful Nuclear Explosives, who in turn forwarded the inquiry to the Lawrence Radiation Laboratory for their consideration. Meanwhile, in June 1963, the Alaska Department of Fish and Game responded to Brunstad, commenting that conventional explosives might be more economical than nuclear explosives and questioning the desirability of introducing radioactive material into the lake system. The letter from the Fish and Game also mentions that Project Chariot was shelved because of objections by Alaskan residents to the use of nuclear explosives in the Cape Thompson area for harbor excavation.

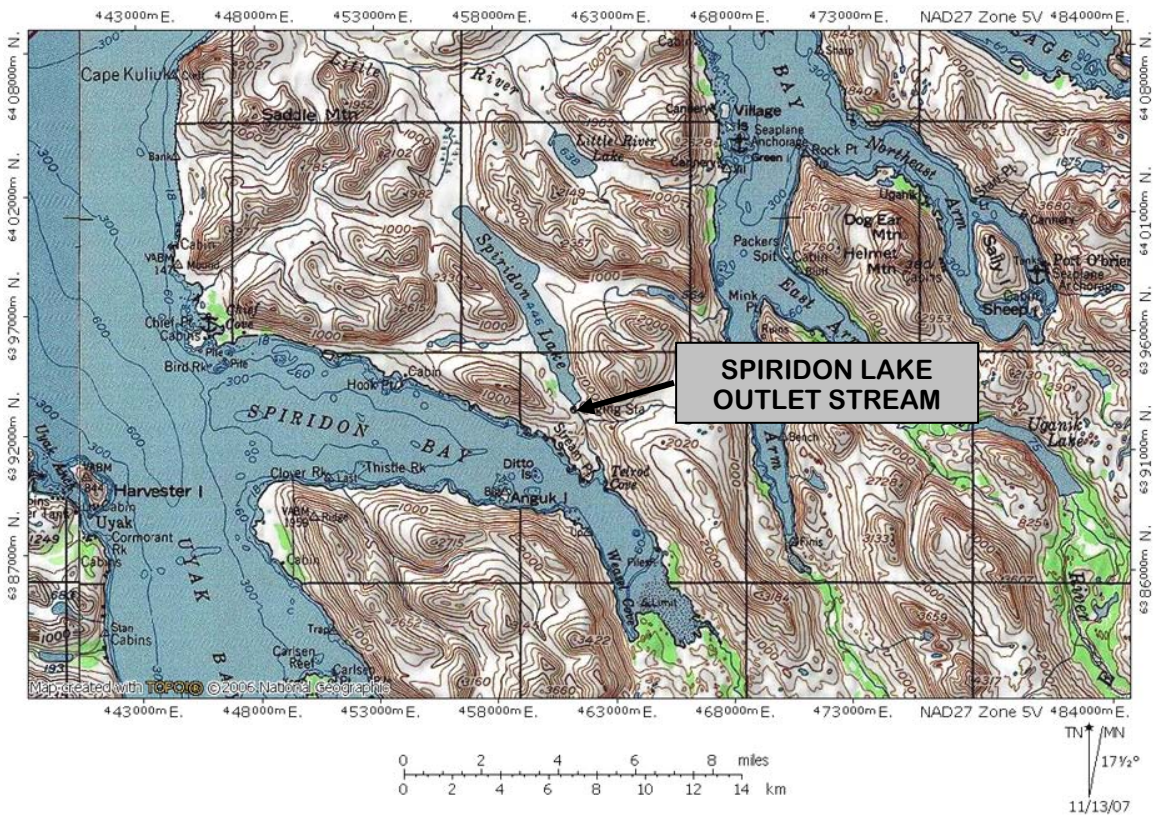


Figure 4.39-2. Location of dam proposed for Spiridon Lake showing the outlet stream and Spiridon Bay (adapted from National Geographic Topographic Maps 2006).

In response, Brunstad wrote directly to the Lawrence Radiation Laboratory in July 1963, including the correspondence from the Alaska Department of Fish and Game. He suggested that scientists from the Laboratory attend meetings of the Pacific Salmon Inter-Agency Council, consisting of representatives from various fishery agencies and the U.S. Fish and Wildlife, to provide information regarding the advantages and possibilities of Plowshare applications. Lawrence Radiation Laboratory responded that they did not have enough information to evaluate the technical feasibility of a Plowshare application at



Spiridon Lake although they did confirm that in some cases nuclear excavation would be more economical than conventional methods.

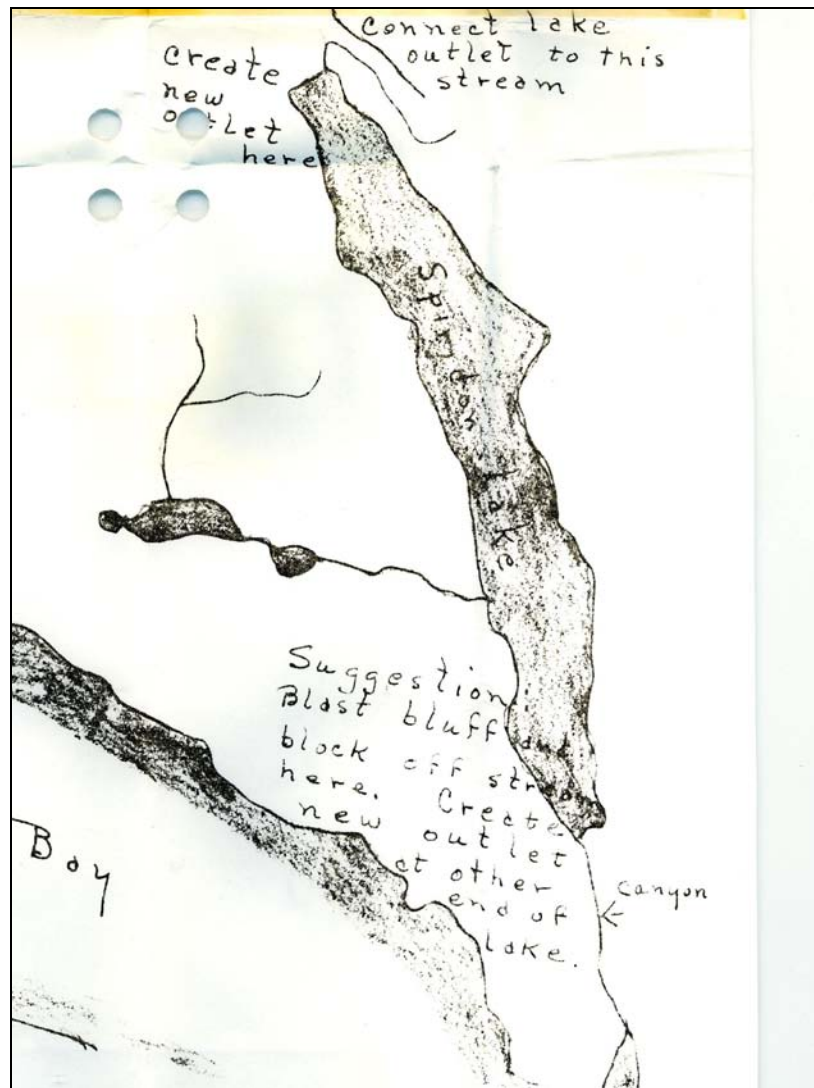


Figure 4.39-3. Drawing showing early project concept for redesigning the drainage of Spiridon Lake [best copy available] (Lawrence Livermore National Laboratory n.d.).

The concept for this project did not end with this correspondence. On February 20, 1964, the State of Alaska Senate passed Resolution No. 9. The resolution was a request that the U.S. Atomic Energy Commission plan and execute a nuclear excavation project at Spiridon Lake. The proposed project was to close the existing Spiridon Lake outlet to allow the lake to drain into Little River. Following this resolution, the correspondence trail is incomplete, but on May 2, 1964, the Governor of Alaska responded to a letter from the Associate Director for Plowshare at the Lawrence Radiation Laboratory referencing Senate Resolution No. 9. The Governor pointed out that the concept for the

project was proposed many years ago by a member of the Alaska Game Commission, but the original proposal did not anticipate the availability of nuclear energy for the project. The Governor outlined the project concept and explained that a detailed study was necessary to determine the project feasibility. A July 1964 report from the Division of Peaceful Nuclear Explosives identifies Spiridon Lake as a project under consideration by the Lawrence Radiation Laboratory. There is no additional documentation for the Spiridon Lake project after 1964.

Spiridon Lake was a Level 5 activity. Activity for this project was confined to conceptual design based on existing data sources.

## **CHRONOLOGICAL BIBLIOGRAPHY**

Brunstad, Karl, 1963. Letter with encl. (drawing of proposed stream for outlet of Spiridon Lake) from Karl Brunstad, Kodiak, AK, to Alaska Department of Fish and Game, May 6. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.

Hamburger, Richard, 1963. Letter from Richard Hamburger, U.S. Atomic Energy Commission, Division of Peaceful Nuclear Explosives, to Karl Brunstad, June 6. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.

Marvich, E. S., 1963. Letter from E. S. Marvich, State of Alaska Department of Fish and Game, to Karl Brunstad, June 24. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.

Brunstad, Karl, 1963. Letter from Karl Brunstad, Kodiak, AK, to Lawrence Radiation Laboratory, July 15. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.

Higgins, Gary H., 1963. Letter from Gary H. Higgins, Lawrence Radiation laboratory, to Karl Brunstad, August 2. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.

Owen and Begich, Senators, 1964. Senate Resolution No. 9: In the Legislature of the State of Alaska, Third Legislature – Second Session, February 20. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.

Egan, William A., 1964. Letter from William A. Egan, Governor, State of Alaska, to Gerald W. Johnson, May 2. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.

U.S. Atomic Energy Commission, 1964. Suggested Nuclear Excavation Projects and Possible Nuclear Excavation Projects. Manuscript, Division of Peaceful Nuclear Explosives, July. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.

Lawrence Livermore National Laboratory, no date. Spiridon Lake map\_05\_a, b, c, d. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA.

**THIS PAGE INTENTIONALLY LEFT BLANK**

## **4.40 SURREY**

### **Plowshare Program Isotope Production Texas and Louisiana**

Project Surrey was in development in 1962 as part of the Plowshare Program. A June 19, 1962 memo from the U.S. Atomic Energy Commission, Nevada Operations Office to Lawrence Radiation Laboratory indicates that the purpose and scope of the Surrey project had been verbally presented to the Nevada Operations Office. The Nevada Operations Office pointed out the need to look at the safety problem related to the Winnfield site (Projects Cowboy and Plowboy), suggesting that the medium for the project was a salt dome. The Nevada Operations Office explained that a more developed project purpose and scope was necessary before initiating the safety evaluation.

An August 15, 1962 memo from the U.S. Atomic Energy Commission, San Francisco Office, to the U.S. Atomic Energy Commission's Nevada Operations Office discusses objectives for a conference with Texas Gulf Sulfur Company regarding Surrey and refers to a recent meeting on site selection for this project. The enlargement of the Surrey project area to a three-mile radius was questioned and information was requested regarding this change. The San Francisco Office recommended that U.S. Atomic Energy Commission commitments with Texas Gulf Sulfur only include obtaining geological data and approval for exploratory drill holes because sufficient site data was not available. The San Francisco Office could commit five to ten thousand dollars for the drilling effort if Lawrence Radiation Laboratory requested authorization for this effort. The Texas Gulf Sulfur Company site was only one of several under consideration for technical acceptability. Several of the other Gulf Coast salt domes being considered for Surrey had been looked at for Vela Uniform Program but were not used in their experiments (Figure 4.40-1).

Surrey was discussed at the Ninth Meeting of the Plowshare Advisory Committee on December 4 and 5, 1962. In the committee report, it states that Surrey was one of the isotope production projects and that these projects required fully tested devices. The committee pointed out that it would be important to obtain information from Project Dribble to advance the design of the Surrey experiment. Project Surrey was described in other documents as a Plowshare cavity experiment tentatively scheduled for the second quarter of FY 1964. In the Atomic Energy Commission's Long-Range Plan 1964-1973 for Plowshare (prepared in March 1963), Surrey is listed as one of the Scientific and Engineering Applications Projects and was rescheduled for FY 1965. There is no additional information on this project and it was not conducted.

The Surrey project was a Level 5 activity as the effort was confined to conceptual design, background research, and meetings.

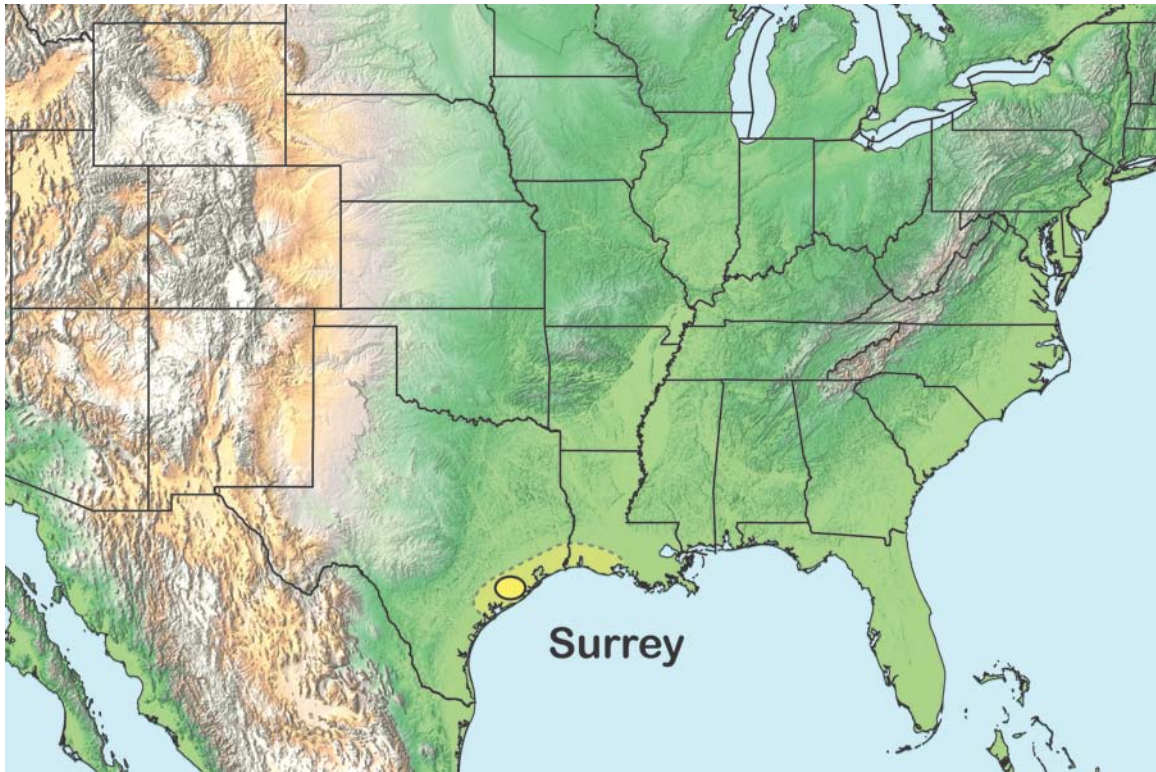


Figure 4.40-1. Proposed locations for Project Surrey in Texas and Louisiana (adapted from USA Relief Maps 2004).

## **CHRONOLOGICAL BIBLIOGRAPHY**

Miller, Robert E., 1962. "Project Surrey." Memo from R. E. Miller, U.S. Atomic Energy Commission, Nevada Operations Office, to Gary H. Higgins, June 19. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0306432.

Philip, John F., 1962. "Approach to Negotiations with Texas Gulf Sulfur Company for Surrey." Telex from John F. Philip, U.S. Atomic Energy Commission, San Francisco Operations Office, to R. E. Miller, August 14. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0306361.

Plowshare Advisory Committee, 1962. Plowshare Advisory Committee, Report on the Ninth Meeting. Meeting held at U.S. Atomic Energy Commission, Nevada Operations Office, Las Vegas, NV, December 4-5. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029 [OUO].

U.S. Atomic Energy Commission, 1963. Long Range Plan, 1964-1973, Peaceful Uses of Nuclear Explosives Program (Plowshare). Report from U.S. Atomic Energy Commission, March 20. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV.

Shafer, David S., William. C. Beck, Dwight Treadwell, and Stephen. A. Mellington, 1995. Inventory of Potential Environmental Restoration Liabilities Associated with Plowshare And Vela Uniform Program Sites. Manuscript, U.S. Department of Energy, Office of Environmental Restoration. On file at: Desert Research Institute, Las Vegas, NV.

**THIS PAGE INTENTIONALLY LEFT BLANK**



## **4.41 SWAN LAKE DAM**

### **Plowshare Program Nuclear Construction of a Rock-Fill Dam Alaska**

In the late 1950s, the Lawrence Radiation Laboratory investigated the possibility of using nuclear explosives to construct earth-fill and rock-fill dams. A preliminary report on the topic was circulated in 1958 and was based on consultations with engineers who specialized in dam construction and design. The report concluded that construction of a rock-fill dam would be feasible using nuclear explosives, although an earth-fill dam would not. The concept of a rock-fill dam was based on the idea of detonating a nuclear explosive in the wall of a canyon to create vast quantities of fractured rock that would be deposited in the canyon, creating a water storage embankment.

The construction of a rock-fill dam was considered possible if the canyon had a hard rock base and gentle sloping sides. In addition, the fractured rock would need to settle prior to constructing an impervious facing on the upriver side of the dam. In the report, Swan Lake in Alaska was selected as a prospective site to demonstrate the application (Figure 4.41-1). Swan Lake is a lake system that drains into Thomas Bay on Frederick Sound approximately 18 miles northeast of Petersburg, Alaska (Figure 4.41-2). The lake is small with a surface area of 514 acres at a surface elevation of 1,514 ft mean sea level. The outlet stream, Cascade Creek, follows a steep descent into Thomas Bay (Figure 4.41-3). Swan Lake was one of a number of lakes in the general area recommended previously by the U.S. Geological Survey for construction of a dam using conventional techniques.

According to the report, the hard rock base in the Swan Lake region is a quartz diorite and plagioclase gneiss, and detonation of a nuclear explosive in this material would provide suitable fractured rock for the foundation of the dam as well as sand and gravel for construction of other dams. The detonation of two 1 kt nuclear explosives emplaced on each side of the canyon was considered sufficient to produce approximately 200,000 tons of fractured rock to form a dam 100 ft high and 400 ft wide across Cascade Creek.

The preliminary report is the only document available mentioning the use of nuclear explosive techniques to construct a dam at Swan Lake. At present, Swan Lake is part of a proposed system of hydroelectric projects for the Thomas Bay Energy Development. Rather than constructing a dam, the project proposes using a lake siphon to draw water from Swan Lake to a powerhouse on Thomas Bay using a 12 ft diameter tunnel 17,000 ft in length. The plan calls for a powerhouse south of the mouth of Cascade Creek, and a transmission line running from the power station south to a substation southwest of Petersburg (Figure 4.41-4).

Swan Lake Dam was a Level 5 activity. Documentation for this project is from a preliminary report that used background research from available sources.



Figure 4.41-1. Proposed location for a rock-fill dam at Swan Lake in southeastern Alaska (adapted from USA Relief Maps 2004).

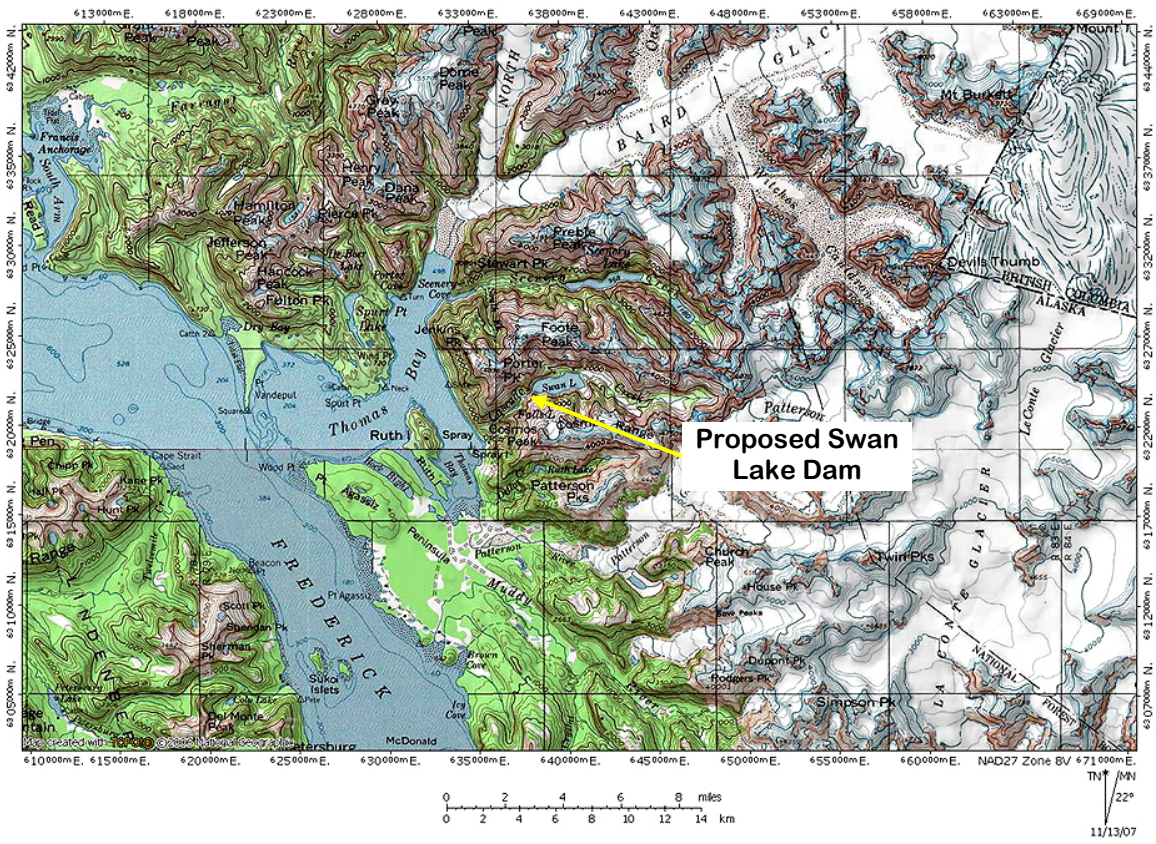


Figure 4.41-2. Proposed location for a rock-fill dam at Swan Lake showing Cascade Creek and Thomas Bay (adapted from National Geographic Topographic Maps 2006).



Figure 4.41-3. Historic photo showing Swan Lake and Cascade Creek (<http://vilda.alaska.edu/cdmg21/image/345.jpg>, last accessed October 2007).

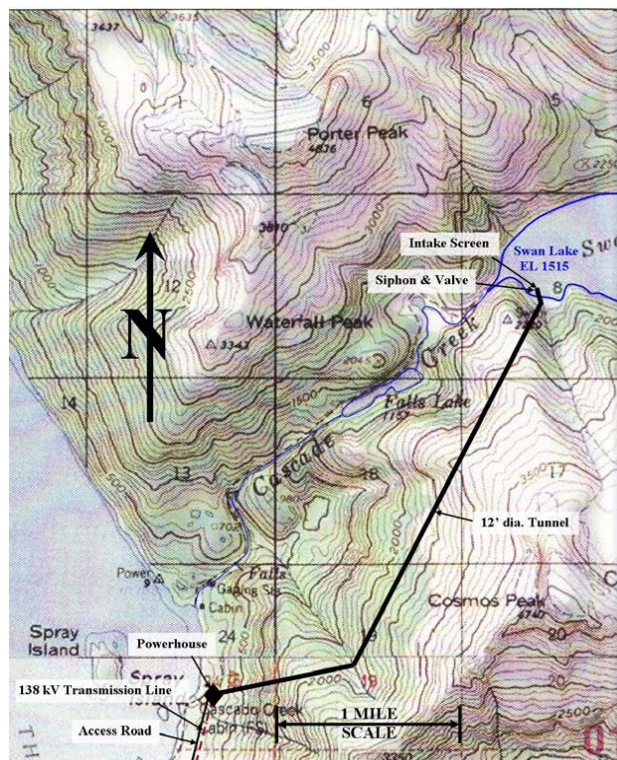


Figure 4.41-4. Map showing current plan for a hydroelectric project at Swan Lake (<http://thomasbayhydro.com/index.html>, last accessed August 2008).

## **CHRONOLOGICAL BIBLIOGRAPHY**

Miles, Robert A., 1958, "Report on Construction of Earth-Fill and Rock-Fill Dams by Nuclear Explosions." Memo with encl. (Construction of Earth-Fill and Rock-Fill Dams by Nuclear Explosions, Manuscript, July 21) to Distribution, September 4. On file at: Archives and Records Center, Lawrence Berkeley National Laboratory, Berkeley, CA, File 434-9001, 2/18.

Thomas Bay Energy Development, <<http://www.thomasbayhydro.com>>, last accessed August 27, 2008.

## 4.42 TAR

### Vela Uniform Program Nuclear Explosive Seismic Monitoring Experiment Mississippi and Texas

Tar was one of three nuclear detonations planned under the 1962 revised theoretical and field experimental Dribble Program. The nuclear explosive seismic monitoring experiments were planned to investigate the theory that the seismic signal of an underground nuclear explosion could be reduced if the detonation occurred in an underground spherical cavity, large enough that the response of the cavity wall would be elastic (referred to as the theory of decoupling). The explosive program called for a 5 kt tamped or coupled shot (Salmon), a 100 ton decoupled shot (Sand), and a 100 ton coupled shot (Tar). Tatum Salt Dome, approximately 20 miles southwest of Hattiesburg, Mississippi, met all the technical criteria for the program and was accepted as the Dribble experimental site in October 1961 (see also Sand – Chapter 4.35) (Figure 4.42-1).

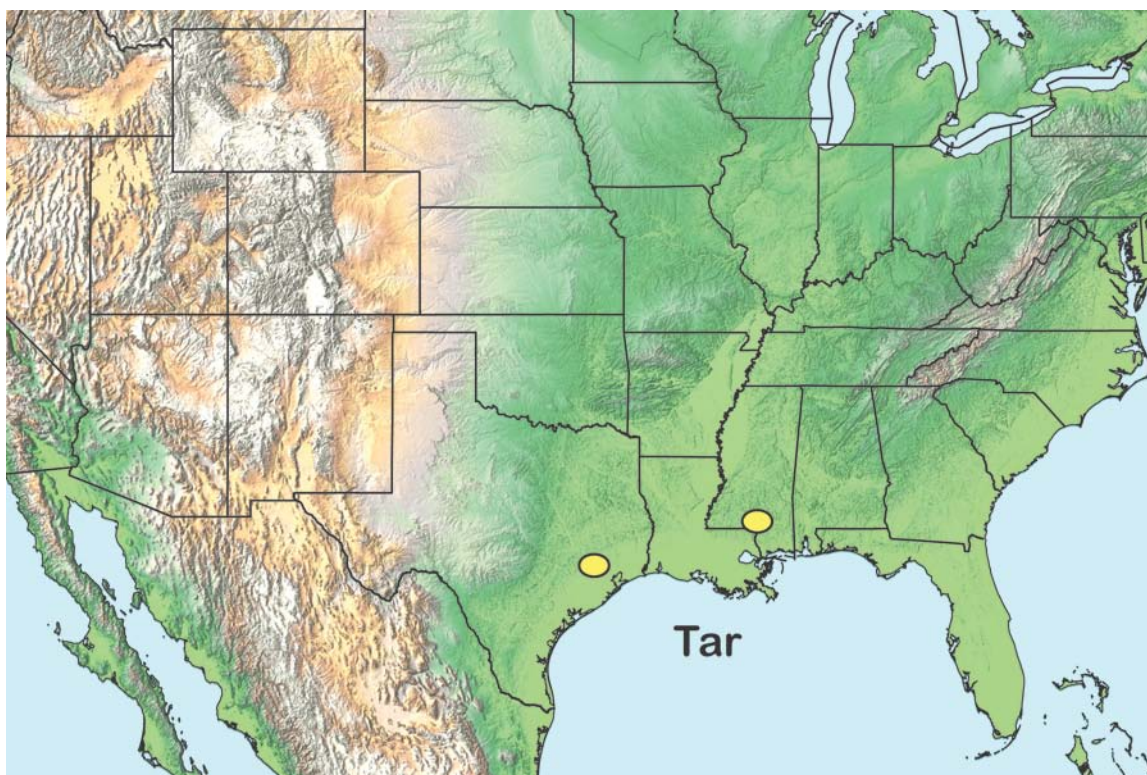


Figure 4.42-1. Proposed locations in Texas and Mississippi for the Tar nuclear explosive test (adapted from USA Relief Maps 2004).

The revised technical concept for the Dribble program issued in September 1962 stated the objectives for the 100 ton coupled explosion. These included determining the source of the seismic function and comparison to the 100 ton decoupled source; measuring and comparing the seismic amplitude of waves in underlying formations out to thirty miles and comparing results with the decoupled explosion; investigation of scaling the 100 ton coupled explosion to the 5 kt coupled explosion; and measuring the yield. By March 1963, the 100 ton coupled experiment was referred to as Tar. The plan for Tar was to drill a 16 inch cased emplacement hole (Station 2) approximately 2,000 ft deep, 700 ft from the Sand shot cavity. Tar was to be conducted two weeks after Sand, a detonation that was initially scheduled for early 1964.

The Dribble program was on schedule until June 1963 when problems were encountered during construction of the emplacement facilities for the Sand detonation at Station 3 when the grout between the casing and the salt formation leaked, causing water seepage into the ventilation and access shaft. Attempted recovery was not successful and the program was put on a stand-by status. By December 1963, the Director of the Division of Military Applications gave authorization to study the Hockley Mine in the Hockley Salt Dome as an alternate location for the Tar and Sand experiments (Figure 4.42-1). The Hockley Dome is in Harris County, Texas, about 35 miles northwest of Houston. The Hockley Mine was owned by the United Salt Company and was located in the north central region of the dome, approximately 5 miles south of the town of Hockley. The mine provided access to the salt deposit and would simplify construction for the emplacement facilities.

During the spring of 1964, a report re-evaluating the Hockley Salt Dome for the Sand and Tar detonations and a report outlining an engineering and construction plan were issued by the U.S. Atomic Energy Commission's Nevada Operations Office. These reports were based on data from a cursory on-site reconnaissance, a review of petroleum industry records, and data collected as part of the Ripple program (original name of Dribble Program). Together the reports provide a conceptual outline of the program including information about the schedule, an outline of the technical program, the engineering and construction plan, and an operational safety plan.

Two alternate sites were selected in the salt dome to execute the project. Both locations were in the area of the existing Hockley Mine shaft (Figure 4.42-2). Construction requirements were the same as specified for the Tatum Dome location—drilling a 16-inch diameter hole to a depth of approximately 2,000 ft below the surface, and 700 ft from the Sand cavity. The report concluded that the Hockley site met necessary technical criteria for the Dribble Program, but detailed on-site studies would be necessary if the site was selected for the Sand and Tar experiments.

In December 1963, at the same time that the study of the Hockley site was authorized, the Division of Military Applications gave authorization for the U.S. Atomic Energy Commission, Nevada Operations Office, to conduct engineering studies and evaluations of construction methods for the Sand and Tar facilities at the Tatum Salt Dome. The report was issued in May 1964 and concluded that drilling problems at Tatum could be

resolved. The emplacement facility for the Tar shot at Tatum Salt Dome (Station 2) would require a hole 2,000 ft deep with a 17 ½ inch diameter.

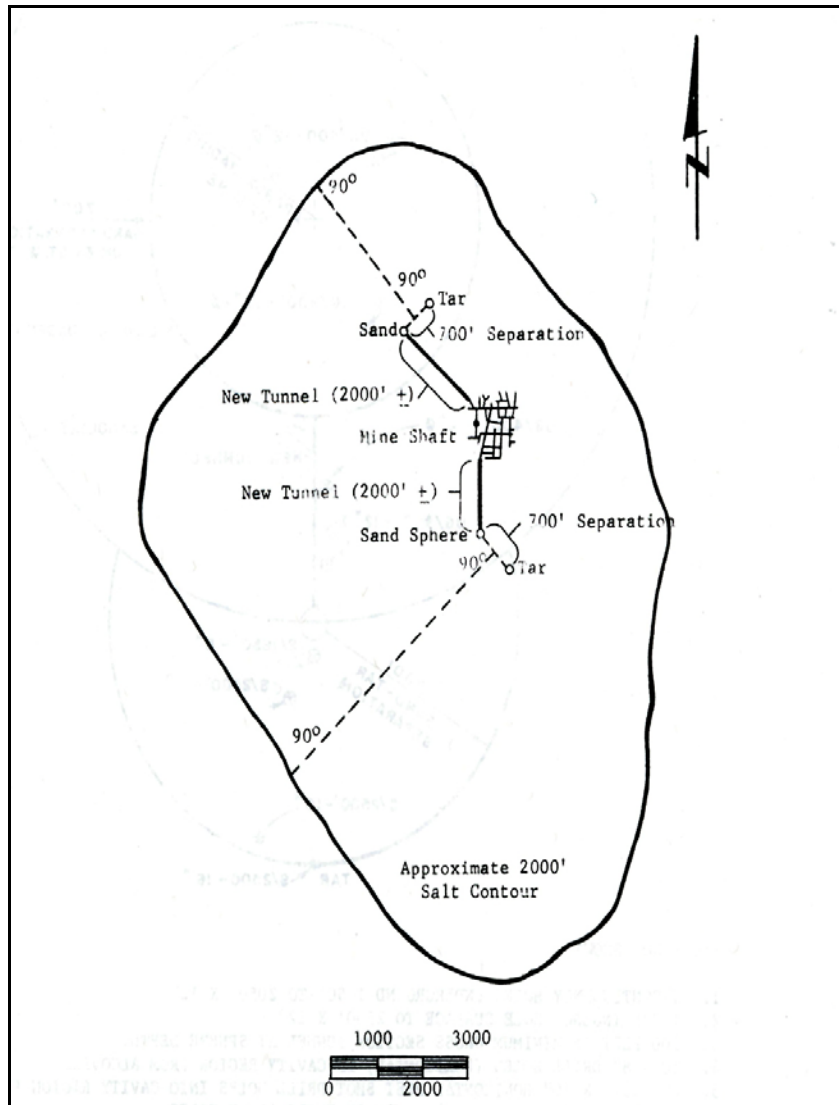


Figure 4.42-2. Location of the proposed Sand and Tar experiments at the Hockley Salt Mine (U.S. Atomic Energy Commission. Nevada Site Office 1964b, no figure number).

In the available documentation there is little mention of the Tar detonation after the May 1964 reports on the Hockley site and Tatum Dome. A report on Project Dribble, issued on August 1, 1964, mentions that the construction of facilities for the Tar and Sand detonation at the Tatum Dome (Station 2 and Station 3a) had not yet been authorized. The Salmon nuclear test was conducted in October 1964, but there was no mention of any plan to conduct the Sand and Tar experiments and it appears that these were cancelled.

However, on December 3, 1966, a 380 ton nuclear decoupling test was conducted in the Salmon Cavity as Project Sterling.

The Tatum Salt Dome is a Department of Energy monitored site. Tar was a Level 4 activity at the Hockley Salt Dome where a pre-existing mine was used to study the salt deposit.

## **CHRONOLOGICAL BIBLIOGRAPHY**

Lawrence Radiation Laboratory, 1962. LRL Technical Concept, Project Dribble, September 10, 1962. Manuscript, Lawrence Radiation Laboratory, September 10. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-013.

Werth, Glenn C., and Phillip Randolph, 1963. Prepared Statement on the Theory of Decoupling and the Status of Project Dribble, for the Joint Committee on Atomic Energy, Congress of the United States. University of California, Lawrence Radiation Laboratory, *Report UCRL-7323*, March 6. Livermore, CA. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV.

Fenix & Scisson, Inc., and Petroleum Consultants, 1964. Project Dribble, Critical Hole Summary, Tatum Dome, Lamar County, Mississippi. Report to U.S. Atomic Energy Commission, Nevada Operations Office, from Fenix & Scisson, Inc. and Petroleum Consultants, Tulsa, OK and Houston, TX, January. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV.

U.S. Atomic Energy Commission, 1964. "AEC Seeks Bids on Drilling for Project Dribble in Mississippi." Press Release from U.S. Atomic Energy Commission, January 16. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.

Lawrence Radiation Laboratory, 1964. "Unclassified TWX MA:358-1, Betts to Reeves, Info R. E. Batzel, dated 12/24/63." Letter from Lawrence Radiation Laboratory to Brigadier General Delmar Crowson, February 24. On file at: Lawrence Berkeley National Laboratory, Berkeley, CA, File 434-900205, 5/48.

Holmes & Narver, Inc., 1964. Dribble Composite Plan. Report to U.S. Atomic Energy Commission, Nevada Operations Office, from Holmes & Narver, Inc., Las Vegas, NV, May. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV.



- U.S. Atomic Energy Commission. Nevada Operations Office, 1964a. Conceptual Engineering and Construction Plan for Tar and Sand Events at Hockley Salt Dome, Project Dribble. Manuscript, U.S. Atomic Energy Commission, May. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV.
- U.S. Atomic Energy Commission. Nevada Operations Office, 1964b. Re-Evaluation of the Hockley Site, Project Dribble. Manuscript, U.S. Department of Energy, May. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV.
- Fenix & Scisson, Inc., 1964. A Report on Engineering Studies to Provide Station 3A, Project Dribble. Report to U.S. Atomic Energy Commission from Fenix & Scisson, Inc. Tulsa, OK; and Petroleum Consultants, Houston, TX, May 13. On file at: Technical Reports Library, Lawrence Livermore National Laboratory, Livermore, CA.
- Seaborg, Glenn T., 1964. Letter from Glenn T. Seaborg, U.S. Atomic Energy Commission, to The President (Lyndon B. Johnson), May 30. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Las Vegas, NV, Accession No. 0075430.
- Patterson, Dan W., 1964. Theory of Nuclear Explosion in a Cavity Including the Effects of Shock and Nonelastic Effects on the Wall and Comparison with Tamped Explosions - Project Dribble. University of California, Lawrence Radiation Laboratory, *Report UCRL-7916*, June 8. Livermore, CA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-012 and PLO-029.
- Lawrence Radiation Laboratory, 1964. Technical Director's Operations Plan, Project Dribble, Salmon Event, July 1964. Manuscript, Lawrence Radiation Laboratory, Livermore, CA.
- U.S. Atomic Energy Commission. Nevada Operations Office, 1964. Project Dribble Facilities and Support Execution. Manuscript, U.S. Department of Energy, Las Vegas, NV, July. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV.
- U.S. Department of Defense and U.S. Atomic Energy Commission, 1964. Project Dribble. Manuscript, U.S. Department of Defense, Hattiesburg, MS; and U.S. Atomic Energy Commission, Las Vegas, NV, August 1. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas NV; and Technical Reports Library, Lawrence Livermore National Laboratory, Livermore, CA.

**THIS PAGE INTENTIONALLY LEFT BLANK**

## **4.43 TENNESSEE-TOMBIGBEE WATERWAY**

### **Nuclear Excavation of a Canal Plowshare Program Mississippi**

The Tennessee-Tombigbee Waterway project was a proposed inland waterway system to connect the Tennessee River in northeastern Mississippi with the Tombigbee River in west-central Alabama, authorized by the U.S. Congress in the 1946 River and Harbor Act. The plan called for construction of a series of locks and dams and a canal that would connect the watersheds of the two river systems. Once completed the project would provide a 253 mile long continuous navigable waterway from the Tennessee and Ohio valleys to the Gulf of Mexico at Mobile, Alabama (Figure 4.43-1). In May 1963, funds were obligated to conduct a study of a nuclear excavation component for the project. The project concept was to use nuclear explosives to excavate portions of the canal in northeastern Mississippi that crossed a ridge dividing the Tennessee Valley from the headwaters of the Tombigbee River (Figure 4.43-2). A status report from the U.S. Army Engineer Nuclear Cratering Group with an effective date of March 31, 1964, states that the U.S. Army Corps of Engineers, Mobile District, and the Mississippi Industrial and Technological Research Commission had agreed to undertake a cooperative feasibility study for nuclear excavation of the divide cut. The Mobile District would perform the engineering design and the Commission would study the social and economic impacts of the project.

In January 1965, the Mississippi Research and Development Center issued their report on economic factors relating to using nuclear explosives to excavate the divide cut, and a copy of the document was included as an appendix in a feasibility study for the project that was issued in February 1966. The study was based on cost and safety studies conducted over the past several years and provided a summary of the general economy, physical man-made features (i.e., residences, commercial and industrial facilities, power transmission lines, etc.), land use, cultural features, and local geology (with emphasis on water resources). The study also examined possible impacts from fallout, airblast damage, seismic damage, and other safety factors and included a series of maps illustrating predicted effects of a nuclear detonation in the geographic region surrounding the project location.

According to a status report from the Nuclear Cratering Group dated March 31, 1965, a draft feasibility study for the nuclear excavation of the Tennessee-Tombigbee divide cut was prepared by the U.S. Army Corps of Engineers, Mobile District. Copies of the document were sent to the U.S. Atomic Energy Commission's Nevada Operations Office and Lawrence Radiation Laboratory for review. A copy of this document has not been obtained, but letters from the Sandia Corporation to the Nevada Operations Office express concern about safety aspects of the project. The correspondence mentions potential problems with fallout in a populated area, the magnitude of airblast and seismic hazards, ground water contamination, and uncertainties about the phenomenology of a nuclear

explosion in a water-saturated medium. According to the scientists at Sandia, additional information was needed from weather data, dairy census data, ground water studies, and local studies of the geology, before the safety of the project could be evaluated.

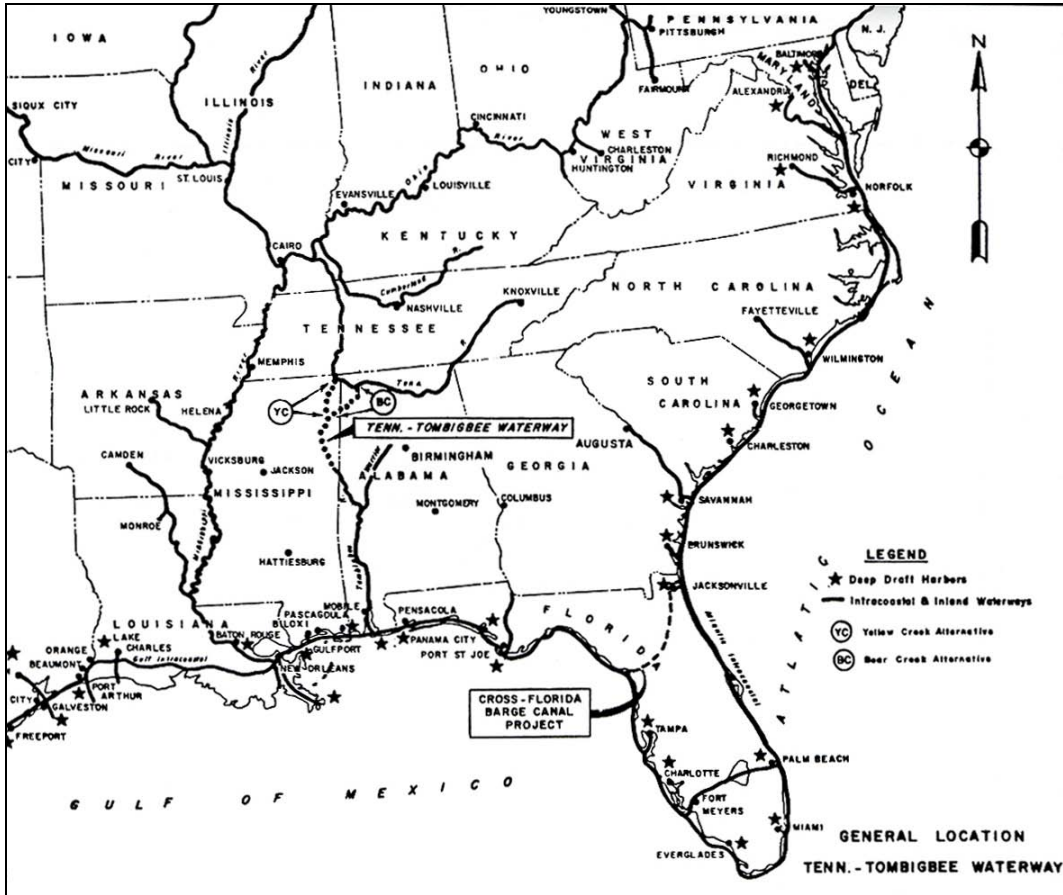


Figure 4.43-1. The Tennessee-Tombigbee Waterway Project was authorized by Congress in 1964 and would connect the Tennessee River in northeastern Mississippi with the Tombigbee River in west-central Alabama, providing a navigable waterway from the Tennessee and Ohio River Valleys to the Gulf of Mexico (U.S. Army Engineer District, Mobile Corps of Engineers 1966, Appendix A, Figure 1).

An appraisal of the nuclear excavation of a divide cut for the Tennessee-Tombigbee Waterway was prepared by the Nevada Operations Office and submitted on May 28, 1965 and included as an appendix in the February 1966 feasibility study. The purpose of the appraisal was to review the safety hazards of the proposed nuclear excavation project. The Nevada Operations Office was responsible for program safety and their review incorporated concern about the safety factors enumerated by the Sandia Corporation. Lt. Colonel Walter Slazak, the Director of the U.S. Army Engineer Nuclear Cratering Group, responded to the review by the Nevada Operations Office in a July 1965 letter. According



Figure 4.43-2. Location of the area proposed for nuclear excavation of a section of the Tennessee-Tombigbee Waterway in northeastern Mississippi (adapted from USA Relief Maps 2004).

to Slazak, the high “cost” estimates for nuclear operations and public safety provided a “pessimistic impression of the practicability of nuclear excavation.” Slazak was concerned that the unfavorable safety assessment would reflect poorly not only on the Tennessee-Tombigbee project, but on other nuclear excavation projects as well. He requested that the project be re-evaluated by the Nevada Operations Office to allow for the possibility that initial site investigations might indicate lower adverse conditions than initially assumed. James E. Reeves, the manager for the Nevada Operations Office, responded in a letter dated September 13, 1965, and reiterated his position that there were serious safety problems with nuclear excavation for Tennessee-Tombigbee due in part to the geographic location of the project. The letter was included in an appendix in the final feasibility study.

The final feasibility study for a nuclear excavation component for the Tennessee-Tombigbee Waterway was prepared by the U.S. Army Corps of Engineers, Mobile District, and issued on February 15, 1966. The study provides a description of the project environment, engineering design, scheduling, effects of project on safety, and cost comparisons with conventional excavation methods. As outlined in the study, the scope of the project was to use nuclear excavation techniques to excavate the divide that separated the Tennessee River from the headwaters of the Tombigbee River. Three routes were considered for the feasibility study: the Yellow Creek route, the Kentucky Pool route, and the Bear Creek route (Figure 4.43-3). The Yellow Creek route was the alignment authorized for construction using conventional means. However, this route was not selected for nuclear excavation because of projected problems with slope stability, a problem that also held for the Kentucky Pool route. The Bear Creek route had been excluded from previous selection studies because of the large volume of rock that would need to be excavated, but it was this attribute that made it the only feasible route for nuclear excavation. Specifically, the plan was to excavate a canal 200 to 300 ft wide from Mackays Creek to Bear Creek, a distance of about 5.3 miles (referred to as the Bear Creek Divide). Details of the excavation and detonation plan were illustrated in a diagram in the feasibility report (Figure 4.43-4). According to estimates the excavation could be accomplished with 81 nuclear devices emplaced along the centerline of the canal, ranging in explosive yield from 10 to 50 kt with a yield of 1.9 megatons in all. Post detonation mechanical means and chemical explosives would be used to complete the cut.

The feasibility study provided cost estimates for the use of conventional techniques alone, and compared the estimate to the combined use of nuclear and conventional techniques. The estimates indicated that nuclear excavation would increase costs by 31 to 73 percent depending on the required measurement for the bottom width of the cut. Thus, the cost-benefit analysis showed that nuclear excavation of the divide was not economically feasible. Also, the study mentioned that the proposed project location in a heavily populated farming area with approximately 345,000 people living within a 50-mile radius of the project site posed substantial safety costs. According to the feasibility study the proposed nuclear detonation would cause severe to total damage of a number of communities from fallout, groundwater contamination, air blast damage, and seismic damage, creating additional high costs for the project.

In a letter dated May 4, 1967, Lt Colonel Maurice K. Kurtz, Jr., the Acting Director of the U.S. Army Engineers Nuclear Cratering Group, informed Michael M. May, the Director of the Lawrence Radiation Laboratory, that based on the results of the feasibility study the Tennessee-Tombigbee divide cut was no longer being considered for a Plowshare demonstration of nuclear excavation technology.

Funds were appropriated for construction of the Tennessee-Tombigbee Waterway in 1971. In December 1984, after 12 years of construction including 10 locks and dams and excavation of the divide along the Yellow Creek route for a canal, the 232 mile inland waterway was completed. Construction of the Tennessee-Tombigbee Waterway required conventional excavation of approximately 310 million cubic yards, making it the largest earth moving project in history.

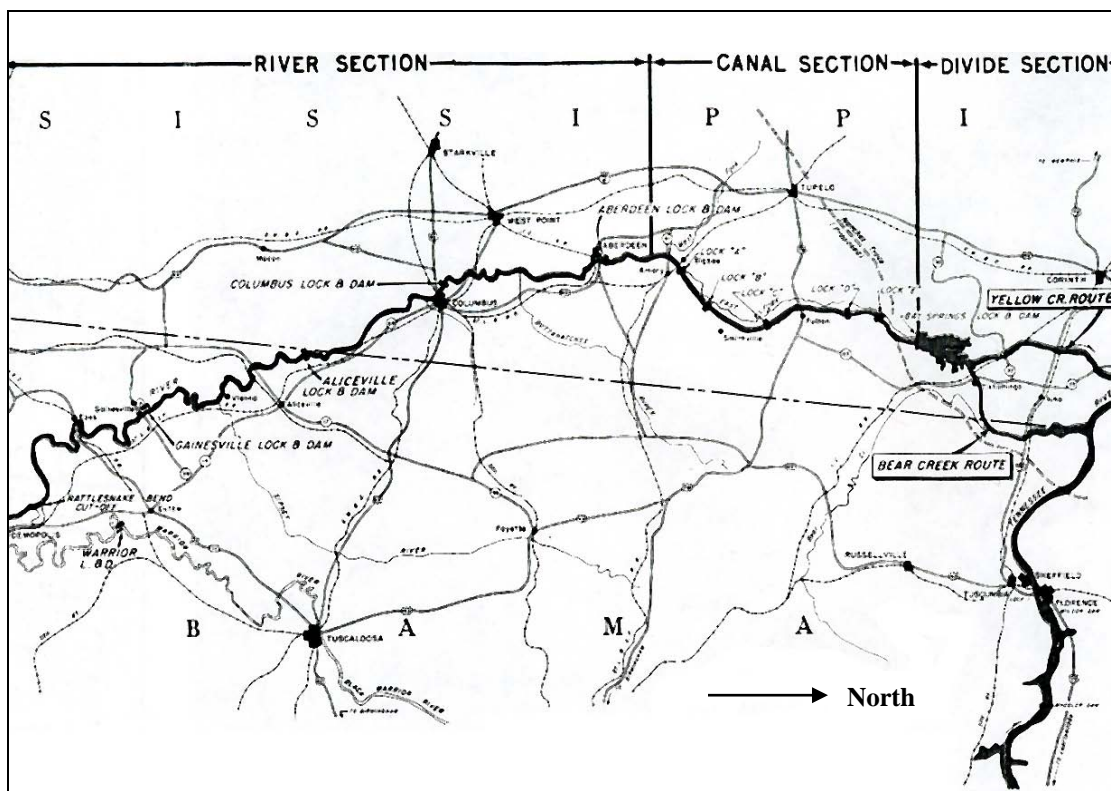


Figure 4.43-3. Map showing the location of the Yellow Creek route planned for conventional excavation and the Bear Creek route proposed for nuclear excavation (adapted from U.S. Army Engineer District, Mobile Corps of Engineers 1966).

Tennessee-Tombigbee Waterway was a Level 5 activity. Activity for the project was limited to conceptual design, background research, and visual field inspections.

**THIS PAGE INTENTIONALLY LEFT BLANK**



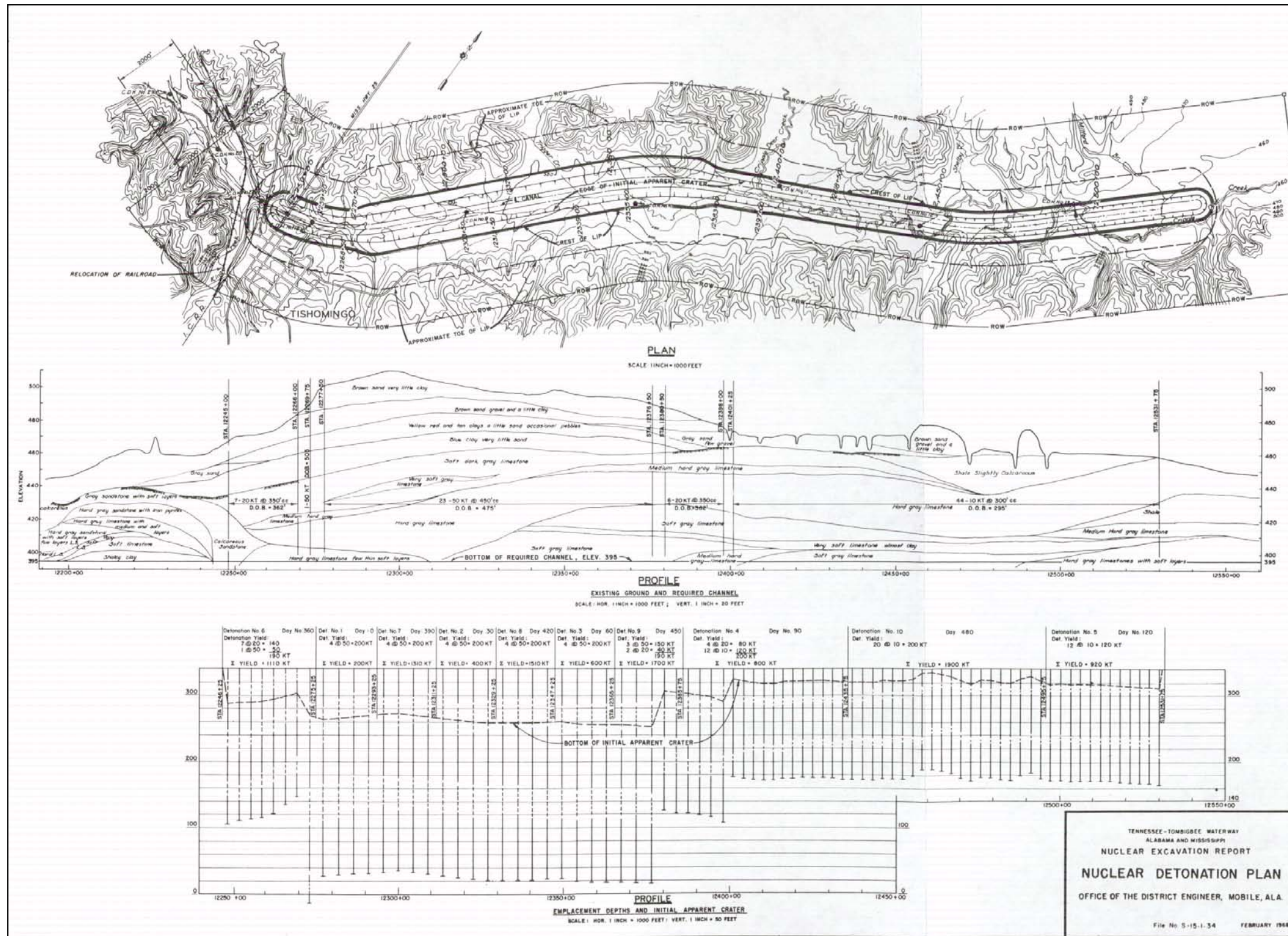


Figure 4.43-4. Schematic showing the nuclear detonation plan for the Bear Creek divide cut excavation (U.S. Army Engineer District, Mobile Corps of Engineers 1966).

**THIS PAGE INTENTIONALLY LEFT BLANK**

## CHRONOLOGICAL BIBLIOGRAPHY

Suttle, Andrew D., 1963. Letter from Andrew D. Suttle, Office of the Director of Defense Research and Engineering, Washington, D.C., to Edward Teller, January 2. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.

Graves, Ernest, 1964. "Status Report - Nuclear Explosives Studies for Civil Construction (Reports Control Symbol ENGCE-E-9)." Memo with encl. ("Status Report, Effective Date: 31 March 1964 - ENGCE-E-9") from Ernest Graves, Lawrence Radiation Laboratory, U.S. Army Engineer Nuclear Cratering Group, to Chief of Engineers, Department of the Army, April 23. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.

U.S. Atomic Energy Commission, 1965. Plowshare Program. In *Annual Report to Congress of the Atomic Energy Commission for 1964*, pp. 155-176, January. U.S. Atomic Energy Commission, U.S. Government Printing Office, Washington D.C.

Plowshare Advisory Committee, 1965. Plowshare Advisory Committee, Report on Thirteenth Meeting. Meeting held at Lawrence Radiation Laboratory, Livermore, CA, January 12-13. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029 [OUO].

Slazak, Walter J., 1965. "Status Report - Nuclear Explosives Studies for Civil Construction (Reports Control Symbol ENGCE-E-9)." Memo with encl. ("Status Report, Effective Date: 31 December 1964 - ENGCE-E-9") from Walter J. Slazak, Lawrence Radiation Laboratory, U.S. Army Engineer Nuclear Cratering Group, to Chief of Engineers, Department of the Army, January 15. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.

Merritt, M. L., 1965. Letter from M. L. Merritt, Sandia Corporation, to Robert E. Miller, March 29. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-065.

Merritt, M. L., 1965. Letter from M. L. Merritt, Sandia Corporation, to Robert E. Miller, March 31. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-065.

Hughes, Bernard C., 1965. "Status Report - Nuclear Explosives Studies for Civil Construction (Reports Control Symbol ENGCE-E-9)." Letter with encl. ("Status Report, Effective Date: 31 March 1965 - ENCGW-P-6(R1)") from Bernard C. Hughes, U.S. Army Engineer Cratering Group, to Chief for Engineers, Department of the Army, April 13. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.

- Slazak, Walter J., 1965. Letter from Walter J. Slazak, Lawrence Radiation Laboratory, U.S. Army Engineer Nuclear Cratering Group, to James E. Reeves, July 16. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-065.
- Tennessee-Tombigbee Waterway Development Authority, [1965]. "The Connecting Link, An Important Asset to the Expanding Industrial South." Brochure, Tennessee-Tombigbee Waterway Development Authority, Columbus, MS. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-065.
- U.S. Army Engineer District, Mobile Corps of Engineers, 1966. Tennessee-Tombigbee Waterway, Divide Cut, Nuclear Excavation Feasibility Study. Manuscript, U.S. Army Engineer District, Mobile Corps of Engineers, Mobile, AL, February 15. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-065 [OUO].
- Kurtz, Maurice K., 1967. Letter from Maurice K. Kurtz, U.S. Army Engineer Nuclear Cratering Group, to Michael M. May, May 4. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-065.
- Kurtz, Maurice K., 1967. Letter from Maurice K. Kurtz, Jr., Lawrence Radiation Laboratory, U.S. Army Engineer Nuclear Cratering Group, to Glenn Werth, August 2. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029 [OUO].
- Lawrence Radiation Laboratory. U.S. Army Engineer Nuclear Cratering Group, 1968. Engineering Applications of Nuclear Explosives, Bi-Monthly Statistics of NCG Technical Reports, Memoranda, and Studies. Manuscript, February 15. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV.
- Vortman, L. J., 1969. Nuclear Excavation. Report, SC-DC-69-1716, Underground Physics Division, Sandia Laboratories, Albuquerque, NM, March. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-104.
- Hughes, Bernard C., 1969. History of the U.S. Army Engineer Nuclear Cratering Group. Lawrence Radiation Laboratory, January. Livermore, CA.
- Tennessee-Tombigbee Waterway Development Authority, 2007.  
<<http://www.tenntom.org/about/ttwconstructio.htm>>. Last accessed July 22, 2008.

## 4.44 WEST VIRGINIA EARTHQUAKE

### **Vela Uniform Program Earthquake Seismic Data West Virginia**

Over the last four decades, one of the primary goals of the Vela Uniform program was to improve the United States seismic verification capabilities in order to accurately distinguish between natural seismic events, chemical explosions, and low yield nuclear detonations. The Long Range Seismic Measurements program was a key component of early U.S. nuclear test detection efforts. Administered by the Advanced Research Projects Agency, the Long Range Seismic Measurements program established a network of seismic monitoring stations to gather data from all types of seismic sources. While the program was critical to the explosion monitoring and detection efforts, it also benefited researchers investigating general seismological phenomenon.

The Long Range Seismic Measurements Program recorded an earthquake in West Virginia that occurred along the state's southern border near the community of Beckley on November 25, 1964 at 02:50:04 GMT (Figure 4.44-1). The epicenter of the 3.95 magnitude quake was originally plotted at 37°18'N Latitude 81°48'W Longitude approximately 13.3 km below the surface. The U.S. Coast and Geodetic Survey supplied this event description to the program seismologists.

Data gathering for the West Virginia Earthquake project included recordings from the permanent seismic installations at Wichita Mountains Seismological Observatory in Lawton, Oklahoma; the Blue Mountains Seismological Observatory in Baker, Oregon; the Uinta Basin Seismological Observatory in Vernal, Utah; the Cumberland Plateau Seismological Observatory in McMinnville, Tennessee; and the Tonto Forest Seismological Observatory, in Payson, Arizona. Mobile field teams scattered across the continental United States and southern Canada also documented the event. As with the previous seismic studies for the Colona and New Madrid earthquakes (see Colona Earthquake and New Madrid Earthquake this volume), vans were equipped with portable three-component short-period Benioff seismographs and three-component long-period Sprengnether seismographs. Both types of instruments recorded the shock wave signals on 35-mm film and magnetic tape. Seismic data for the project were also obtained from several experimental or temporary stations operated in connection with other research programs. These included facilities in Adak Island, Alaska; Oslo, Norway; Grafenberg, Germany; and La Paz, Bolivia.

Thirty-six monitoring locations were used to record the West Virginia Earthquake. Twenty-five were west of the Mississippi River and eleven were to the east of the river (Figure 4.44-2). At the time of the quake, nearly a quarter of mobile stations were concentrated in Arizona around the Tonto Forest Observatory. Only the Beckley, West Virginia station, located 180 km from the epicenter, picked up both short- and long-

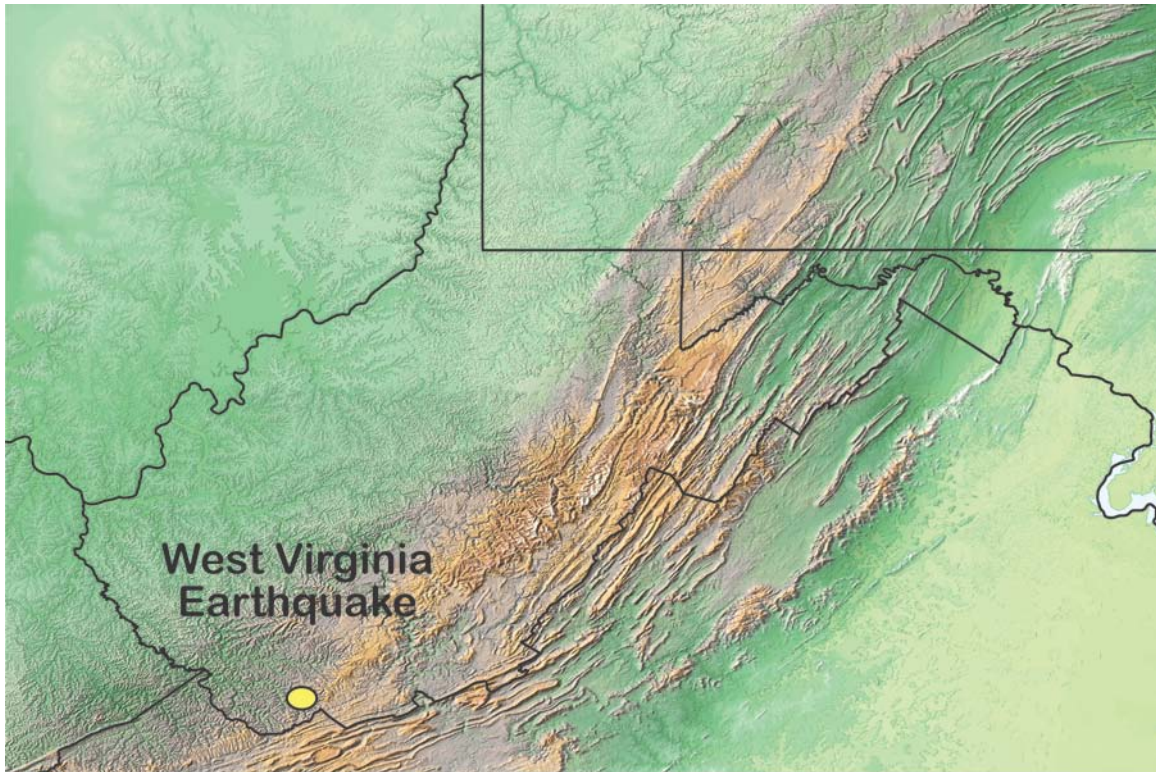


Figure 4.44-1. Location of West Virginia Earthquake in West Virginia (adapted from USA Relief Maps 2004).

period shock waves from the quake. Twenty-five locations recorded short-pulse signals. No signals were recorded at the Adak Island station or at two of the Canadian facilities and none of the overseas stations registered any signals from the seismic event.

Like other Long Range Seismic Measurements projects, the West Virginia Earthquake provided valuable comparative data on seismic wave attenuation patterns and amplitude curves. With each project, improvements were made in the detection instrumentation and seismic systems. Because of the 1963 Test Ban Treaty, accurately determining the epicenter or hypocenter location became increasingly important in discriminating between natural and explosive seismic sources. Based on the data obtained from the Long Range Seismic Measurements seismic network, the epicenter of the West Virginia quake was recalculated as 37°26'13"N Latitude 81°45'43"W Longitude, a shift of about 21 km to the north-northeast. The time of origin was also adjusted with the computed event time set approximately three minutes later. The comparative study also revealed differences in the rate of attenuation of the higher frequency signals when compared to readings obtained from underground nuclear tests. The seismic signature for the West Virginia quake exhibited higher frequency shock waves than those from most nuclear explosives.

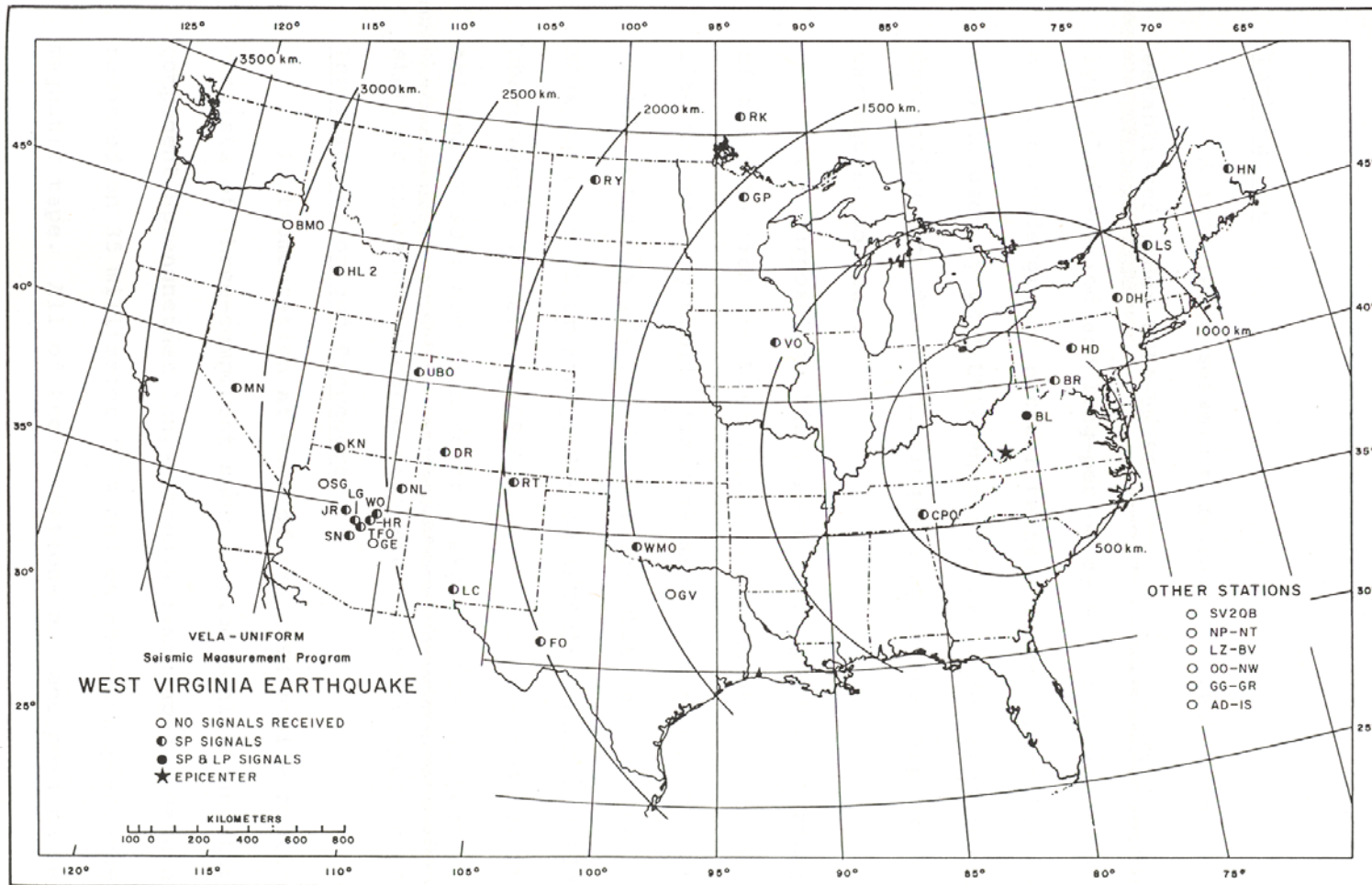


Figure 4.44-2. Distribution of seismic recording stations and signals received for the West Virginia Earthquake (Teledyne 1965, Figure 1).

Long Range Seismic Measurements data analysis for the West Virginia Earthquake appears to have been completed by mid-1965. Field activity was limited to the use of the permanent seismic observatories and the temporary placement of the mobile seismic monitoring vans. While some of the mobile units remained in place for several months or longer, most units were relocated on a regular basis either to record a planned series of nuclear detonations or to monitor areas experiencing elevated levels of natural seismic activity.

The West Virginia Earthquake was a Level 4 activity with data gathered from existing instrumentation.

### **CHRONOLOGICAL BIBLIOGRAPHY**

Teledyne, Inc., 1965. West Virginia Earthquake, 25 November 1964: Long Range Seismic Measurements Project 8.4. Report to Air Force Technical Applications Center from UED Earth Sciences Division, Seismic Data Laboratory Report No. 117, Alexandria, VA, March 1. On file at: Technical Reports Library, Lawrence Livermore National Laboratory, Livermore, CA.

Marshall, P. D., and A. Douglas, 1985. Earthquake or Explosion: Teleseismic Monitoring – Where Are We Now? In *The Vela Program: A Twenty-Five Year Review of Basic Research*, Ann U. Kerr, editor, pp. 633-657. Defense Advanced Research Projects Agency, Arlington, VA.



## 4.45 WHEELBARROW

### Plowshare Program Limestone Chemical Experiment for Mining and Petroleum Recovery West Virginia

The Wheelbarrow project was a proposed underground nuclear chemical experiment in a limestone medium with Plowshare applications. At a closed Gnome Review Committee meeting (date unknown), Gerald Johnson requested consideration for a contained nuclear detonation experiment in limestone. At an open Gnome committee meeting on March 13, 1961, Lawrence Radiation Laboratory personnel presented the proposal for this project. Gnome was a Plowshare nuclear experiment that was conducted in New Mexico to study the feasibility of converting nuclear explosive energy into heat for the production of electrical power. Although the Gnome project was not related to Wheelbarrow, the committee meeting offered the opportunity to discuss the proposed limestone experiment. Of scientific interest was a prediction that a nuclear detonation in a limestone environment would produce large quantities of uncondensable gases that might significantly change the physical processes associated with the explosion. This was a very different scenario from experiments in other media that produced non-condensable gases.

An April 6, 1961 review of the limestone experiment proposal by other Lawrence Radiation Laboratory personnel pointed out that this project was conceived as basic physics and chemistry research and overlooked possible Plowshare applications. Limestone is commonly found with mineral and petroleum deposits and the Plowshare participants thought this experiment could provide valuable information for Plowshare applications in mining and petroleum recovery. Six site selection criteria were presented: 1) 95% to 99%  $\text{CaCO}_3$  (lime) content, 2) water less than 10% of volume, 3) working point to have 500 ft of limestone in all directions in a limestone interval 2,000 ft thick, 4) medium to be compact, massive and structurally homogeneous, 5) include an outcrop, if possible, and 6) terrain suitable for surface drilling. The U.S. Geological Survey had identified 19 possible sites with plans for Lawrence Radiation Laboratory geologists to inspect the most promising locations. The Gnome Committee recommended that a second committee review the limestone proposal in six months to a year after a technical document was written that included progress on the research regarding chemical reactions, laboratory explosions, and theoretical calculations as well as a review of site selection criteria, and an explanation regarding how this shot would contribute to understanding underground explosions. An April 7, 1961 U.S. Atomic Energy Commission report on the Plowshare Program mentions this unnamed limestone experiment and, sometime after April 1961, the experiment was temporarily named Streetcar.

The limestone experiment was approved for site selection as part of the Plowshare Program, probably in early 1962. By September 1962, the experiment had been renamed the Wheelbarrow project. On September 12, 1962, there was a site investigation trip to

West Virginia by representatives of the Lawrence Radiation Laboratory and the U.S. Atomic Energy Commission's San Francisco and Nevada Operations offices. The purpose was to meet with the West Virginia Geological Survey to discuss the objectives of the Wheelbarrow project and inspect the possible sites that had been selected by the West Virginia Geological Survey. Four sites were visited (Figure 4.45-1) on September 12<sup>th</sup> and 13<sup>th</sup>. R.E. Raese, the general manager of the Germany Valley Limestone Corporation, accompanied the group. He was in charge of limestone mining in the area of one of the sites.

Available documents describe the proposed experiment sites, but the accompanying maps were missing. All four locations were in the northeastern portion of the state near the communities of Petersburg and Moorefield. Site No. 1 was located within the Monongahela National Forest. Situated closer to the Virginia border, Sites 2, 3, and 4 fell within the George Washington National Forest. However, some small private farms were scattered throughout the region creating access and land acquisition issues that needed to be resolved. The site selection committee judged that manpower, equipment and the drilling/mining expertise were readily available in the surrounding area and the neighboring states of Virginia and Pennsylvania. While local transportation (highway, rail, and air) systems were deemed more than adequate, the local communication network would need upgrading. Water and power for construction activities was available either on-site or at a reasonable distance.

The preliminary project concept required at least 50 to 60 ft of high quality limestone around the shot point with at least 400 ft of competent limestone above the detonation point. Depending on the geological and hydrological conditions of the final site selected, the required depth of burial could range from 600 to 1,500 ft. An exploratory drilling program would be necessary to properly site the zero point. The initial design called for the construction of a shaft and adit for placement of the device and execution of the experiment.

The site investigation group concluded that: 1) all four sites met the criteria for availability and accessibility of high purity limestone; 2) ground water was a problem area; and 3) the possibility of voids or caverns in the limestone would have to be studied further. The trip report says that West Virginia was determined to be a second choice when compared to Toana, Virginia, another area under consideration. However, West Virginia officials were actively seeking industrial applications for the use of nuclear explosives and Governor Barron of West Virginia appointed a West Virginia Atomic Energy Committee to study the merit of the Plowshare Program in relationship to the development of the state's resources. In a September 15, 1962 report, this committee recommended to the governor that West Virginia cooperate with the U.S. Atomic Energy Commission and offer facilities and sites for Plowshare experiments.

Concurrent with the site inspections on September 12<sup>th</sup> and 13<sup>th</sup>, representatives from the U.S. Atomic Energy Commission, the Nevada Operations Office, and Lawrence Radiation Laboratory met with the State Geologist at the invitation of the Chair of the West Virginia Atomic Energy Committee in Morgantown, West Virginia. Subsequently,

they met with the Committee itself and several representatives from industry and energy to discuss several potential Plowshare projects for the state. The Plowshare Program participants recommended further investigations of the proposed Wheelbarrow sites as well as exploring other Plowshare nuclear projects related to dam construction (Project Mountain Lake), electric power generation (Project Megawatt), underground smelting

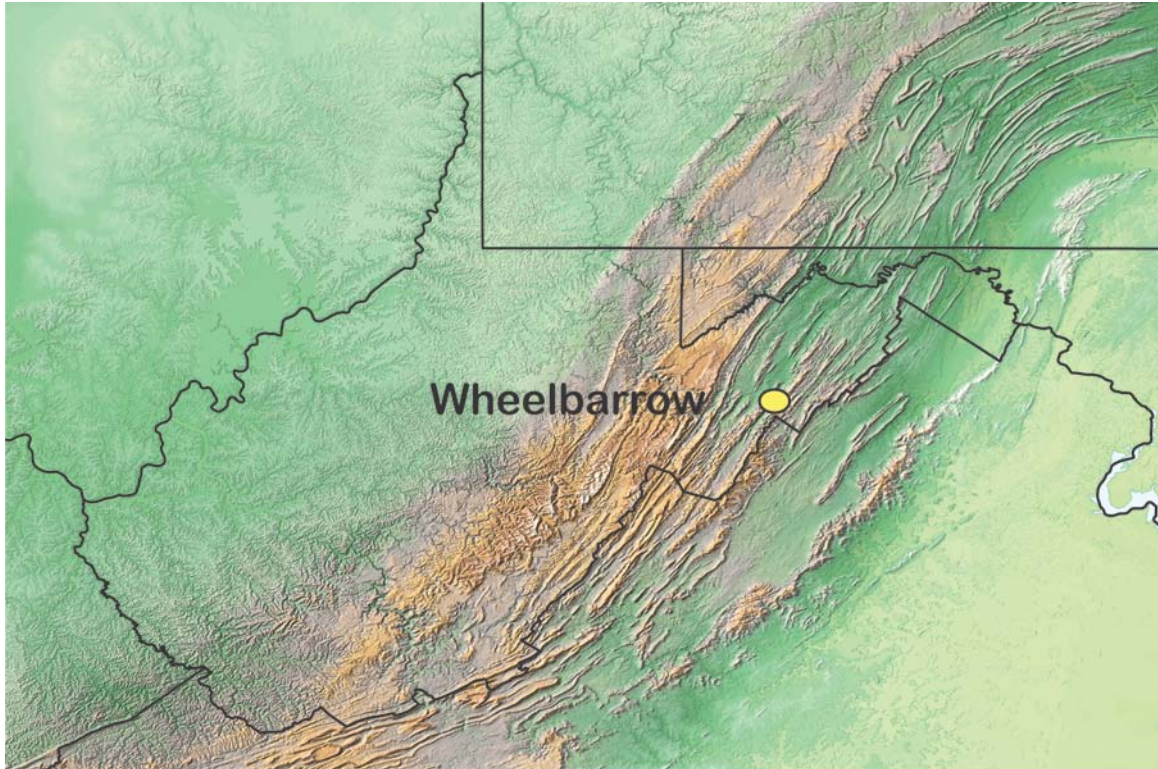


Figure 4.45-1. Location of Wheelbarrow in West Virginia (adapted from USA Relief Maps 2004).

(Project Earth Furnace), and additional raw material recovery (Project Experiment). After a promising beginning, enthusiasm for Project Wheelbarrow, as well as the other potential West Virginia projects, waned after 1963. The last reference identified for Project Wheelbarrow appeared in a planning document for the Plowshare Program issued in March 1963. The summary report specified FY 1966 (July 1966-June 1967) as the target date for the Wheelbarrow project. A January 1964 report discusses the interest of the State of West Virginia in Plowshare projects but no specific project was listed. Wheelbarrow was not conducted.

Wheelbarrow was a Level 5 project because it involved utilizing existing data and visual field inspections.

## CHRONOLOGICAL BIBLIOGRAPHY

- Werth, G. C., W. Heckrotte, S. Bloom, R. James, and M. Nordyke, 1961. Review of the Proposed Limestone Experiment. Manuscript, Lawrence Radiation Laboratory, Livermore, CA, April 6.
- U.S. Atomic Energy Commission, 1961. Plowshare Program. Report to the General Manager by Director of Military Application, April 7 [OUO].
- Goris, Charles A., 1962. Trip Report - West Virginia Site Investigation - Project Wheelbarrow." Memo from Charles A. Goris, U.S. Atomic Energy Commission, Nevada Operations Office, to William D. Smith, September 21. On file at: Nuclear Testing Archives, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0309952.
- Miller, Robert E., 1962. "Meeting with West Virginia Atomic Energy Commission." Memo from Rober E. Miller, U.S. Atomic Energy Commission, to Those Listed, September 21. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0309951.
- U.S. Atomic Energy Commission, 1962. Atomic Energy Commission Meeting 1872: Tuesday, September 11, 1962. Minutes from U.S. Atomic Energy Commission, November 9. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0032480.
- U.S. Atomic Energy Commission, 1963. Long Range Plan, 1964-1973, Peaceful Uses of Nuclear Explosives Program (Plowshare). Report from U.S. Atomic Energy Commission, March 20. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV.
- U.S. Atomic Energy Commission, 1964. Plowshare Program. In *Annual Report to Congress of the Atomic Energy Commission for 1963*, pp. 2241-252, January. Government Printing Office, Washington, D. C.

## 4.46 WHITESTONE NARROWS

### Nuclear Explosives to Remove Navigation Hazards Plowshare Program Alaska

Whitestone Narrows was a proposal to use nuclear excavation techniques to make navigation improvements to a section of Neva Strait in Alaska (Figure 4.46-1). Whitestone Narrows is located at southern end of Neva Strait between Baranof Island and Partofshikof Island. Travel through the narrow channel is hazardous due to rock protrusions. In the early 1960s, the U.S. Army Corps of Engineers, Alaska District studied conventional techniques to remove rock hazards and widen the channel to improve travel to the Sitka area from the Alaska Inside Passage. The District Engineer recommended the project for a Plowshare application and the project was included in a list of “suggested” nuclear excavation projects in a July 1964 document from the U.S. Atomic Energy Commission, Division of Peaceful Nuclear Explosives.



Figure 4.46-1. Location of proposed Whitestone Narrows project in southeastern Alaska (adapted from USA Relief Maps 2004).

In November 1968, an analysis of feasibility for using nuclear explosives to make channel improvements at Whitestone Narrows was issued (see also Sergius Narrows – Chapter 3.19). Two alignments were considered, but the alignment favored for the nuclear excavation project was the same alignment recommended by the Alaska District using conventional methods (Figure 4.46-2). The feasibility study called for using nuclear explosives to remove rock formations from the north and south end of the existing

channel to a depth of 24 ft, eliminating two rapid course changes and widening the channel to 300 f t. According to estimates, the channel improvements could be accomplished with a single 10 kt explosive at the north end of the channel and a 1 kt explosive at the south end. Technically the project was considered feasible; however, nuclear detonations would result in deposition of ejecta into the existing channel. The feasibility study concluded that the cost of extensive post-shot dredging to clear the channel made the project uneconomical. The estimated cost for conventional methods was about \$3 million compared to almost \$14 million using nuclear explosives. The feasibility study recommended that no additional consideration be given to a Plowshare application for Whitestone Narrows.

Whitestone Narrows was a Level 5 activity. Activity was confined to conceptual design and background research.

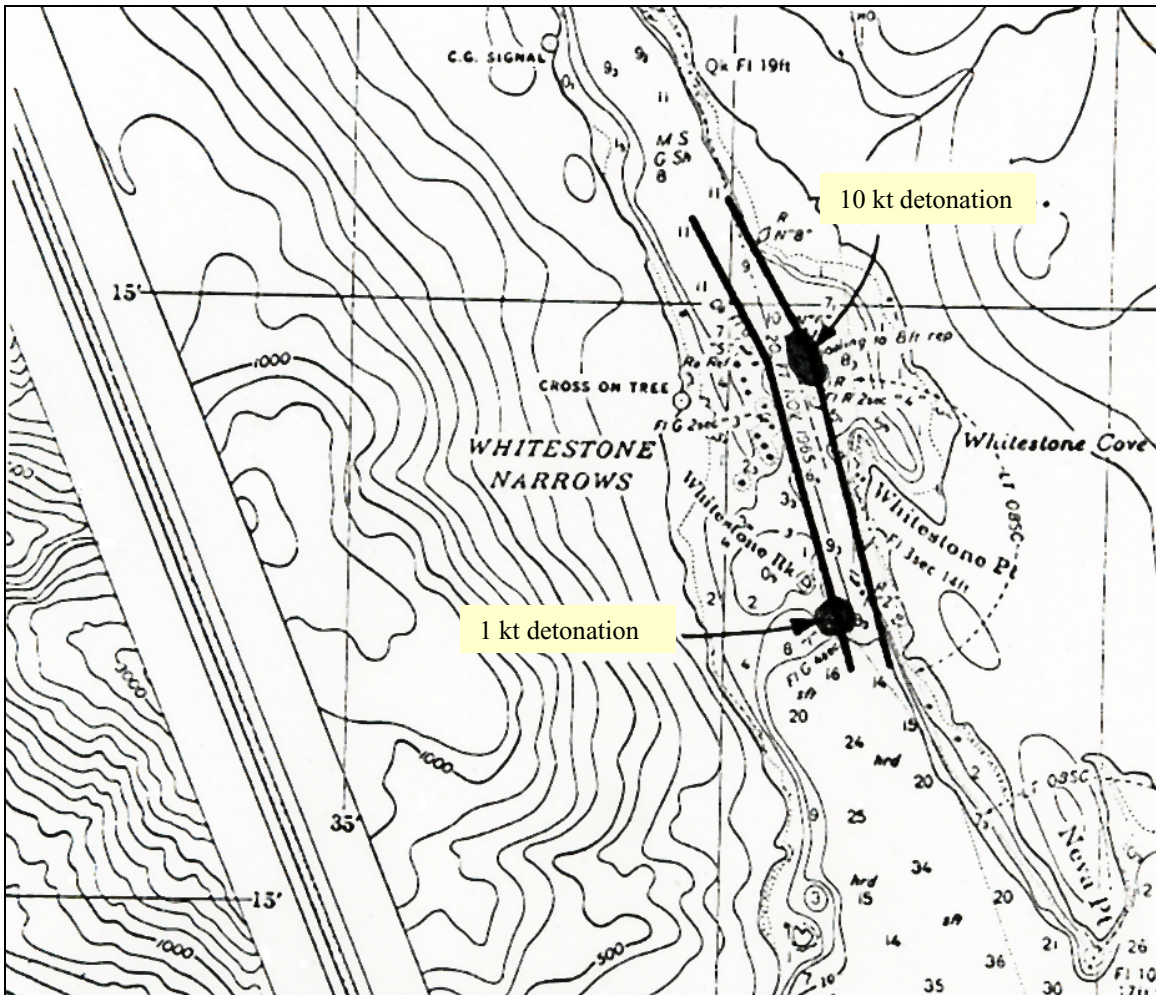


Figure 4.46-2. Map showing the location of “Alignment D” studied for navigation improvements at Whitestone Narrows using nuclear explosives (adapted from Mattes 1968, Figure 5).

## **CHRONOLOGICAL BIBLIOGRAPHY**

U.S. Atomic Energy Commission, 1964. Suggested Nuclear Excavation Projects and Possible Nuclear Excavation Projects. Manuscript, Division of Peaceful Nuclear Explosives, July. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.

Mattes, Richard W., 1968. Analysis of the Feasibility of Channel Improvement by Nuclear Excavation at Sergius and Whitestone Narrows, Alaska. U.S. Army Engineer Nuclear Cratering Group, *Technical Memorandum* No. NCG/TM 68-13, November. Livermore, CA. On file at: Technical Information Center, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

**THIS PAGE INTENTIONALLY LEFT BLANK**



## CHAPTER 5.0 OTHER LOW LEVEL ACTIVITY PROJECTS

This chapter contains brief descriptions of 97 projects and project concepts (Table 5.0-1) not presented in Chapters 3 and 4. There are 94 Plowshare projects and three Vela Uniform projects. Six are Level 4 field activities, 75 are Level 5 projects, and 16 projects have no activity level assigned. The no activity level reflects projects that did not include a project location. The origin of these projects varies with some proposed by Lawrence Livermore National Laboratory, the Department of Defense, state and federal government agencies, research entities, commercial and industrial companies, and private citizens. As reflected by the low activity levels, none of these projects have potential environmental liabilities.

The Levels 4 and 5 projects included in this chapter are described in short write-ups instead of full descriptions with map locations. In general, each project identified in the course of the research was written up when enough information was obtained that it was possible to complete a project data summary including assignment of an activity level. However, not all low level activity projects could be fully written up within the project time frame. Full project descriptions were completed for as many of the Level 4 and 5 projects as possible. For the others, short project descriptions are provided with bibliographic references.

For Level 4 activities, there are six projects. Five are Plowshare and one is Vela Uniform. The Plowshare projects are three for the fracture of copper ore (Cactus Ore Copper Recovery, Copper Flat, and the Newmont Project), one to fracture oil shale (Wyoming Oil Shale), and one to control oil leakage (Santa Barbara Channel Oil Leakage). The Vela Uniform project (Payette) was for construction of a cavity for seismic monitoring research.

Of the 75 Level 5 projects, only two are proposed Vela Uniform high explosives projects, Vaquero and Winnow. For the 73 Plowshare projects, there are 69 nuclear explosives projects and three high explosives projects. One other project had both high explosive and nuclear components. The projects include a wide variety of proposed applications. Nuclear explosives were proposed for mining copper, magnesium, molybdenite, phosphates, silver, uranium, and zinc. Some projects discuss fracturing oil shale and conducting oil stimulation studies. Water management projects are both land and sea based and include water containment and distribution; excavating harbors; dredging; creating channels, dams, canals, and reservoirs; diverting a river channel; and clearing hazards from a sea route and a delta. Excavations were proposed for highway construction and to reconfigure a mountainside, a sandbar, and a rock plateau. Using nuclear explosives to create storage chambers included projects for water storage, gas storage, radioactive waste storage, sewage disposal, and the undersea storage of fuel oil. Other projects were to develop chemical resources, power generation, and a desalinization plant. The three high explosives projects were for a calibration study, oil shale stimulation, and a cratering experiment.

Sixteen projects have no activity level. All 16 are Plowshare nuclear explosives projects. Proposed projects include ammonia production, gas storage, rock breaking applications, excavating a lake, detonations to relieve stress along earthquake fault lines, and power generation; and to use nuclear explosives for national and world emergencies, to construct a radio telescope facility, for radioactive waste disposal, to shut down runaway gas and oil wells, for canal and harbor construction, to pulverize basalt, and to create synthetic diamonds.

The project descriptions are presented in alphabetical order. There are no project data summaries for these projects in Appendix A.

Table 5.0-1. Other Low Level Projects by Activity Level

<b>Name</b>	<b>Description</b>	<b>Activity Level</b>
Cactus Ore Copper Recovery	Nuclear Explosives to Fracture Ore Deposits for In Situ Leaching of Copper	Level 4
Copper Flat	Nuclear Explosives to Fracture Ore for In Situ Copper Leaching	Level 4
Newmont Project	Nuclear Explosives to Fracture Copper Ore for Underground Chemical Mining	Level 4
Payette (Vela Uniform)	Construction of a Cavity for a Nuclear Mining Experiment	Level 4
Santa Barbara Channel Oil Leakage	Nuclear Explosives to Control Oil Leakage	Level 4
Wyoming Oil Shale	Nuclear Explosives to Fracture Oil Shale	Level 4
Alamo Dam Spillway	Nuclear Excavation for Dam Spillway	Level 5
Alaska Copper Leaching	Nuclear Explosives to Fracture Copper Ore for Underground Chemical Mining	Level 5
Anderson Proposals	Suggested Nuclear Excavation Applications	Level 5
Appalachian Gas Storage	Nuclear Chimney for Underground Gas Storage	Level 5
Argo Tunnel	Possible Location for Nuclear Explosive Experiments	Level 5
Arizona Aqueduct	Nuclear Explosives for Water Redistribution System	Level 5
Bering Strait	Nuclear Excavation to Deepen Waterway	Level 5
Buchanan Dam	Nuclear Quarrying for Dam Construction	Level 5
Butler Valley Dam	Nuclear Quarrying for Dam Construction	Level 5
Buttes Dam	Nuclear Explosives for Dam Construction and Quarry	Level 5

Table 5.0-1. Other Low Level Projects by Activity Level (continued)

<b>Name</b>	<b>Description</b>	<b>Activity Level</b>
Buttes Reservoir Copper Recovery	Nuclear Explosives to Fracture Ore Deposits for In Situ Leaching of Copper	Level 5
California Water Plan	Nuclear Explosives for Water Management Project	Level 5
Camelsback Dam	Nuclear Excavation of a Spillway and Quarrying for Dam Construction	Level 5
Cape Cod Canal	Nuclear Explosives to Dredge a Channel	Level 5
Carmel-San Simeon Harbor	Nuclear Excavation of a Harbor	Level 5
Catherine Creek	High Explosive Calibration Study and Nuclear Quarrying for Dam Construction	Level 5
Coconino Dam	Nuclear Explosives to Construct a Slide Dam and Spillway	Level 5
Colorado River Desalination	Nuclear Craters for Desalination Plant	Level 5
Columbia River Delta Clearance	Nuclear Explosives to Clear a Delta	Level 5
Cross-Continent Barge Canal	Nuclear Excavation for Canal Construction	Level 5
Earth Furnace	Nuclear Explosives to Develop Mineral Resources	Level 5
El Centro Canal	Nuclear Explosives for Canal Excavation	Level 5
Etsel Dam	Nuclear Quarrying for Construction of a Dam	Level 5
Experiment	Nuclear Industrial Plowshare Experiment	Level 5
Feather River Project	Nuclear Explosives for Water Redistribution	Level 5
Garden Valley Dam	Nuclear Explosives for Construction of a Slide Dam	Level 5
Gas Hills Uranium Mine	Nuclear Explosives to Mine Uranium	Level 5
Hawaii Harbor for Inter-Island Ferries	Nuclear Excavated Harbor	Level 5
Honokahau Small Craft Harbor	Nuclear Excavated Harbor	Level 5
Idaho Phosphates	Use of Nuclear Explosives to Mine Phosphates	Level 5
John Day River	Nuclear Construction of a Slide Dam	Level 5
Kaalualu Harbor	High Explosive Cratering Tests for Small Craft Harbor	Level 5

Table 5.0-1. Other Low Level Projects by Activity Level (continued)

<b>Name</b>	<b>Description</b>	<b>Activity Level</b>
Keetch Plan for Water Conservation	Nuclear Explosives for Water Storage System	Level 5
Lake Erie - Lake Ontario Waterway	Nuclear Explosives to Construct a Waterway	Level 5
Lake Erie - Ohio River Canal	Nuclear Explosives to Excavate a Canal	Level 5
Laurel River Dam	Nuclear Quarrying for a Rock-Fill Dam	Level 5
Livermore Valley Sewage Disposal	Nuclear Chimneys for Sewage Disposal	Level 5
Magnesium Recovery	Nuclear Explosives for Mining Magnesium	Level 5
Megawatt	Underground Nuclear Explosions for Power Generation	Level 5
Missouri River Reservoir	Nuclear Excavation for Reservoir Project	Level 5
Modesto Waste Disposal	Nuclear Chimneys for Sewage Disposal	Level 5
Molybdenite Recovery	Nuclear Explosives for Molybdenite Mining	Level 5
Montana Silver Retarc	Nuclear Explosives for Silver Mining	Level 5
Mountain Lake	Nuclear Explosives for Water Resource Development	Level 5
Mt. Snow	Nuclear Excavation of Mountainside	Level 5
New York Plateau Excavation	Nuclear Excavation of a Rock Plateau	Level 5
Nuclear Explosive Power Generation	Underground Nuclear Explosions for Power Generation	Level 5
Offshore Fuel Oil Storage	Nuclear Chimneys for Undersea Storage of Fuel Oil	Level 5
Pre-Dogsled	High Explosive Cratering Experiment	Level 5
Pre-Vintage	High Explosive Tests	Level 5
Pumped Storage Reservoirs	Nuclear Excavation of Storage Reservoirs	Level 5
Raymondville Harbor	Nuclear Explosives to Remove a Sandbar	Level 5
Red Mountain Mineral Extraction	Nuclear Mining Application	Level 5
Saline River Canal	Nuclear Excavation of a Canal	Level 5

Table 5.0-1. Other Low Level Projects by Activity Level (continued)

Name	Description	Activity Level
San Diego - Imperial Valley Interstate/ Laguna Mountains Highway	Nuclear Explosives for Highway Construction	Level 5
San Luis Dam	Nuclear Quarrying for Construction of a Dam	Level 5
Santa Rosa Canal	Nuclear Excavation of a Canal	Level 5
Santa Rosa Wash Basin	Nuclear Excavation Application	Level 5
Savannah River Nuclear Plant Waste Disposal	Nuclear Chimney for Storage of Radioactive Waste	Level 5
Shelter Cove Harbor	Nuclear Excavation of a Small Craft Harbor	Level 5
Smackover Formation Oil Stimulation	Nuclear Explosives for Oil Stimulation	Level 5
Trinity River Canal	Nuclear Explosives for Canal Construction	Level 5
Upper Midwest Geostorage Facility	Nuclear Chimney for Gas Storage	Level 5
Vaquero (Vela Uniform)	High Explosive Seismic Monitoring Experiment	Level 5
Vintage	Nuclear Explosives to Fracture Oil Shale	Level 5
Wagon	Nuclear Cratering Experiment	Level 5
Wenaha Dam	Nuclear Quarrying for Construction of a Dam	Level 5
West Kentucky Turnpike	Nuclear Explosives for Highway Construction	Level 5
White Bird Hill	Nuclear Explosives for Highway Construction	Level 5
Wilkins Dam	Nuclear Explosives to Construct a Dam	Level 5
Winnow (Vela Uniform)	Nuclear Explosive Seismic Monitoring Experiment	Level 5
Yaquina Bay and Harbor Improvement	Nuclear Explosives for Bay and Harbor Improvement	Level 5
Young Bay Channel	Nuclear Explosives for Channel Excavation	Level 5
Yukon River Diversion	Nuclear Explosives to Divert River Channel	Level 5
Zinc Recovery	Nuclear Explosives for Mining Zinc	Level 5
Ammonia Production	Nuclear Explosives in Geothermal Formations for Synthesizing Ammonia	--
Atlantic Gas Storage	Nuclear Chimney for Gas Storage	--
Basalt Fracturing	Nuclear Explosives to Pulverize Basalt	--

Table 5.0-1. Other Low Level Projects by Activity Level (continued)

Name	Description	Activity Level
Dow Chemical Proposals	Various Plowshare Applications	--
Fault Lines	Nuclear Explosives to Relieve Stress along Fault Lines	--
Hansom	Nuclear Explosives in Rock Breaking Applications	--
PACER	Underground Nuclear Explosions for Power Generation	--
Plowshare Emergency Capability Program	Nuclear Explosives for Use in National and World Emergencies	--
Radio Telescope Facility	Nuclear Explosive to Create Crater for Radio Telescope Facility	--
Radioactive Waste Disposal	Nuclear Chimney for Radioactive Waste Disposal	--
Runaway Gas or Oil Wells	Nuclear Explosives to Shut Off a Gas or Oil Well	--
Southwest Water Reservoirs	Nuclear Craters for Water Reservoirs	--
Subway	Nuclear Explosive Test for Canal or Harbor Construction	--
Synthetic Diamond	Nuclear Explosives to Create Diamond Crystals	--
U.S. Navy Proposals	Peaceful Applications of Nuclear Explosives for the U.S. Navy	--
Wisconsin Lakes	Nuclear Explosives to Create Lakes	--

## **5.1 Alamo Dam Spillway**

Nuclear Excavation for Dam Spillway

Plowshare Program

Arizona

Alamo Dam was a U.S. Army Corps of Engineers project on the Bill Williams River, a tributary of the lower Colorado River, in western Arizona, about 35 miles north of the town of Wenden. The dam was authorized by the Flood Control Act of 1937. In a July 1964 document from the U.S. Atomic Energy Commission, Division of Peaceful Nuclear Explosives, nuclear excavation for construction of the dam spillway was listed as a suggested nuclear excavation project. The nuclear excavated spillway was proposed for a valley pass several miles from the dam site using one to three nuclear devices in the 10 to 100 kt yield range. The spillway was eventually built next to the dam using conventional techniques and the dam was completed in 1968.

U.S. Atomic Energy Commission, 1964. Suggested Nuclear Excavation Projects and Possible Nuclear Excavation Projects. Manuscript, Division of Peaceful Nuclear Explosives, July. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.

## **5.2 Alaska Copper Leaching**

Nuclear Explosives to Fracture Copper Ore for Underground Chemical Mining

Plowshare Program

Alaska

In a March 12, 1971 letter from R. B. Fulton of Newmont Exploration Limited to E. Lewis at the Lawrence Radiation Laboratory, Fulton suggested that large low-grade copper deposits in the eastern part of the Alaska Range in Alaska might be suitable for a Plowshare project to demonstrate the feasibility of mining primary sulfide copper deposits. In the early 1970s this approach to mining copper ore was being studied by scientists at the Lawrence Radiation/Livermore Laboratory (see Copper Ore Chemical Mining – Chapter 4.11). The proposed technique for mining primary copper deposits was twofold: 1) nuclear explosives would be used to fracture the deposit, and 2) in situ leaching based on oxygenation would be used to recover copper. There is no documentation to suggest that copper ore deposits in the Alaska Range were considered for a nuclear application.

Fulton, R. B., 1971. Letter from R. B. Fulton, Newmont Exploration Limited, New York, NY, to A. E. Lewis, March 15. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-089.

### **5.3 Ammonia Production**

Nuclear Explosives in Geothermal Formations for Synthesizing Ammonia

Plowshare Program

No Location

The idea of synthesizing ammonia in a nuclear geothermal well is outlined in a February 11, 1961 manuscript from the Chemistry Department at the Lawrence Radiation Laboratory. Geothermal formations have ambient rock temperatures that are high enough that an underground nuclear explosion might provide a reaction chamber for chemical processing. Synthesis of ammonia would depend on temperature and pressure conditions and how effectively an underground rubble chimney would act as a chemical and/or radiation induced catalyst. The project did not proceed beyond the concept phase.

Krikorian, Oscar H., 1971. A Proposal to Develop Geothermal Formations with Nuclear Explosives for Chemical Processing Purposes. Manuscript, Chemistry Department, Inorganic Materials Division, Lawrence Radiation Laboratory, February 11. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-098.

### **5.4 Anderson Proposals**

Suggested Nuclear Excavation Applications

Plowshare Program

Western U.S.

In a May 9, 1963 letter, Everett Anderson from San Francisco, California wrote to the U.S. Atomic Energy Commission with his ideas for international and domestic projects he felt might be suitable for the Plowshare Program. The domestic projects were: 1) to remove portions of the high elevations of the Rocky Mountains and Sierra Nevada Mountains to increase precipitation in arid areas of the southwest, and 2) to construct a canal from the Rio Grande to the Pacific Coast. The U.S. Atomic Energy Commission responded to this letter and forwarded the inquiry to the Lawrence Radiation Laboratory.

Anderson, Everett B., 1963. Letter from Everett B. Anderson to Plowshare Program, May 9, and response from Richard Hamburger, May 23. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.

### **5.5 Appalachian Gas Storage**

Nuclear Chimney for Underground Gas Storage

Plowshare Program

Kentucky

A March 1966 Lawrence Radiation memo enumerates a number of inquiries to the U.S. Atomic Energy Commission, Nevada Operations Office about possible industrial applications for the Plowshare Program. One of the inquiries concerned underground storage of gas in the Appalachian area. In November 1965, representatives from Texas



Eastern Gas and the Birdwell Company had contacted the Nevada Operations Office requesting information about how to conduct a feasibility study for an underground gas storage project in the Appalachian area. During an informal visit to the Nevada Operations Office on March 11, 1966, the Manager of Storage Facilities from Texas Eastern Gas Transmission mentioned that the project concept was still under consideration, but did not yet have management approval. There is no indication that a feasibility study was ever done.

Miller, Robert E., 1966. "Inquiries to NVOO Regarding Industrial Application of Nuclear Explosives." Memo from Robert E. Miller, U.S. Atomic Energy Commission, Nevada Operations Office, to List, March 23. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.

## **5.6 Argo Tunnel**

Possible Location for Nuclear Explosive Experiments

Plowshare Program

Colorado

In October 1961, Plowshare Program scientists along with representatives from the American Mining Company met at the Argo Tunnel, Colorado, to conduct a site evaluation of the possible use of the tunnel for nuclear explosive experiments. An August 1963 telex to the company states that the location was not suitable due to public safety hazards. In particular, ground water from the tunnel drained into a source for the local water supply and through Denver.

Reeves, James E., 1963. Telex from James E. Reeves, U.S. Atomic Energy Commission, Nevada Operations Office, to George S. Groves, August 27. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.

## **5.7 Arizona Aqueduct**

Nuclear Explosives for Water Redistribution System

Plowshare Program

Arizona

In 1966, the Ralph Parsons Company, at the request of the State of Arizona, studied developing a water distribution system in central Arizona that would redistribute water taken from Lake Havasu on the Colorado River to the Phoenix and Tucson metropolitan areas. Apparently, the aqueduct system had been studied by the Bureau of Reclamation using conventional means, but construction was considered cost prohibitive. Parsons' proposed Plowshare application was to use nuclear explosives to develop a 1,200 ft lift pumping system near Lake Havasu and to excavate a 20 mile long tunnel in the mountains near Phoenix. On October 27, 1966, Parsons Company personnel met with scientists from the Lawrence Radiation Laboratory and the U.S. Atomic Energy Commission, San Francisco Operations Office to discuss the project. A December 15, 1966 memo indicates that the Arizona Atomic Energy Commission and the Lawrence

Radiation Laboratory would evaluate Parsons' proposed application. Meanwhile, a number of government agencies in Arizona (including the Interstate Stream Commission, the Arizona Power Authority, and the Arizona Atomic Energy Commission) were interested in the possible use of Plowshare techniques to create artificial aquifers as a substitute for an aqueduct tunnel (see also Aquarius – Chapter 4.1).

Philip, John F., 1967. Letter with encls. (memo from H. B. Curtis to J. F. Philip, November 22, 1966; and memo from H. B. Curtis to J. F. Philip, December 15, 1966) from Harold B. Curtis for John F. Philip, U.S. Atomic Energy Commission, San Francisco Operations Office, to Glenn C. Werth, January. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-109.

## **5.8 Atlantic Gas Storage**

Nuclear Chimney for Gas Storage

Plowshare Program

Offshore Location

The concept of using underground chambers produced by nuclear explosions to store liquefied natural gas was presented in a July 1972 preliminary proposal submitted to the Lawrence Livermore Laboratory from the Office of Research Services at the University of California, Berkeley. In a hypothetical situation, 10 storage facilities created by 50 kt explosives at a depth of approximately 3,000 ft, and at a distance of 12 to 15 miles offshore, could provide storage for liquid natural gas and a source for distribution to the eastern U.S. market. Pipelines would transport the liquefied gas from the storage cavities to a shore-based facility for re-gasification. Thus, underground storage cavities would provide a link between intermittent tanker supplies and steady base-load requirements of a main pipeline. The project did not proceed beyond the concept phase.

van der Harst, Leo, and Robert S. Brundage, 1971. Base-Load LNG Storage in Underground Reservoirs Created by Nuclear Explosives. Manuscript, CER Geonuclear Corporation, Las Vegas, NV. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-095.

Witherspoon, P. A., 1972. Letter with encl. (Underground Storage of Liquefied Natural Gas in Nuclear Chambers, proposal to University of California, Lawrence Livermore Laboratory, Livermore, CA, from University of California, College of Engineering, Berkeley, CA, April 14) from P. A. Witherspoon to John Toman, April 12. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-095.

Brim, G. V., 1972. "Intramural Order 9081509." Letter from G. V. Brim, University of California, to John Hiles, September 14. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-095.

Lawrence Livermore National Laboratory, no date. "Gas/LNG Storage in Multiple Offshore Geonuclear Chimneys." Offshore geonuclear chimneys drawing. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-096.

Lawrence Livermore National Laboratory, no date. "Offshore Storage & Production System." Offshore storage drawing\_05\_a. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA.

## **5.9 Basalt Fracturing**

Nuclear Explosives to Pulverize Basalt  
Plowshare Program  
Western United States

In a letter dated December 20, 1968, a faculty member at the University of Idaho wrote to the Lawrence Radiation Laboratory with a query concerning the possible use of nuclear explosives to fracture surface basalt deposits to improve the agricultural potential of western deserts in the United States. The Lawrence Radiation Laboratory responded in a letter dated January 6, 1969, expressing interest in the concept and in setting up a preliminary feasibility analysis. However, there is no documentation to suggest that a preliminary analysis took place.

Watson, R. D., 1968. "Peaceful Uses of Explosive Power ' Atomic' Energy." Letter from R. D. Watson, College of Agriculture, University of Idaho, to Gary H. Higgins, December 20. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.

Higgins, Gary H., 1969. Letter from Gary H. Higgins, Lawrence Radiation Laboratory, to R. D. Watson, January 6. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.

## **5.10 Bering Strait**

Nuclear Excavation to Deepen Waterway  
Plowshare Program  
Alaska

The use of nuclear explosives to deepen the Bering Strait off the northwest coast of Alaska was a project proposed by the Lawrence Radiation Laboratory for a Plowshare application. In July 1964, the U.S. Atomic Energy Commission, Division of Peaceful Nuclear Explosives, issued a list of "suggested" and "possible" nuclear excavation projects. The "possible" projects were ones that had been considered, but were not considered technically or economically feasible using conventional methods, and included the project to deepen the Bering Strait.

U.S. Atomic Energy Commission, 1964. Suggested Nuclear Excavation Projects and Possible Nuclear Excavation Projects. Manuscript, Division of Peaceful Nuclear Explosives, July. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.

## 5.11 Buchanan Dam

Nuclear Quarrying for Dam Construction

Plowshare Program

California

Buchanan Dam was a proposal for using nuclear explosives for a quarry to provide aggregate for a dam on the Chowchilla River in Madera County, California. The quarry was a proposed demonstration project by the U.S. Army Engineers Nuclear Cratering Group. The project description is included with the Travois Project (see Chapter 3.2).

Lawrence Radiation Laboratory. U.S. Army Engineer Nuclear Cratering Group, 1966. Plan for Accomplishment of a Demonstration of the Application of Nuclear Excavation in Civil Works Projects. Manuscript, August 27. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-100.

Slazak, Walter J., 1966. Letter with encl. ("Summary of Possible Quarrying Projects") from Walter J. Slazak, Lt. Colonel, Lawrence Radiation Laboratory, U.S. Army Engineer Nuclear Cratering Group, to Michael M. May, September 20. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.

Lawrence Radiation Laboratory. U.S. Army Engineer Nuclear Cratering Group, [1966]. Demonstration Project Summary. Manuscript. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-103 [OUO].

U.S. Department of the Interior. Geological Survey. [1966]. Summary of Water Conditions and Suggested Programs for Evaluation of Hydrological Safety of Nuclear Excavation at Three Proposed Dam Sites: Buchanan Damsite, California; Twin Springs Damsite, Idaho; and Cochiti Damsite, New Mexico. Report to U.S. Atomic Energy Commission from Geological Survey. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV [OUO].

U.S. Public Health Service. Department of Health, Education and Welfare, [1966]. PHS Off-Site Evaluation of Buchanan Dam and Reservoir Project Chowchilla, California. Manuscript, Las Vegas, NV. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV.

Nordyke, Milo D., 1967. "Status Review of Field Project Studies." Memo from Milo Nordyke, Lawrence Radiation Laboratory, to G. Higgins, April 14. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore CA, File PLO-026.

Rabb, David D., 1967. Plowshare Program May 1, 1967 – July 31, 1967, Vol. II, No. 6. University of California, Lawrence Radiation Laboratory, *Report UCRL-50008-67-3*, July 31. Livermore, CA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.

Kurtz, Maurice K., 1967. Letter from Maurice K. Kurtz, Jr., Lawrence Radiation Laboratory, U.S. Army Engineer Nuclear Cratering Group, to Glenn Werth, August 2. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029 [OUO].

Reeves, James E., 1967. "Unclassified Reference: Letter, Miller, NVOO, to Kurtz, NCG, May 10, 1967." Telex from James E. Reeves, U.S. Atomic Energy Commission, Nevada Operations Office, to John S. Kelly, December 19. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-065.

Miller, Robert E., 1967. "Budgetary Estimates for Travois." Telex from Robert E. Miller, U.S. Atomic Energy Commission, Nevada Operations Office, to Lt Col M. K. Kurtz, December 26. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-065.

Hoggan, Daniel H., and M. Nordyke, 1968. "Project Travois: Preliminary Safety, Evaluation – Buchanan Dam Site." Memo with encls. ("Project Travois - Air Blast," memo from D. N. Montan to D. H Hoggan, August 25; and "Project Safety: Project Travois, Buchanan Dam," memo from Daniel H. Hoggan to Distribution, August 14) from Daniel H. Hoggan and M. Nordyke, Lawrence Radiation Laboratory, January 9. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-065.

Hughes, Bernard C., 1968. "Status Report - Nuclear Explosives Studies for Civil Construction (RCS ENGCW-P-6 (R-1))." Letter with encl. ("Status Report, Effective Date: 31 December 1967") from Bernard C. Hughes, Lawrence Radiation Laboratory, U.S. Army Engineer Nuclear Cratering Group, to Chief of Engineers, Department of the Army, January 13. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.

Lawrence Radiation Laboratory. U.S. Army Engineer Nuclear Cratering Group, 1968. Engineering Applications of Nuclear Explosives, Bi-Monthly Statistics of NCG Technical Reports, Memoranda, and Studies. Manuscript, February 15. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV.

California Statistical Abstract, 1999. Major Dams and Reservoirs of California, Table G-3. *California Statistical Abstracts*, Section G.

## **5.12 Butler Valley Dam**

Nuclear Quarrying for Dam Construction

Plowshare Program

California

The Butler Valley Dam was a planned rock-fill structure located on the Mad River, about 15 miles east of Eureka in Humboldt County, California. A proposal to use nuclear explosives to quarry rock for the dam was outlined in a Demonstration Project Summary issued by the U.S. Army Engineer Nuclear Cratering Group, and submitted by the U.S. Army Corps of Engineers, San Francisco District. Two alternate rock sources were identified for a nuclear quarrying project, one a mile north and the other a mile south of the dam site. An estimated explosive yield of 20 to 50 kts in one or more detonations would be necessary to produce a sufficient quantity of aggregate for the rock-fill structure. The dam was not built.

Lawrence Radiation Laboratory. U.S. Army Engineer Nuclear Cratering Group, [1966]. Demonstration Project Summary. Manuscript. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-103 [OUO].

### **5.13 Buttes Dam**

Nuclear Explosives for Dam Construction and Quarry  
Plowshare Program  
Arizona

The excavation of a spillway for the Buttes Dam, a rock-fill dam planned on the Gila River, was a “suggested” project named in a July 1964 document from the U.S. Atomic Energy Commission, Division of Peaceful Nuclear Explosives. The concept was to use nuclear explosives to crater the ridge at the dam site to cut a spillway, and to use the fractured rock as fill for the dam. The proposed Buttes Dam site was about 15 miles east of Florence in Pinal County, Arizona, four miles upstream from the Ashurst-Hayden Diversion Dam. The Bureau of Reclamation began studies for building the dam in the early 1960s. Buttes Dam was authorized by the Colorado River Basin Project Act of 1968, but was never constructed.

U.S. Atomic Energy Commission, 1964. Suggested Nuclear Excavation Projects and Possible Nuclear Excavation Projects. Manuscript, Division of Peaceful Nuclear Explosives, July. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.

### **5.14 Buttes Reservoir Copper Recovery**

Nuclear Explosives to Fracture Ore Deposits for In Situ Leaching of Copper  
Plowshare Program  
Arizona

In the 1960s, the Bureau of Reclamation studied building a rock-fill dam on the Gila River; about 15 miles west of Florence, in Pinal County, Arizona (see Buttes Dam – Chapter 5.13). On June 9, 1964, in an internal memo to the Hansom Committee at the Lawrence Radiation Laboratory, there is a discussion about mineral resources in the impoundment area known as the Riverside mining area or the Cochran Basin. The dam site and the area upstream contained a low-grade copper ore, and drilling operations were underway to determine the size, grade, and potential depth of the deposit. According to the memo, Bureau of Mines personnel were planning to propose that the area be considered for a test site for a nuclear mining experiment. On April 13, 1965, members of the Hansom Committee visited the Buttes Reservoir site to conduct a preliminary evaluation of the area for an oxidized copper ore leaching demonstration experiment. Their field evaluation was summarized in an April 26, 1965 memo. A discussion of the Buttes Reservoir project is included with Copper Recovery (see Copper Recovery - Chapter 4.12).

Rabb, David D., 1964. "The Buttes Reservoir Site." Memo from David D. Rabb, Lawrence Radiation Laboratory, to Hansom Committee, June 9. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-109 and PLO-086.

Hansen, Spenst M., 1965. "Report of Field Evaluation of Alternate Sites for Oxidized Copper Ore Leaching Demonstration Experiment." Memo from S. M. Hansen, Lawrence Radiation Laboratory, to Hansom Committee, April 26. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-087.

### **5.15 Cactus Ore Copper Recovery**

Nuclear Explosives to Fracture Ore for In Situ Leaching of Copper

Plowshare Program

Arizona

The Cactus Ore deposit in Gila County, Arizona, was one of the locations proposed for the use of nuclear explosives to fracture a copper ore deposit prior to in situ leaching. The property was owned by the Miami Copper Company. Representatives from the company held a meeting with scientists from Lawrence Radiation Laboratory on November 7, 1964 concerning the possibility of conducting an experimental copper recovery project. The project description for Cactus Ore is included with Copper Recovery (see Copper Recovery - Chapter 4.12).

Lekas, Mitchell A., 1963. "Trip Report, Miami Copper Corporation." Memo from Mitchell A. Lekas, U.S. Atomic Energy Commission, San Francisco Operations Office, to Files, November 12. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-085 [OUO].

Rabb, David D. 1964. "Plowshare Mining Prospect - Miami Copper Company." Memo from David D. Rabb, Lawrence Radiation Laboratory, to Hansom Committee, January 21. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-085.

Shaffer, Lysle E., 1964. "Comments on Plowshare Mining Prospect -- Miami Mining Company." Memo with encl. ("Barren Pinal Schist," drawing) from L. E. Shaffer, University of California, Department of Mineral Technology, to Gary H. Higgins, January 29. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-085.

Hansen, Spenst M., 1964. "Trip Report - Tour of Southwest Copper Leaching Operations." Memo from S. M. Hansen, Lawrence Radiation Laboratory, to Hansom Committee, April 15. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-086.

## 5.16 California Water Plan

Nuclear Explosives for Water Management Project

Plowshare Program

California

During the early 1960s, the Lawrence Radiation Laboratory and the California Department of Water Resources held discussions concerning the use of nuclear excavation technology for the development and conservation of water resources in California. On June 30, 1963, the *Oakland Tribune* and the *San Francisco Chronicle* ran articles reporting on the discussions, mentioning that the state was trying to find ways to curtail costs of the California Water Plan. In April 1964, a paper was presented at the Third Plowshare Symposium entitled: "Excavation for Water Conveyance with Nuclear Explosives." The paper outlined a project to use nuclear explosives to assist with the construction of the West Side Conveyance System. This system would divert water from the Trinity River southwards to the Glenn Reservoir, and include a series of interconnected reservoirs extending for a distance of about 40 miles along the west side of the Sacramento Valley, primarily in Tehama County. Lawrence Radiation Laboratory investigated a route for nuclear excavation in sections where a cut of over 120 ft would be needed to remove overburden. The proposed project would consist of 11 separate nuclear excavations with a maximum yield of 500 kts for a single device. The application was listed as a "suggested" project in a July 1964 document from the U.S. Atomic Energy Commission, Division of Peaceful Nuclear Explosives.

Teller, Edward, 1963. Letter from Edward Teller to Edgar F. Kaiser, April 29. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-109.

Southwick, Rodney L., 1963. "Inquiry on Plowshare - State-LRL Studies." Memo from Rodney L. Southwick, Lawrence Radiation Laboratory, to Those Listed Below, June 28. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-109.

Garretson, Fred, 1963. State May Atom-Blast for Water. *Oakland Tribune*, June 30. Oakland, CA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-109.

San Francisco Chronicle, 1963. A-Blast Studied for State Water Plan. *San Francisco Chronicle*, June 30. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-109.

Southwick, Rodney L., 1963. "News Clippings on California Water Studies - Plowshare." Memo from Rodney L. Southwick, Lawrence Radiation Laboratory, to Duncan Clark, July 1. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-109.



Keysor, J. W., and M. B. Andrews, 1964. Excavation for Water Conveyance with Nuclear Explosives. Paper to be presented at Third Plowshare Symposium, University of California, Davis, CA, April 21-23. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA. File PLO-109.

Keysor, J. W., and M. B. Andrews, 1964. Excavation for Water Conveyance with Nuclear Explosives. In *Engineering with Nuclear Explosives, Proceedings of the Third Plowshare Symposium*, April 21-23, University of California, Lawrence Radiation Laboratory, Report TID-7695, pp. 363-370. Livermore, CA.

U.S. Atomic Energy Commission, 1964. Suggested Nuclear Excavation Projects and Possible Nuclear Excavation Projects. Manuscript, Division of Peaceful Nuclear Explosives, July. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.

Vortman, L. J., 1969. Nuclear Excavation. Report, SC-DC-69-1716, Underground Physics Division, Sandia Laboratories, Albuquerque, NM, March. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-104.

Toman, John, 1970. Summary of Nuclear-Excavation Applications. Paper prepared for Proceedings of the ANS Topical Meeting, Engineering with Nuclear Explosives, Las Vegas, Nevada, January 14-16, 1970. University of California, Lawrence Radiation Laboratory, *Preprint UCRL-72220*, January 29. Livermore, CA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-104.

Toman, John, 1970. Summary of Nuclear-Excavation Applications. In *Symposium on Engineering with Nuclear Explosives: Proceedings*, Report CONF-700101, Vol. 1, pp. 245-279, May. American Nuclear Society, Hinsdale, IL.

## **5.17 Camelsback Dam**

Nuclear Excavation of a Spillway and Quarrying for Dam Construction  
Plowshare Program  
Arizona

The project concept was to use nuclear explosives to obtain aggregate for a rock-fill dam and to excavate a spillway in a deeply entrenched canyon. The use of nuclear excavation techniques to build a dam on the Gila River at the Camelsback site, Graham County, Arizona, was included in a July 1964 document of "suggested" nuclear excavation projects by the U.S. Atomic Energy Commission, Division of Peaceful Nuclear Explosives. Status reports dated between October 1964 and April 1965 show that the U.S. Army Corps of Engineers, South Pacific Division, Los Angeles District, submitted a preliminary feasibility study for using nuclear explosives in the Camelsback Dam project. A copy of this document has not been located; however, a 1969 Nuclear Cratering Group document states that the Los Angeles District studied using a 5 kt nuclear explosive to excavate the spillway and to use the rockfill for construction of the dam, but geological faulting was observed at the spillway site and the project was discontinued.

- U.S. Atomic Energy Commission, 1964. Suggested Nuclear Excavation Projects and Possible Nuclear Excavation Projects. Manuscript, Division of Peaceful Nuclear Explosives, July. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.
- Slazak, Walter J., 1964. "Status Report - Nuclear Explosives Studies for Civil Construction (Reports Control Symbol ENGCE-E-9)." Letter with encl. ("Status Report, Effective Date: 30 September 1964 - ENGCE-E-9") from Walter J. Slazak, Lawrence Radiation Laboratory, U.S. Army Engineer Nuclear Cratering Group, to Chief of Engineers, Department of the Army, October 26. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.
- Slazak, Walter J., 1965. "Status Report - Nuclear Explosives Studies for Civil Construction (Reports Control Symbol ENGCE-E-9)." Memo with encl. ("Status Report, Effective Date: 31 December 1964 - ENGCE-E-9") from Walter J. Slazak, Lawrence Radiation Laboratory, U.S. Army Engineer Nuclear Cratering Group, to Chief of Engineers, Department of the Army, January 15. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.
- Hughes, Bernard C., 1965. "Status Report - Nuclear Explosives Studies for Civil Construction (Reports Control Symbol ENGCE-E-9)." Letter with encl. ("Status Report, Effective Date: 31 March 1965 - ENCGW-P-6(R1)") from Bernard C. Hughes, U.S. Army Engineer Cratering Group, to Chief for Engineers, Department of the Army, April 13. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.
- Lawrence Radiation Laboratory. U.S. Army Engineer Nuclear Cratering Group, [1966]. Demonstration Project Summary. Manuscript. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-103 [OUO].
- Lawrence Radiation Laboratory. U.S. Army Engineer Nuclear Cratering Group, 1968. Engineering Applications of Nuclear Explosives, Bi-Monthly Statistics of NCG Technical Reports, Memoranda, and Studies. Manuscript, February 15. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV.
- Vortman, L. J., 1969. Nuclear Excavation. Report, SC-DC-69-1716, Underground Physics Division, Sandia Laboratories, Albuquerque, NM, March. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-104.
- Hughes, Bernard C., 1969. History of the U.S. Army Engineer Nuclear Cratering Group, January. Lawrence Radiation Laboratory, January. Livermore, CA.
- Toman, John, 1970. Summary of Nuclear-Excavation Applications. Paper prepared for Proceedings of the ANS Topical Meeting, Engineering with Nuclear Explosives, Las Vegas, Nevada, January 14-16, 1970. University of California, Lawrence Radiation Laboratory, *Preprint UCRL-72220*, January 29. Livermore, CA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-104.

Toman, John, 1970. Summary of Nuclear-Excavation Applications. In *Symposium on Engineering with Nuclear Explosives: Proceedings*, Report CONF-700101, Vol. 1, pp. 245-279, May. American Nuclear Society, Hinsdale, IL

### **5.18 Cape Cod Canal**

Nuclear Explosives to Dredge a Channel  
Plowshare Program  
Massachusetts

In April 1963, the towns of Orleans and Eastham Massachusetts on Cape Cod contacted the U.S. Atomic Energy Commission concerning a possible Plowshare application to dredge a channel from Rock Harbor Creek, across the tidal flats, to deep water. In 1968, the U.S. Army Corps of Engineers, Jackson District, completed a study on the Cape Cod Canal. The document has not been located and the relationship of the canal study to the proposed channel is not known.

Norgeot, Gaston L., 1963. Letter from Gaston L. Norgeot, Boards of Public Health and Welfare, Orleans, MA, to U.S. Atomic Energy Commission, April 3. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.

Hamburger, Richard, 1963. Letter from Richard Hamburger, U.S. Atomic Energy Commission, Division of Peaceful Nuclear Explosives, to Gaston L. Norgeot, April 12. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.

U.S. Army Corps of Engineers. Jacksonville District, 1968. Cape Cod Canal. U.S. Army Corps of Engineers. Jacksonville District. Not on file at the Desert Research Institute.

### **5.19 Carmel – San Simeon Harbor**

Nuclear Excavation of a Harbor  
Plowshare Program  
California

The proposal was to use nuclear explosives to excavate a harbor on the central California coast between Carmel and San Simeon. The project is listed as a “possible” application on a list compiled by the U.S. Atomic Energy Commission, Department of Peaceful Nuclear Explosives, dated to July 1964.

U.S. Atomic Energy Commission, 1964. Suggested Nuclear Excavation Projects and Possible Nuclear Excavation Projects. Manuscript, Division of Peaceful Nuclear Explosives, July. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.

## **5.20 Catherine Creek**

High Explosive Calibration Study and Nuclear Quarrying for Dam Construction  
Plowshare Program  
Oregon

The Catherine Creek dam site was a proposed location for the Travois and Excavator projects. Catherine Creek is a tributary of the Grande Ronde River in northeastern Oregon. The plan was to conduct a series of high explosive calibration shots at the site for the Catherine Creek Dam (see Excavator Chapter 3.6) and to use the location for a nuclear quarrying experiment (see Travois - Chapter 3.21).

McCarvill, Thomas J., 1968. "Proposed Alternate Site for Project Travois--Catherine Creek, Oregon." Letter with encl. ("Catherine Creek Project," Memo from Thomas W. Nelson, Department of the Army, to Thomas McCarvill, October 24 [OUO]) from Thomas J. McCarvill, U.S. Atomic Energy Commission, Division of Peaceful Nuclear Explosives, October 31. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-065.

Nelson, Thomas W., 1968. "Catherine Creek Project." Memo from Thomas W. Nelson, U.S. Atomic Energy Commission, Division of Peaceful Nuclear Explosives, to Thomas McCarvill, October 24 [OUO].

## **5.21 Coconino Dam**

Nuclear Explosives to Construct a Slide Dam and Spillway  
Plowshare Program  
Arizona

In the mid-1960s, the construction of a slide dam and remote spillway for the Coconino Wash and Reservoir Project, using nuclear excavation techniques, was outlined in a Demonstration Project Summary document from the U.S. Army Engineer Nuclear Cratering Group at Lawrence Radiation Laboratory. The dam would be located on the Little Colorado River about 9 miles below Cameron, Arizona, and provide sediment and debris control for the Grand Canyon National Park. The project proposal was submitted by the U.S. Army Corps of Engineers, Los Angeles District.

Lawrence Radiation Laboratory. U.S. Army Engineer Nuclear Cratering Group, [1966]. Demonstration Project Summary. Manuscript. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-103 [OUO].

## **5.22 Colorado River Desalinization**

Nuclear Craters for Desalinization Plant

Plowshare Program

Arizona

In 1965, Paul Ager from the U.S. Atomic Energy Commission, Albuquerque Office contacted the U.S. Department of the Interior, Office of Saline Water and the U.S. Atomic Energy Commission, Office of Research and Development about a possible Plowshare application to decrease the salt content of water from the Colorado River. The concept was to use nuclear explosives to create two craters below the Welland-Mohawk Canal on the Gila River in Arizona for an irrigation water treatment project. One of the craters would function as a settling basin, and the other as a waste detention basin for non-commercial salts. A desalinization plant would be located in the vicinity of the craters.

Ager, Paul W., 1965. Letter from Paul W. Ager, U.S. Atomic Energy Commission, to Frank C. DiLuzio, April 9. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA. File PLO-030.

Ager, Paul W., 1965. Letter from Paul W. Ager, U.S. Atomic Energy Commission, to George M. Kavanagh, April 28. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030 [OUO].

Kavanagh, George M., 1965. Letter from George M. Kavanagh, U.S. Atomic Energy Commission, to Paul W. Ager, May 17. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.

## **5.23 Columbia River Delta Clearance**

Nuclear Explosives to Clear a Delta

Plowshare Program

Oregon

The use of nuclear explosives to clear the delta of the Columbia River was a project proposed by the Lawrence Radiation Laboratory. The project concept occurs on a list of “possible” Plowshare projects in a U.S. Atomic Energy Commission, Division of Peaceful Nuclear Explosives document dated July 1964.

U.S. Atomic Energy Commission, 1964. Suggested Nuclear Excavation Projects and Possible Nuclear Excavation Projects. Manuscript, Division of Peaceful Nuclear Explosives, July. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.

## 5.24 Copper Flat

Nuclear Explosives to Fracture Ore for In Situ Copper Leaching  
Plowshare Program  
New Mexico

Copper Flat in Sierra County, New Mexico, was a proposed location for using nuclear explosives to fracture a copper deposit prior to in situ leaching. During 1963, a representative from the U.S. Atomic Energy Commission, San Francisco Operations Office visited Copper Flat and suggested the location for a possible demonstration project. At a Plowshare Advisory Committee meeting held in January 1965, Copper Flat was included on the agenda for a possible Plowshare application. However, studies by scientists from Lawrence Radiation Laboratory, outlined in a report issued later in January, showed that the Copper Flat ore was not suitable for in situ leaching. A discussion of Copper Flat is included with Copper Recovery (see Copper Recovery - Chapter 4.12).

Lekas, Mitchell A., 1963. "Trip Report, Hillsboro, New Mexico." Memo from Mitchell A. Lekas, U.S. Atomic Energy Commission, San Francisco Operations Office, to Distribution, September 20. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-085.

Evaluation of Copper Flat, 1964. "Evaluation of Copper Flat Prospect as a Potential Hansom Plowshare Application." Handwritten notes, October 16. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-086.

Rabb, David D., 1964. "Brief on Copper Flats." Memo from David D. Rabb, Lawrence Radiation Laboratory, to Record, October 16. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-086.

Higgins, Gary H., 1964. Letter from Gary H. Higgins, Lawrence Radiation Laboratory, to George O. Lotspeich, Jr., November 10. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-086.

Lotspeich, George O. Jr., 1964. Letter from George O. Lotspeich, Jr. to Gary Higgins, December 30. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-086.

Plowshare Advisory Committee, 1965. Plowshare Advisory Committee, Report on Thirteenth Meeting. Meeting held at Lawrence Radiation Laboratory, Livermore, CA, January 12-13. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029 [OUO].

Hansen S. M., and D. B. Lombard, 1965. Report of Field Examination of the Copper Flat Prospect, Sierra County, New Mexico. Manuscript, University of California, Lawrence Radiation Laboratory, Livermore, CA, January 24. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-087.

Lekas, Mitchell A., 1965. "Interest of Mountain Copper Company in Copper Flat Orebody." Memo from M.A. Lekas, U.S. Atomic Energy Commission, San Francisco Operations Office, to Files, February 8. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-087.

Patton, Henry H., 1965. Letter from Henry H. Patton, Frederic H. Hatch & Co., Inc., to Gerald W. Johnson, February 16. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-087.

Philip, John F., 1965. Letter with encl. (Project Sloop Status Report, February 25, 1965, manuscript and draft outline of Project Sloop study) from John F. Philip, U.S. Atomic Energy Commission, San Francisco Operations Office, to Gerald W. Johnson, February 26. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-087 [OUO].

Johnson, Gerald W., 1965. Letter from Gerald W. Johnson, Lawrence Radiation Laboratory, to Henry H. Patton, March 5. On file at: Archives and Research, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-087.

Copper Flat, 1965, "Copper Flat." Handwritten Note, July 30. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-085.

## **5.25 Cross-Continent Barge Canal**

Nuclear Excavation for Canal Construction  
Plowshare Program

A June 1972 *Sierra Club Bulletin* reports on a joint program between the U.S. Atomic Energy Commission and the U.S. Army Corps of Engineers to build a barge canal across the U.S. that would link Boston with San Diego. The bulletin cites a 640 page document issued by the U.S. Army Corps of Engineers on May 18, 1972 that was a preliminary analysis for the barge canal. The Cross-Continent Barge Canal (also called the Cro-Con Canal) was to be a multiple use project that would improve capacity to transport coal; create deep-water ports in Cincinnati, Louisville, Tulsa, and Aspen; provide flood control and water supply; and have a recreational benefit. The article notes that another justification for the project was to provide a canal for movement of aircraft carriers across the U.S. The U.S. Army Corps of Engineers document for this project 3 has not been found.

Ela, Jonathan, 1972. From Sea to Shining Sea or through the Rockies at 31 Knots. *Sierra Club Bulletin*, pp. 26-27, June. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.

## 5.26 Dow Chemical Proposals

Various Plowshare Applications

Plowshare Program

No Location

In 1958, scientists from the Dow Chemical Company contacted the U.S. Atomic Energy Commission, expressing a general interest in participating in the Plowshare Program and detailing a number of research areas in which they had interest. These included oil and gas from oil shale, underground water storage, isotope preparation, endothermic reaction, and food production. In a subsequent letter, dated July 26, 1962, John J. Grebe notified the Lawrence Radiation Laboratory that the Dow Chemical Company was interested in a possible Plowshare application for modifying weather to provide water to arid areas in the southwest. Edward Teller, on behalf of the Lawrence Radiation Laboratory, responded that they did not have plans to use nuclear explosives for this kind of application. In a final correspondence dated October 9, 1964, Grebe proposed using Plowshare techniques to interconnect aquifers for water redistribution in the State of Washington. There is no documentation to suggest that Dow Chemical's participation in Plowshare developed beyond these inquiries before the late 1960s when they participated in studies on gold leaching (see Gold Leaching - Chapter 4.16).

Grebe, John J., and Alden W. Hanson, 1958. Letter with encls. (appendices) from John J. Grebe and Alden W. Hanson, Dow Chemical Company, Midland, MI, to Willard F. Libby and Gerald W. Johnson, April 7. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-109.

Hanson, Alden W., 1958. Letter from Alden W. Hanson, Dow Chemical Company, Midland, MI, to Harold A. Fidler, April 23. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA.

Grebe, John J., 1962. Letter with encl. (Comments on Fresh Water Portion of J.E.C. Report "The Industry Review" sent by R. C. Allen and E. G. Bailey: Subcommittee on Violent Storms) from John J. Grebe, The Dow Chemical Company, Midland, MI, to Edward Teller, July 26. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-109.

Teller, Edward, 1962. Letter from Edward Teller to John J. Grebe, August 6. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-109.

Grebe, John J., 1964. Letter from John J. Grebe to Arvi O. Waananen, October 9. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.



### **5.27 Earth Furnace**

Nuclear Explosives to Develop Mineral Resources  
Plowshare Program  
West Virginia

Project Earth Furnace was proposed by the West Virginia Atomic Energy Committee to use an area in West Virginia, preferably a limestone deposit, to release atomic energy within underground cavities for smelting or converting mineral resources into “useful chemicals in recoverable form.” During September 1962, meetings were held between representatives from the U.S. Atomic Energy Commission and the West Virginia Atomic Energy Committee to discuss the project as well as other possible sites for Plowshare experiments in West Virginia.

Miller, Robert E., 1962. "Meeting with West Virginia Atomic Energy Commission." Memo from Robert E. Miller, U.S. Atomic Energy Commission, to Those Listed, September 21. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0309951.

### **5.28 El Centro Canal**

Nuclear Explosives for Canal Excavation  
Plowshare Program  
California

A nuclear excavation project to construct a canal from the Gulf of California to El Centro, California was suggested by the general manager of Radio Station KICO in El Centro, California. The project is listed as a “possible” nuclear excavation project on a list compiled by the U.S. Atomic Energy Commission, Division of Peaceful Nuclear Explosives, dated to July 1964.

U.S. Atomic Energy Commission, 1964. Suggested Nuclear Excavation Projects and Possible Nuclear Excavation Projects. Manuscript, Division of Peaceful Nuclear Explosives, July. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.

### **5.29 Etsel Dam**

Nuclear Quarrying for Construction of a Dam  
Plowshare Program  
California

A nuclear quarrying project for a dam on the Middle Fork of the Eel River near Covelo, California, was one of five locations being studied for a Plowshare quarrying demonstration project (see Travois – Chapter 3.21). A Demonstration Project Summary from the U.S. Army Corps of Engineers Nuclear Cratering Group outlines the project features. The dam was a California State project that was turned over to the U.S. Army Corps of Engineers, San Francisco District. The plan called for construction of a rock-fill

structure requiring 14 million bank cubic yards of rock. A sandstone source for the rock was located 6 to 7 miles northeast of the dam site. An estimated yield of 50 to 100 kts, in one or more detonations, was required to create enough aggregate. The project was not selected for demonstration. The proposed Etsel Dam was never built.

Slazak, Walter J., 1966. Letter with encl. ("Summary of Possible Quarrying Projects") from Walter J. Slazak, Lt. Colonel, Lawrence Radiation Laboratory, U.S. Army Engineer Nuclear Cratering Group, to Michael M. May, September 20. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.

Lawrence Radiation Laboratory. U.S. Army Engineer Nuclear Cratering Group, [1966]. Demonstration Project Summary. Manuscript. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-103 [OUO].

### **5.30 Experiment**

Nuclear Industrial Plowshare Experiment

Plowshare Program

West Virginia

Project Experiment was proposed by the West Virginia Atomic Energy Committee in cooperation with the U.S. Atomic Energy Commission. The objective of the project was to make the mineral resources and geological formations in the state of West Virginia available for Plowshare experiments. According to the Atomic Energy Committee, West Virginia had geological deposits suitable for Plowshare experiments including formations with limestone, sandstone, natural gas in shale beds, asphalt intersecting limestone deposits, and high pressure carbon dioxide with methane at depth. Project Experiment is discussed in a September 21, 1962 memo that summarizes a meeting held between the West Virginia Atomic Energy Committee and the U.S. Atomic Energy Commission.

Miller, Robert E., 1962. "Meeting with West Virginia Atomic Energy Commission." Memo from Robert E. Miller, U.S. Atomic Energy Commission, to Those Listed, September 21. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0309951.

### **5.31 Fault Lines**

Nuclear Explosives to Relieve Stress along Fault Lines

Plowshare Program

San Andreas Fault, California

John S. Kelly from the U.S. Atomic Energy Commission responded to a letter from the Ocean Science and Engineering, Inc., concerning a suggestion for using nuclear explosives along active fault lines, such as the San Andreas Fault, to relieve stress. Kelly commented that this application was probably not plausible, but would forward the inquiry to the Lawrence Radiation Laboratory for comment.

Kelly, John S., 1967. Letter from John S. Kelly, U.S. Atomic Energy Commission, to Willard Bascom, January 30.

### **5.32 Feather River Project**

Nuclear Explosives for Water Redistribution  
Plowshare Program  
California

A plan to redistribute water from the Feather River into central and southern California using Plowshare techniques is first documented in a February 4, 1963 publication by Edward Teller from the Lawrence Radiation Laboratory, and is also mentioned in a March 1963 publication by Teller in *Nuclear News*. The idea was to use nuclear explosive technology to assist in creation of a dam and reservoir near Oroville, California, and to excavate several small mountains for aqueduct construction. A July 1964 document from the U.S. Atomic Energy Commission, Division of Peaceful Nuclear Explosives, lists the Feather River Project as a project that had been considered by the State of California for nuclear excavation. However, an earthen dam constructed by conventional techniques was considered more economical. The Oroville dam was completed in 1968 as a water storage facility for the California State Water Project.

Teller, Edward, 1963. Plowshare. University of California, Lawrence Radiation Laboratory *Report UCRL-7222*, February 4. Livermore, CA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.

Teller, Edward, 1963. Plowshare. *Nuclear News*, Vol. 6, No. 3, pp. 4-12, March. American Nuclear Society.

Garretson, Fred, 1963. State May Atom-Blast for Water. *Oakland Tribune*, June 30. Oakland, CA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-109.

Vortman, L. J., 1969. Nuclear Excavation. Report, SC-DC-69-1716, Underground Physics Division, Sandia Laboratories, Albuquerque, NM, March. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-104.

Toman, John, 1970. Summary of Nuclear-Excavation Applications. Paper prepared for Proceedings of the ANS Topical Meeting, Engineering with Nuclear Explosives, Las Vegas, Nevada, January 14-16, 1970. University of California, Lawrence Radiation Laboratory, *Preprint UCRL-72220*, January 29. Livermore, CA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-104.

Toman, John, 1970. Summary of Nuclear-Excavation Applications. In *Symposium on Engineering with Nuclear Explosives: Proceedings*, Report CONF-700101, Vol. 1, pp. 245-279, May. American Nuclear Society, Hinsdale, IL.

### **5.33 Garden Valley Dam**

Nuclear Explosives for Construction of a Slide Dam

Plowshare Program

Idaho

In the 1960s, Garden Valley Dam was submitted by the U.S. Army Corps of Engineers, Walla Walla District, to the Chief of Engineers, as a civil works project that had potential for accomplishment using nuclear explosives. The project was proposed as a slide dam application at a site on the Payette River about 34 miles north of Boise, Idaho. The dam was a Bureau of Reclamation project and the feasibility study for construction using conventional methods was to be completed in 1969. The demonstration project summary does not recommend the project for a nuclear slide dam application. The possibility of using nuclear explosives to fracture rock for aggregate was also not recommended because there was an ample supply of river gravel in the area.

Lawrence Radiation Laboratory. U.S. Army Engineer Nuclear Cratering Group, [1966]. Demonstration Project Summary. Manuscript. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-103 [OUO].

### **5.34 Gas Hills Uranium Mine**

Nuclear Explosives to Mine Uranium

Plowshare Program

Wyoming

Gas Hills Uranium Mine was a project concept from Floyd B. Odlum of the Atlas Corporation to use nuclear explosives to strip a uranium ore deposit in the Gas Hills District of Wyoming. The concept is listed as a “possible” nuclear excavation project in a July 1964 document from the U.S. Atomic Energy Commission, Division of Peaceful Nuclear Explosives.

U.S. Atomic Energy Commission, 1964. Suggested Nuclear Excavation Projects and Possible Nuclear Excavation Projects. Manuscript, Division of Peaceful Nuclear Explosives, July. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.

### **5.35 Hansom**

Nuclear Explosives in Rock Breaking Applications

Plowshare Program

Various Locations and Applications

The Hansom Project Committee was formally established by the Lawrence Radiation Laboratory in September 1963. The Hansom Project was an overarching program with the goal of demonstrating the use of nuclear explosives in rock breaking applications. The specific technical objectives were: 1) to demonstrate the technical capabilities of rock fracturing in an industrial application, 2) to demonstrate the feasibility of using the

broken rock zone, and 3) to gain experience that could be used for practical economic and engineering analyses of similar projects of larger magnitude. The Hansom Committee investigated a broad range of projects including fracturing and in situ leaching of ore deposits, aggregate production, gas reservoir stimulation, oil shale retorting, nuclear caving for metallic ores, underground waste storage and/or disposal, and gas storage. However, most correspondence directed to the Hansom Committee/Group pertained to mining systems to obtain ore (especially Copper Recovery – Chapter 4.12 and Sloop – Chapter 4.37). No documents mention the Hansom Project after 1965, and it is assumed that specific tasks for the Hansom goals were named according to the project.

Higgins, Gary H., 1963. "Description of Project Hansom." Letter from Gary Higgins, Lawrence Radiation Laboratory, to John S. Kelly, September 11. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-102.

Higgins, Gary H., 1963. "Declassification of Description of Project Hansom." Letter from Gary Higgins, Lawrence Radiation Laboratory, to John S. Kelly, October 16. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-102.

Plowshare Advisory Committee, 1963. Plowshare Advisory Committee Meeting. Agenda from Plowshare Advisory Committee, October 28-29. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV.

Plowshare Advisory Committee, 1963. Plowshare Advisory Committee, Report on Eleventh Meeting. Meeting held at Lawrence Radiation Laboratory, Livermore, CA, October 28-29. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.

Lawrence Livermore National Laboratory, 1964. Status of Plowshare Field Programs. Report from Lawrence Livermore National Laboratory, May 6. On file at: Technical Reports Library, Lawrence Livermore National Laboratory, Livermore, CA.

Lombard, D. and J. Knox, 1965. "Hansom Economic Potential." Letter from D. Lombard and J. Knox, Lawrence Radiation Laboratory, to G. Johnson and G. Higgins, January 19. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-102 [OUO].

U.S. Department of the Interior. Bureau of Mines, 1965. Minutes Third Annual Plowshare Review Meeting, Denver, Colorado, January 28, 1965. Bureau of Mines and Atomic Energy Commission, March. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV [OUO].

### 5.36 Hawaii Harbor for Inter-Island Ferries

Nuclear Excavated Harbor

Plowshare Program

Hawaii

In a 1963 paper entitled "Plowshare," Edward Teller mentions that there had been discussion of using nuclear explosives to construct harbors in the Hawaiian Islands to increase traffic and commerce in the island chain. A project for harbors in the Hawaiian Islands for inter-island ferries is included on a list of "possible" nuclear excavation projects in a 1964 document from the U.S. Atomic Energy Commission, Division of Peaceful Nuclear Explosives. A series of status reports from the Nuclear Cratering Group with effective dates between December 31, 1963 and December 31, 1964 mention that the Honolulu District had briefly investigated the feasibility of using nuclear explosives in harbor excavation projects, although no specific project or location is named.

Teller, Edward, 1963. Plowshare. University of California, Lawrence Radiation Laboratory *Report UCRL-7222*, February 4. Livermore, CA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.

Graves, Ernest, 1964. "Status Report - Nuclear Explosives Studies for Civil Construction (Reports Control Symbol ENGCE-E-9)." Letter with encl. ("Status Report, Effective Date: 31 December 1963 - ENGCE-E-9") from Ernest Graves, Lawrence Radiation Laboratory, U.S. Army Engineer Nuclear Cratering Group, to Chief of Engineers, Department of the Army, February 4. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.

Graves, Ernest, 1964. "Status Report - Nuclear Explosives Studies for Civil Construction (Reports Control Symbol ENGCE-E-9)." Memo with encl. ("Status Report, Effective Date: 31 March 1964 - ENGCE-E-9") from Ernest Graves, Lawrence Radiation Laboratory, U.S. Army Engineer Nuclear Cratering Group, to Chief of Engineers, Department of the Army, April 23. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.

Slazak, Walter J., 1965. "Status Report - Nuclear Explosives Studies for Civil Construction (Reports Control Symbol ENGCE-E-9)." Memo with encl. ("Status Report, Effective Date: 31 December 1964 - ENGCE-E-9") from Walter J. Slazak, Lawrence Radiation Laboratory, U.S. Army Engineer Nuclear Cratering Group, to Chief of Engineers, Department of the Army, January 15. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.

Hughes, Bernard C., 1965. "Status Report - Nuclear Explosives Studies for Civil Construction (Reports Control Symbol ENGCE-E-9)." Letter with encl. ("Status Report, Effective Date: 31 March 1965 - ENCGW-P-6(R1)") from Bernard C. Hughes, U.S. Army Engineer Cratering Group, to Chief for Engineers, Department of the Army, April 13. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.

### **5.37 Honokahau Small Craft Harbor**

Nuclear Excavated Harbor

Plowshare Program

Hawaii

In the 1960s, the Honolulu District submitted a project for building a small-craft harbor on the Island of Hawaii as a possible demonstration project for the Plowshare Program. The harbor was planned at Honokahau on the west coast of Hawaii. The harbor had been authorized by the River and Harbor Act of 1965. Nuclear excavation was proposed to excavate a basin and an entrance channel in a recent lava flow using row charge detonations. The plan called for a channel 840 ft by 120 ft with a rectangular basin approximately 17.5 acres in area. The harbor was eventually built using conventional methods and was completed in 1970. It is maintained by the U.S. Army Corps of Engineers.

Lawrence Radiation Laboratory. U.S. Army Engineer Nuclear Cratering Group, [1966]. Demonstration Project Summary. Manuscript. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-103 [OUO].

### **5.38 Idaho Phosphates**

Use of Nuclear Explosives to Mine Phosphates

Plowshare Program

Idaho

The Thomas B. Trent Organization contacted the Lawrence Radiation Laboratory about the possibility of using nuclear explosives to mine the McIlwee phosphate deposits. In an October 8, 1963 letter, the Lawrence Radiation Laboratory responded that they were familiar with the Idaho phosphate deposits, as they had been studied in the past as a possible source of uranium. However, the large yields involved with nuclear explosives as well as the massive fracturing effects would not be practical for the McIlwee deposits due to probable over-fracture and dilution of the deposit.

Rabb, David D., 1963. Letter from David D. Rabb, Lawrence Radiation Laboratory, to T. B. Trent, October 8. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.

### **5.39 John Day River**

Nuclear Construction of a Slide Dam

Plowshare Program

Oregon

The initial project concept for the John Day River Storage and Irrigation Project was a plan to build a conventional dam at the head of the John Day River area of the John Day Reservoir on the Columbia River. The project was submitted by the U.S. Army Corps of Engineers, North Pacific Division, Walla Walla District, as a possible Plowshare project.

The demonstration project summary mentions the possible use of nuclear excavation to build a slide dam, but the preliminary appraisal stated that a slide dam application required more study. No other nuclear demonstration application was suggested for this project. The John Day Dam on the Columbia River was completed in 1971.

Lawrence Radiation Laboratory. U.S. Army Engineer Nuclear Cratering Group, [1966]. Demonstration Project Summary. Manuscript. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-103 [OUO].

#### **5.40 Kaalualu Harbor**

High Explosive Cratering Tests for Small-Craft Harbor  
Plowshare Program  
Hawaii

In a series of status reports from the Explosive Excavation Research Office with effective dates between April 10, 1972 and September 30, 1972, there is mention of the proposed Kaalualu Bay explosive experiments. In 1972, a series of underwater cratering tests were planned at the southern tip of the Island of Hawaii. The U.S. Army Corps of Engineers, Pacific Coast Division was studying the possibility of constructing a small boat harbor and the Explosive Excavation Research Office was to provide an explosive excavation design for the entrance channel and basin. The cratering tests were to provide information on underwater cratering in hard rock. The test series was scheduled for November 1972. However, the June 30, 1972 report notes that the project would be postponed due to a conflict between the state and county concerning the best location for a harbor. The State of Hawaii funded an independent study for the harbor location, and the Pacific Coast Division recommended that the experimental tests be postponed until 1974. The harbor was not constructed and there is no information about the status of the experimental tests at Kaalualu.

LaFrenz, Robert L., 1972. "Status Report - Rapid Excavation with Explosives." Letter with encl. ("Status Report, Effective Date: 31 March 1972") from Robert L. LaFrenz, Explosive Excavation Research Office, Corps of Engineers, to Director, U.S. Army Engineer Waterways Experiment Station, April 10. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-108.

Mills, Robert R., Jr., 1972. "Status Report - Rapid Excavation with Explosives." Letter with encl. ("Status Report, Effective Date: 30 June 1972") from Robert R. Mills, Jr., U.S. Army Engineer Waterways Experiment Station Explosive Excavation Research Laboratory, Corps of Engineers, to Director, U.S. Army Engineers Waterways Experiment Station, July 28. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-108.

Mills, Robert R., Jr., 1972. "Status Report - Rapid Excavation with Explosives." Letter with encl. ("Status Report, Effective Date: 30 September 1972") from Robert R. Mills, Jr., U.S. Army Engineer Waterways Experiment Station Explosive Excavation Research Laboratory, Corps of Engineers, to Director, U.S. Army Engineer Waterways Experiment Station, October 10. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-108.



#### **5.41 Keetch Plan for Water Conservation**

Nuclear Explosives for Water Storage System

Plowshare Program

Texas

In a November 29, 1963 letter, J.A. Keetch from Corpus Christi, Texas contacted the U.S. Atomic Energy Commission about his idea to use Plowshare techniques to implement a water storage system. The “Keetch Plan for Water Conservation” was based on the concept of excavating a perennial stream bed to the depth of about 30 ft to provide a water “trap” or reservoir. Keetch was interested in finding out if an underground nuclear explosion would be feasible for creating the reservoir. The inquiry was forwarded to the Lawrence Radiation Laboratory who, in a January 9, 1964 letter, responded favorably to the idea and mentioned that the proposal had been taken under consideration.

Vermillion, Henry G., 1963. Letter with encl. (Letter from J. A. Keetch to Henry Vermillion, November 29) from Henry G. Vermillion, U.S. Atomic Energy Commission, Nevada Operations Office, to Gary Higgins, December 6. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.

Circeo, Louis J., 1964. Letter from Louis J. Circeo, Lawrence Radiation Laboratory, to J. A. Keetch, January 9. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.

#### **5.42 Lake Erie – Lake Ontario Waterway**

Nuclear Explosives to Construct a Waterway

Plowshare Program

New York

The project concept was to build a navigable waterway between Lake Erie and Lake Ontario. Construction of the waterway would require removing approximately 100 million cubic yards of soil and rock, and nuclear explosive techniques were proposed for part of the excavation, especially in areas of hard rock. The project is included in a list of “suggested” nuclear excavation projects on a U.S. Atomic Energy Commission, Division of Peaceful Nuclear Explosives, July 1964 document.

U.S. Atomic Energy Commission, 1964. Suggested Nuclear Excavation Projects and Possible Nuclear Excavation Projects. Manuscript, Division of Peaceful Nuclear Explosives, July. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.

### **5.43 Lake Erie – Ohio River Canal**

Nuclear Explosives to Excavate a Canal

Plowshare Program

Ohio

The Pittsburgh Engineer District proposed a study of a project to use nuclear explosives to build a canal between Lake Erie and the Ohio River. However, the project would be located in the industrialized and populated area of northeastern Ohio in the vicinity of Warren and Youngstown, and side effects from the project would be unacceptable. The study effort for this project was, therefore, canceled.

Hughes, Bernard C., 1969. History of the U.S. Army Engineer Nuclear Cratering Group, January. Lawrence Radiation Laboratory, January. Livermore, CA.

### **5.44 Laurel River Dam**

Nuclear Quarrying for a Rock-Fill Dam

Plowshare Program

Kentucky

The project was a proposal to use nuclear explosives to fracture rock to produce aggregate for construction of the Laurel River Dam. Congress authorized the dam on the Laurel River in Kentucky at a location 2.3 miles above the confluence with the Cumberland River. Approximately 2,610,000 cubic yards of aggregate were needed to construct the rock-fill dam and nuclear explosives would possibly provide a reduction in construction costs. The Laurel River Dam was a “suggested” project on a list compiled by the U.S. Atomic Energy Commission, Division of Peaceful Nuclear Explosives, dated July 1964. The dam was constructed using conventional methods and was completed in 1974.

U.S. Atomic Energy Commission, 1964. Suggested Nuclear Excavation Projects and Possible Nuclear Excavation Projects. Manuscript, Division of Peaceful Nuclear Explosives, July. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.

### **5.45 Livermore Valley Sewage Disposal**

Nuclear Chimneys for Sewage Disposal

Plowshare Program

California

Livermore Valley was one of three areas investigated during 1964 and 1965 for the possible use of nuclear chimneys to store sewage (see also Lake Tahoe Sewage – Chapter 4.23 and Modesto Waste Disposal – Chapter 5.49). A feasibility study for Livermore Valley was completed in 1963, but was unpublished and has not been located. A March 1964 study for Lake Tahoe sewage disposal mentions that the method for using deep well injection for the disposal of effluent for the Livermore Valley had encouraging results.

However, a January 8, 1971 memo states that while the application for sewage disposal was feasible, it had a number of problems, primarily danger of seismic effects from creating chimneys large enough to store the effluent and insufficient data about fluid flow from the chimneys. Finally, the application was not considered cost effective.

Korver, John A., 1964. Lake Tahoe Sewage Disposal Study (Draft). Manuscript, Lawrence Radiation Laboratory, UOPKA 64-17, March 25. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-100.

Cohen, Jerry J., 1971. "Summary of Investigations into Sewage Disposal by Plowshare Methods." Memo from J. J. Cohen, Lawrence Radiation Laboratory, to A. E. Lewis, January 8.

Werth, Glenn C., 1971. Letter from Glenn C. Werth, Lawrence Radiation Laboratory, to John S. Kelly, January 25.

#### **5.46 Magnesium Recovery**

Nuclear Explosives for Mining Magnesium  
Plowshare Program  
Georgia and North Carolina

In a 1965 letter, the U.S. Atomic Energy Commission made a request to the Oak Ridge National Laboratory to propose projects for the Plowshare Program that would be suitable for the Appalachian area. H. G. MacPherson, then the Deputy Director of the Laboratory, responded that a possible application might be the recovery of magnesium metal from olivine deposits in western North Carolina and northern Georgia.

Kelly, John S., 1965. Letter from John S. Kelly, U.S. Atomic Energy Commission, to H. G. MacPherson, February 16.

MacPherson, H. G., 1965. Letter from H. G. MacPherson, Oak Ridge National Laboratory, Oak Ridge, TN, to John S. Kelly, April 28.

#### **5.47 Megawatt**

Underground Nuclear Explosions for Power Generation  
Plowshare Program  
West Virginia

Megawatt was a proposal to convert energy from underground nuclear explosions into electricity in West Virginia. The source of this project concept was the West Virginia Atomic Energy Committee and was introduced to representatives from the U.S. Atomic Energy Commission during a meeting held in September 1962. The cost of using nuclear explosives to generate electricity was not considered more cost effective than the use of coal, and the U.S. Atomic Energy Commission did not recommend the project concept for the state of West Virginia.

Miller, Robert E., 1962. "Meeting with West Virginia Atomic Energy Commission." Memo from Robert E. Miller, U.S. Atomic Energy Commission, to Those Listed, September 21. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0309951.

Shackelford, Terry J., 1972. Project Mini-Mound. U.S. Army Engineer Waterways Experiment Station Explosive Excavation Research Laboratory, Technical Memorandum EERO TM/71-10, March. On file at: Technical Information Center, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MI.

U.S. Army Engineer Waterways Experiment Station Explosive Excavation Research Laboratory, 1972. "Listing and Publication Schedule of EERO Reports." Schedule from Explosive Excavation Research Laboratory, Livermore, CA, March 31. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-108.

#### **5.48 Missouri River Reservoir**

Nuclear Excavation for Reservoir Project

Plowshare Program

Montana

A project for a multiple use reservoir between the Fort Peck Reservoir and Fort Benton on the Missouri River in Montana was submitted as a potential Plowshare demonstration project for the U.S. Army Engineer Nuclear Cratering Group. The proposal to construct two earth-fill dams was a joint U.S. Army Corps of Engineers, Omaha District, and Bureau of Reclamation project. The Omaha District did not identify a potential nuclear excavation application in the summary for this project.

Lawrence Radiation Laboratory. U.S. Army Engineer Nuclear Cratering Group, [1966]. Demonstration Project Summary. Manuscript. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-103 [OUO].

#### **5.49 Modesto Waste Disposal**

Nuclear Chimneys for Sewage Disposal

Plowshare Program

California

Use of nuclear explosives to create an underground chimney for waste disposal in the San Joaquin Valley, California is discussed in a newspaper article from the *Modesto Bee*, dated April 9, 1965. The article reports that the director of the Modesto Public Works contacted scientists from the Lawrence Radiation Laboratory about a possible Plowshare approach to solving Modesto's sewage storage problems. Preliminary studies for the project were conducted by Lawrence Radiation Laboratory. A January 1971 memo from the Lawrence Radiation Laboratory states that from 1964 through 1965 three feasibility studies were conducted for sewage waste disposal using underground chimneys (see also Lake Tahoe Sewage – Chapter 4.23 and Livermore Area Sewage – see Chapter 5.45). The unpublished report "Modesto Sewage Disposal Study" has not been located.

Knoll, Bernie, 1965. A Modesto Atom Bomb? It Could Happen--For a Sewer Plant. *Modesto Bee*, April 9. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.

Cohen, Jerry J., 1971. "Summary of Investigations into Sewage Disposal by Plowshare Methods." Memo from J. J. Cohen, Lawrence Radiation Laboratory, to A. E. Lewis, January 8.

Werth, Glenn C., 1971. Letter from Glenn C. Werth, Lawrence Radiation Laboratory, to John S. Kelly, January 25.

Hansen, S., no date. Modesto Sewage Disposal, unpublished. Not Available.

### **5.50 Molybdenite Recovery**

Nuclear Explosives for Molybdenite Mining  
Plowshare Program  
Colorado

In 1964, the American Metal Climax Company approached the Hansom Committee at the Lawrence Radiation Laboratory, regarding the possible application of nuclear explosives to the recovery of molybdenite ore from the Urad Mine, about 40 miles west of Golden, Colorado. The Laboratory agreed to proceed with a preliminary design for using nuclear explosives as well as an investigation of the potential hazards. In a memo dated February 28, 1964, they proposed a rock-breaking plan that would use seven nuclear devices with a total yield of 60 kts positioned in an array pattern beneath the ore body. In turn, the Climax Molybdenum Company, a Division of American Metal Climax, Inc., prepared a paper to be presented at the American Institute of Chemical Engineers in September 1964, evaluating the use of nuclear explosives in mining. Documentation is available that provides comments on the draft paper, but there is no additional documentation about the project itself.

Rabb, David D., 1964. Memo from David D. Rabb, Lawrence Radiation Laboratory, to Record/Hansom Group, January 28. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-085.

Lombard, D. B., and S. M. Hansen, 1964. "Climax Ore Body." Memo from D. B. Lombard and S. M. Hansen, Lawrence Radiation Laboratory, to Hansom Committee, February 3. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-102.

Lombard, David B., 1964. "Disposition of the Climax Caper." Memo from D. B. Lombard, Lawrence Radiation Laboratory, to Hansom Committee, February 28. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-102.

Jones, W. Ernest, 1964. Letter with encl. (Evaluation of Nuclear Explosives in Mining an Ore Body by Underground Methods, manuscript) from W. Ernest Jones, Climax Molybdenum Company, Golden, CO, to David D. Rabb, June 10. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-086.

Lombard, David B., 1964. Letter with encl. (Evaluation of Nuclear Explosives in Mining an Ore Body by Underground Methods, manuscript, revised) from David B. Lombard, Lawrence Radiation Laboratory, to W. E. Jones, June 22. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-102 and PLO-086.

### **5.51 Montana Silver Retarc**

Nuclear Explosives for Silver Mining

Plowshare Program

Montana

In a letter dated May 21, 1969, Milo Nordyke from the Lawrence Radiation Laboratory notified the U.S. Atomic Energy Commission of a meeting he had with a representative of the Goodsin Mining Corporation, regarding a possible Plowshare project. The mining company expressed interest in mining a low-grade silver deposit by detonating a deeply buried nuclear explosive beneath the ore to produce a retarc. The company held patented claims in the Beaverhead National Forest and was interested in the possibility of using nuclear explosives to fracture and mound the ore body to make it more amenable to open-pit mining. Milo Nordyke felt the application had “significant” potential and recommended that the company contact the U.S. Atomic Energy Commission for project approval.

Nordyke, Milo D., 1969. Letter from Milo D. Nordyke, Lawrence Radiation Laboratory, to John S. Kelly, May 21. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA.

### **5.52 Mountain Lake**

Nuclear Explosives for Water Resource Development

Plowshare Program

West Virginia

The project was a proposal to use nuclear explosives for water development projects in the State of West Virginia. A specific project application was not formulated, but was framed generally as using Plowshare techniques to create craters, dams, and lakes for recreational use and/or to develop water resources for industrial or agricultural purposes in West Virginia. The project was proposed by the West Virginia Atomic Energy Committee and presented to the U.S. Atomic Energy Commission at a meeting held in September 1962. The project concept appears on a list of “possible” nuclear excavation projects compiled by the U.S. Atomic Energy Commission, Division of Peaceful Nuclear Explosives, dated July 1964.

Miller, Robert E., 1962. "Meeting with West Virginia Atomic Energy Commission." Memo from Robert E. Miller, U.S. Atomic Energy Commission, to Those Listed, September 21. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0309951.

### **5.53 Mt. Snow**

Nuclear Excavation of Mountainside  
Plowshare Program  
Vermont

Mt. Snow was a proposal by the Mt. Snow Development Corporation to re-shape the northern side of Mt. Snow in southern Vermont for recreational purposes. The project is listed as a "possible" nuclear excavation project on a July 1964 document from the U.S. Atomic Energy Commission, Division of Peaceful Nuclear Explosives.

U.S. Atomic Energy Commission, 1964. Suggested Nuclear Excavation Projects and Possible Nuclear Excavation Projects. Manuscript, Division of Peaceful Nuclear Explosives, July. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.

### **5.54 New York Plateau Excavation**

Nuclear Excavation of a Rock Plateau  
Plowshare Program  
New York

Joseph L. Colosimo contacted the U.S. Atomic Energy Commission about a proposal to use nuclear explosives to excavate a 60-acre rock plateau in upper New York to a depth of 100 ft. The project is listed on a July 1964 document from the U.S. Atomic Energy Commission, Division of Peaceful Nuclear Explosives as a "possible" nuclear excavation project.

U.S. Atomic Energy Commission, 1964. Suggested Nuclear Excavation Projects and Possible Nuclear Excavation Projects. Manuscript, Division of Peaceful Nuclear Explosives, July. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.

### **5.55 Newmont Project**

Nuclear Explosives to Fracture Copper Ore for Underground Chemical Mining  
Plowshare Program  
Arizona

The Newmont Mining Corporation requested that their Copper Creek property in Pinal County, Arizona be evaluated for a mining experiment to recover deeply buried primary copper ore. The Lawrence Radiation Laboratory issued a project concept on August 10,

1970. The primary objectives of a chemical mining experiment were to: 1) produce and define the limits of the chimney, 2) determine the rate of solution of copper from the chemical leach process, and 3) evaluate the results in terms of a commercial process. Preliminary cost estimates for the project were provided in a memo dated August 18, 1970 under the name of Project Newmont. However, the metallurgical research group at the Newmont Mining Company raised concerns about the ability to verify the chemical mining technique proposed by Lawrence Radiation Laboratory and deferred submitting a proposal for a chemical mining project. A discussion of the Newmont Project is included with Copper Ore Chemical Mining (see Chapter 4.11).

Lawrence Radiation Laboratory, 1970. Concept of a Proposed Chemical Mining Experiment at Copper Creek, Arizona. Manuscript, Lawrence Radiation Laboratory, Livermore, CA, August 10. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-087.

Lewis, A. E., 1970. Letter from A. E. Lewis, Lawrence Radiation Laboratory, to A. H. Ewing, August 11. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-087.

Cramer, James L., 1970. "Project Newmont, Preliminary Cost Estimate." Memo from J. L. Cramer, Lawrence Radiation Laboratory, to Art Lewis, August 18. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-087.

Cramer, James L., 1970. "Pumping Costs for Leaching Projects." Memo from James L. Cramer, Lawrence Radiation Laboratory, to Art Lewis, August 31. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-087.

Fulton, R. B., 1970. Letter from R. B. Fulton, Newmont Mining Corporation, New York, NY, to Anthony H. Ewing, September 2. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-087.

Lewis, A. E., 1970. Letter from Arthur E. Lewis, Lawrence Radiation Laboratory, to A. F. Osborne, December 16. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-087.

Holzer, Fred, 1972. "Du Pont, in cooperation with Ranchers Mining Company..." Telex from Fred Holzer, Lawrence Livermore Laboratory, to E. M. Douthett, January 28. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-087.

## **5.56 Nuclear Explosive Power Generation**

Underground Nuclear Explosions for Power Generation

Plowshare Program

Salt Dome in the United States

The idea of using nuclear explosives to generate power was introduced at the first Plowshare conference held in 1957. Salt domes in three regions were identified as



suitable for the Plowshare experiment and are described in a 1958 document. These regions are: 1) the Gulf Coast of Texas, Louisiana, Mississippi, and Alabama, 2) the Paradox basin of Colorado and Utah, and 3) the Delaware and Permian basins in southeastern New Mexico and western Texas. On May 16, 1958, the Westinghouse Electric Company submitted a proposal to the U.S. Atomic Energy Commission to conduct a feasibility study for converting heat from sequential nuclear explosions in a salt dome into electric power. Westinghouse proposed studies to investigate the ability of rock salt to retain heat, the homogeneity of heat distribution in a salt cavern, and the mechanical stability of a salt cavern. A letter from Westinghouse to the Lawrence Radiation Laboratory, dated June 20, 1960, indicates that due to disagreements over legal requirements, a cooperative study was not established. However, Westinghouse was interested in renegotiating a contract for the project. The response to this request is not known, but this early project concept provided the theoretical basis for a sequential fission project concept explored in the early 1970s (see PACER – Chapter 5.58).

Read, Charles B., 1958. "Site for Plowshare Experiment in Salt." Letter from Charles B. Read to Gerald W. Johnson, April 16. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV.

Wells, Robert L., 1958. "Proposal for the Utilization of Heat from Underground Nuclear Detonations." Letter from Robert L. Wells, Westinghouse Electric Corporation, Atomic Power Department, to Harold A. Fidler, May 16. On file at: Archives and Records Office, Archives and Records Office, Lawrence Berkeley National Laboratory, Berkeley, CA, File 434-900157, 7/18.

Westinghouse Electric Corporation. Atomic Power Department, 1958. Proposal for the Utilization of Heat from Underground Nuclear Detonations. Report to U.S. Atomic Energy Commission, from Westinghouse Electric Corporation, Pittsburgh, PA, May 16. On file at: Archives and Records Office, Lawrence Berkeley Laboratory, Berkeley, CA, File 434-900157, 7/18.

Butler, P. J., 1960. "Utilization of Heat from Underground Nuclear Detonations." Letter from P. J. Butler, Westinghouse Electric Corporation, to C. L. Blue, June 20. On file at: Archives and Records Office, Lawrence Berkeley National Laboratory, Berkeley, CA, File 434-900157, 7/18.

### **5.57 Offshore Fuel Oil Storage**

Nuclear Chimneys for Undersea Storage of Fuel Oil

Plowshare Program

Guam

The offshore storage of fuel oil in nuclear created chimneys was proposed as a possible Plowshare application by the Lockheed Missiles & Space Company. In July 1968, Lockheed submitted a document to the U.S. Navy titled, "Proposed Pilot Project for Underground Fuel storage in Cavities Created by Nuclear Explosives." A schematic figure from the document illustrates the oil transfer system showing a cavity, pump house, strainers, and tanker berth. A copy of the document itself has not been located. A

1969 telex from the Laboratory indicates that Lockheed was developing a plan for oil storage for the U.S. Navy on the island of Guam. According to a Lawrence Radiation Laboratory memo dated January 28, 1971, the use of nuclear explosives to construct a storage chimney was feasible. However, the memo raises concerns about possible contamination of fuel oil that might result from a salt water displacement system planned for forcing oil out of the chimney.

McCool, W. B., 1968. "Atomic Energy Commission Status of Plowshare Industrial Projects." Memo with encl. ("Status of Plowshare Industrial Projects," memo from John S. Kelly, U.S. Atomic Energy Commission, Division of Peaceful Nuclear Explosives, to List) from W. B. McCool, U.S. Atomic Energy Commission to Distribution, April 26. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029 [OUO].

Lockheed Missiles & Space Company, 1968. "Fig. 2-5 Oil Transfer System Schematic." Figure from LMSC-D080035, Proposed Pilot Project for Underground Fuel Storage in Cavities Created by Nuclear Explosives, July 18.

Nordyke, Milo D., 1969. Telex from Milo D. Nordyke, Lawrence Radiation Laboratory, to John S. Kelly, May 7.

Green, J. B., Jr., 1971. "Possible Peaceful Applications of Nuclear Explosive by the U. S. Navy." Memo from J. B. Green, Jr., Lawrence Radiation Laboratory, to Glenn C. Werth, January 28.

Lawrence Livermore National Laboratory, no date. "Undersea Oil Storage Concepts." Undersea storage drawing\_05\_a. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA.

## **5.58 PACER**

Underground Nuclear Explosions for Power Generation  
Plowshare Program  
Salt Dome in the United States

Project PACER was an investigation into the use of sequential fusion explosions in a cavity to generate electric power. The general idea was first proposed in 1957 (see Nuclear Explosive Power Generation – Chapter 5.56), but the technical aspects of the project were not studied until the 1970s. The project concept of using thermonuclear explosions as an energy source was developed through a joint Explosive Research and Development Administration project by Research and Development Associates and Los Alamos Laboratory. The final report on the Project PACER concept was issued in July 1974. The generalized plan was to use sequential firings in an underground salt cavity to create radioactive steam. The steam would be used to make secondary steam, by means of a heat exchanger, to operate turbine-electrical generators. The plan called for an underground cavity about 300 m in diameter and at a depth of 1500 m. According to the conceptual plan, the PACER fusion power facility would be capable of detonating of 50 kt nuclear explosive devices, roughly 750 times a year, for about 40 years. In a 1975 analysis for the U.S. Arms Control and Disarmament Agency, technical and economic

uncertainties with PACER were pointed out, namely, the stability of the salt cavity used for the explosions, difficulties with radiation, probable damage in the surrounding area from continuous ground motion, and the cost of production. PACER did not proceed beyond the conceptual phase.

U.S. Atomic Energy Commission. Nevada Operations Office, [1974]. Analysis of Operation Costs by Program, FY 1975, FY 1976, FY 1977, Schedule 21a. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.

Elkins, Lloyd E., Richard Garwin, Ted Greenwood, Claude Hocott, Henry Jacoby, Gerald W. Johnson, Richard Morse, and F. A. Long (Chairman), 1975. An Analysis of the Economic Feasibility, Technical Significance, and Time Scale for Application of Peaceful Nuclear Explosions in the U.S., with Special Reference to the GURC Report Thereon. Report to U.S. Arms Control and Disarmament Agency from The Program on Science, Technology and Society, Cornell University, Ithaca, NY, April. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-028.

Carter, Luther J., 1975. Peaceful Nuclear Explosions: Promises, Promises. *Science*, Vol. 188, June 6. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.

Metzger, H. Peter, 1975. Nuclear Stimulation Plan Limpes Into Oblivion. *Rocky Mountain News "Trend,"* August 31. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.

Rowen, Henry, 1976. The Economics for Peaceful Nuclear Explosions. Report to International Atomic Energy Authority from Stanford University, February. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-028.

Bratton, J. K., 1976. "IAEA Fifth PNE Technical Committee Meeting." Letter from J. K. Bratton, Major General, U.S. Director of Military Application, to E. B. Giller, September 7. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.

Long, F. A., 1976. Peaceful Nuclear Explosions. *Bulletin of the Atomic Scientists*, pp. 18-26, October. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.

Hubbard, H. W. and R. P. Hammond, [1976]. PACER--A Practical Fusion Power Concept. Paper prepared for Intersociety Energy Conversion Conference, 1976. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.

## 5.59 Payette

Construction of a Cavity for a Nuclear Monitoring Experiment

Vela Uniform

Mississippi

Payette was a study to investigate the feasibility of constructing an underground chamber for a nuclear monitoring experiment in the 5 to 10 kt range. The program was initiated to evaluate if a large underground spherical cavity, approximately 300 ft in diameter, could be built to act as a decoupling chamber. The program was conducted by the Advanced Research Projects Agency and the U.S. Department of Defense in cooperation with the U.S. Atomic Energy Commission, Nevada Operations Office. The final summary report for Project Payette was issued in March 1970. The results of the program suggested that a large chamber could be constructed in a salt dome using conventional or solution mining techniques. The Tatum Salt Dome near Hattiesburg, Mississippi, was selected for a potential Payette experiment. The proposed Payette cavity would be approximately 315 ft in diameter at a depth of 2,700 ft. The Project Payette plan called for three phases: Phase I was to include a site evaluation and engineering design, during Phase II the cavity would be constructed, and Phase III would include the emplacement of instruments and device, detonation, and post-shot programs. There is no documentation available to indicate that the project was conducted beyond the feasibility study.

Lawrence Radiation Laboratory, 1965. Costs and Time Variations in Construction of Large Underground Cavities. Manuscript, Lawrence Radiation Laboratory, December 16, Livermore, CA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-031.

Wallsterdt, R. W., 1966. "Payette Site Selection." Memo from R. W. Wallsterdt to G. C. Werth, February 11. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-031.

U.S. Atomic Energy Commission. Nevada Operations Office, 1966. Project Payette, Proposal - Phase I. Manuscript, U.S. Atomic Energy Commission, June. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV [OUO].

U.S. Atomic Energy Commission. Nevada Operations Office, 1966. Phase I, Project Payette. Manuscript, U.S. Atomic Energy Commission, June 20. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-031.

Reeves, James E., 1966. Letter from James E. Reeves, U.S. Atomic Energy Commission, Nevada Operations Office, to G. C. Werth, July 1. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-031 [OUO].

Rabb, David D., 1966. Plowshare Program, October 1, 1965 – July 15, 1966, Vol. II, No. 2. University of California, Lawrence Radiation Laboratory, *Report UCRL-50008-66-1*, July 15. Livermore, CA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.

- Reeves, James E., 1966. Telex from James E. Reeves, U.S. Atomic Energy Commission, Nevada Operations Office, to J. Barton, August 29. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-031.
- Reeves, James E., 1966. "Project Payette Proposal - Phase I - Dated June 1966." Memo from James E. Reeves, U.S. Atomic Energy Commission, Nevada Operations Office, to Gen. Delmar L. Crowson, September 1. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-031.
- U.S. Atomic Energy Commission. Nevada Operations Office, 1966. Press Release, Subject: Project Payette proposals, from U.S. Atomic Energy Commission, NV-66-118, October 7. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-031.
- Rawson, Don, 1967. "Solution-Mine the Salmon-Sterling Cavity to Construct the Payette Cavity." Memo from Don Rawson, Lawrence Radiation Laboratory, to Gary Higgins, February 8. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-031.
- NTS News, 1967. Preliminary Planning for Project Payette. *NTS News*, Vol. 10, No. 9, May 12. Reynolds Electrical & Engineering Company, Inc., Mercury, NV. On file at: Nuclear Testing Archives, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0112281.
- Benedix, C. P., 1967. "Payette--Status of Engineering Studies." Memo from C. P. Benedix, Lawrence Radiation Laboratory, to V. N. Karpenko, August 31.
- Nair, Keshavan, 1967. Stability Studies for Project Payette, Final Report. Report to Fenix & Scisson, Inc., Tulsa, OK, from Woodward-Clyde-Sherard & Associates, Materials Research & Development, Inc., Oakland, CA, October.
- Fenix & Scisson, Inc., 1967. Project Payette: Phase I - A Study of the Technical Feasibility of Constructing a Large Cavity in Tatum Salt Dome. Report to U.S. Atomic Energy Commission, Nevada Operations Office, from Fenix & Scisson, Inc, Tulsa, OK and Petroleum Consultants, Houston, TX, November 6. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-031.
- Reeves, James E., 1967. "ARPA Work Authorization No. 5 - Project Payette, Feasibility Studies - Phase I." Memo from James E. Reeves, U.S. Atomic Energy Commission, Nevada Operations Office, to William D. Smith, Jr., December 5. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-031.
- U.S. Atomic Energy Commission, 1968. Chapter 11 - The Plowshare Program. In *Annual Report to Congress of the Atomic Energy Commission for 1967*, pp. 199-208, January. U.S. Government Printing Office, Washington, D.C.
- Rodean, H. C., 1968. "Payette Review Meeting." Memo (UOPOKA 68-9) from H. C. Rodean, Lawrence Radiation Laboratory, to Distribution, March 8. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-031.

- Reeves, James E., 1968. Telex from James E. Reeves, U.S. Atomic Energy Commission, Nevada Operations Office, to E. B. Giller, Brig. Gen., March 23. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-031.
- Reeves, James E., 1968. Telex from James E. Reeves, U.S. Atomic Energy Commission, Nevada Operations Office, to E. B. Giller, Brig. Gen., April 23. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-031.
- Rodean, H. C., 1968. "Payette Meeting at NVOO on July 9, 1968." Memo from H. C. Rodean, Lawrence Radiation Laboratory, to Distribution, July 10. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-031.
- Allen, Kermit, Jr., 1968. Project Payette; Proposed Solution Mining Program for the Creation of a 315-foot Diameter Unsupported Sphere at a Depth of 2,700-feet. Report to U.S. Atomic Energy Commission from Fenix & Scisson, Inc., Tulsa, OK, August 19.
- Dahle, Donald G., 1968. Project Payette; Introduction and Background. Paper Presented at the Fall Meeting of the American Institute of Mining, Metallurgical and Petroleum Engineers, September 18-20, Minneapolis, MN. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV.
- Stone, Ronald B., 1968. "Project Payette" Proposed Conventional Mining Method for the Creation of a 315 Foot Diameter Unsupported Sphere at a Depth of 2700 Feet. Paper Presented at the Fall Meeting of the American Institute of Mining, Metallurgical and Petroleum Engineers, September 18-20, Minneapolis, MN.
- Rodean, H. C., 1968. "Payette Meeting at NVOO on October 10, 1968." Memo (UOPKA 68-25) from H. Rodean, Lawrence Radiation Laboratory, to Distribution, October 11. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-031.
- Stone, Ronald B., 1968. "Project Payette - Final Summary Report." Letter with encl. (Final Summary Report) from Ronald B. Stone, Fenix & Scisson, Inc., Tulsa, OK, to Donald G. Dahle, November 22. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV.
- Benedix, Claude P., 1969. "Project PAYETTE Status Report." Memo from Claude P. Benedix to V. Karpenko and G. Broadman, January 16. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-031.
- Rodean, H. C., 1969. "Payette Meeting at NVOO on January 15, 1969." Memo (UOPKA 69-3) from H. Rodean, Lawrence Radiation Laboratory, to Distribution, January 16. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-031.
- Benedix, Claude P., 1969. "Project PAYETTE Status Report." Memo from Claude P. Benedix to V. Karpenko and G. Broadman, March 24. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-031.

- Benedix, Claude P., 1969. "Payette Status Report." Memo from Claude P. Benedix to V. Karpenko and G. Broadman, June 10. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-031.
- Benedix, Claude P., 1969. "Project PAYETTE Review Meeting." Memo from Claude P. Benedix to V. Karpenko and G. Broadman, July 17. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-031.
- Rodean, H. C., 1969. "Project Payette Meeting at NVOO on September 10, 1969." Memo (UOPKA 69-46) from H. C. Rodean, Lawrence Radiation Laboratory, to Distribution, September 11. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-031.
- Benedix, Claude P., 1969. "Salt Cavity Solution Mining Experiment - Project Payette." Memo from Claude P. Benedix to V. Karpenko and G. Broadman, November 19. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-031.
- Rodean, H. C., 1969. "November 18, 1969, Payette Meeting." Memo (UOPKA 69-59) from H. C. Rodean, Lawrence Radiation Laboratory, to Distribution, November 19. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-031.
- Rodean, H. C., 1969. "Memo for Glenn's Trip to Washington on December 17, 1969." Memo with encl. (Project Payette Final Summary Report) from Howard Rodean to Glenn Werth, December 15. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-031.
- Fenix & Scisson, Inc., 1970. Project Payette Final Summary Report on the Feasibility of Constructing a Large Underground Chamber for Clandestine Nuclear Testing. Report for U.S. Atomic Energy Commission, Nevada Operations Office, from Fenix & Scisson, Inc., Tulsa, OK, March. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-031.
- Rodean, H. C., 1971. Cavity Decoupling of Nuclear Explosions. University of California, Lawrence Radiation Laboratory, *Report UCRL-51097*, August 2. Livermore, CA. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV.
- Lukasik, S. J., 1973. Letter from S. J. Lukasik, Defense Advanced Research Projects Agency, to Major General Frank A. Camm, September 10. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-078.
- Camm, Frank A., 1973. "Project Payette." Letter from Frank A. Camm, U.S. Atomic Energy Commission, to Mahlon E. Gates, September 28.
- Operation Payette Tasks, 1973. Operation Payette Tasks. Schedule, November 27. On file at: Nuclear Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0187811.

Thome, D. J., C. A. Fontana, and C. F. Costa, 1991. Onsite and Offsite Environmental Monitoring Report: Radiation Monitoring Around Tatum Salt Dome, Lamar County, Mississippi, April 1990. U.S. Environmental Protection Agency EPA/600/4-91/005. Environmental Monitoring Systems Laboratory, Las Vegas, NV.

Warner, D., no date, Project Payette. University of California, Lawrence Livermore National Laboratory, *Report UCRL-124988*; 10150. Livermore, CA.

## **5.60 Plowshare Emergency Capability Program**

Nuclear Explosives for Use in National and World Emergencies

Plowshare Program

No Location

During 1964, Lawrence Radiation Laboratory requested that the Sandia Corporation prepare a proposal for Plowshare capability for emergencies that occurred nationally or world-wide. The idea originated after the Samarkand Landslide in Russia, during April 1964. The landslide blocked the Zeravashan River channel and endangered the city of Samarkand. An initial attempt to clear the channel with high explosives was not successful and American authorities proposed using Plowshare techniques. However, a second attempt with high explosives successfully cleared the landslide. Following the crisis, the concept developed of a Plowshare Emergency Capability Program to prepare for future emergency situations. A "Technical Proposal Cost Estimate" was issued by the Sandia Corporation on June 30, 1964. Objectives of the program fell into two phases. Phase I would involve tasks to make available a specialized nuclear firing system to be used in emergency peacetime situations including design, development, testing, and stockpiling. A number of requirements would be necessary for the firing system. For example, the system needed to be capable of firing 20 devices simultaneously and designed for different electrical systems, readily transportable by air, and flexible enough to be used in a variety of situations. Phase II of the program involved field testing the system in an emergency situation. In August 1964, Edgerton, Germeshausen & Grier, Inc. submitted a proposal to participate in the program and, in an August 12, 1964 memo, Lawrence Radiation Laboratory recommended allocating \$20,000 for equipment, payroll, and expenses. This memo is the final document available for the proposed Plowshare Emergency Capability Program.

Duncan, Jack, 1964. "Placing Nuclear Explosives in Wells." Memo from Jack Duncan, Lawrence Radiation Laboratory, to G. Johnson, June 8. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.

Edgerton, Germeshausen & Grier, Inc., 1964. Plowshare Emergency Capability: Timing and Firing Cost Estimate and Preliminary Concept. Manuscript, June 8. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.



Fowler, Glenn A., 1964. "Plowshare Emergency Capability Program." Letter with encls. (Technical Proposal Cost Estimate and memo from F. J. Circeo, Lawrence Radiation Laboratory, to M. D. Nordyke, April 29) from Glenn A. Fowler, Sandia Corporation, to G. H. Higgins, June 30. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.

Hamburger, Richard, 1964. Letter with encl. (Minutes of Portland Meeting, May 24, 1962) from Richard Hamburger, U.S. Atomic Energy Commission, Division of Peaceful Nuclear Explosives, to Gary H. Higgins, August 11. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.

Johnson, Gerald W., 1964. "Plowshare Emergency Capability Program." Memo from Gerald W. Johnson, Lawrence Radiation Laboratory, to Ward Miller, August 12. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.

### **5.61 Pre-Dogsled**

High Explosive Cratering Experiment  
Plowshare Program  
Arizona and Utah

Pre-Dogsled was proposed in 1963 as a low-yield (approximately 20 ton) cratering experiment in sandstone. The Pre-Dogsled experiment was planned to provide data to refine design requirements for Project Dogsled, a 100 kt cratering experiment in sandstone (see Dogsled – Chapter 4.13). Although not specified, the location for the Pre-Dogsled experiment was probably adjacent to Dogsled in either Arizona or Utah, and was to be funded and executed by the U.S. Army Engineer Nuclear Cratering Group. There is no documentation for a Pre-Dogsled program beyond the initial proposal.

Miller, Robert E., 1963. "Project Dogsled." Memo from Robert E. Miller, U.S. Atomic Energy Commission, Nevada Operations Office, to List, April 30. On file at: Nevada Testing Archive, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV, Accession No. NV0018528 [OUO].

### **5.62 Pre-Vintage**

High Explosive Tests  
Plowshare Program  
Colorado

Pre-Vintage was a high explosive test, planned in 1959, to investigate the characteristics of gas migration in shale and to examine seismic effects in oil shale, as well as other studies. The Rifle mine in Colorado was selected for the experiment. In 1960, the project concept was scaled-back to focus on the safety aspects of a nuclear explosion in oil shale, specifically to study if venting would occur along the bedding planes in shale. The scaled-back project was referred to as pre-Pre-Vintage, and on March 29, 1960 named Pinot (see Pinot – Chapter 3.11).

- Denton, Vern, 1959. Letter from Vern Denton, Lawrence Radiation Laboratory, to Paul L. Russell, June 10. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-105.
- Violet, C. E., 1959. Letter from C. E. Violet, Lawrence Radiation Laboratory, to John E. Crawford, November 4. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-105.
- Ball, R. H., 1959. "LRL, SAN, and the U.S. Bureau of Mines Have All Agreed to Initiate a Plowshare Project." Telex from R. H. Ball, U.S. Atomic Energy Commission, San Francisco Operations Office, to James E. Reeves, November 6. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-105 [OUO].
- Edgerton, Germeshausen & Grier, Inc., 1959, Pre-Vintage Operational Plan. Manuscript, Edgerton, Germeshausen & Grier, Inc., Boston, MA, November 17. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV.
- Johnson, Gerald W., 1959. Letter from Gerald W. Johnson, Lawrence Radiation Laboratory, to General Alfred D. Starbird, November 18. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-105.
- Petrie, R. B., 1959. "Pre-Vintage Cost Estimate - Basic Construction Only." Memo from R. B. Petrie, Lawrence Radiation Laboratory, to Frank Adelman, November 19. On file at: Archives and Records Office, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-105.
- Petrie, R. B., 1959. "Project Pre-Vintage, Construction Time Schedule." Memo from R. B. Petrie, Lawrence Radiation Laboratory, to Frank Adelman, November 19. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, PLO-105.
- Violet, C. E., 1959. Memo from C. E. Violet, Lawrence Radiation Laboratory, to List, November 20. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-105 [OUO].
- U.S. Atomic Energy Commission. Albuquerque Operations Office, 1959. "Pre-Vintage Meetings to be Held at LRL." Telex to U.S. Bureau of Mines, December. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-105.
- Edgerton, Germeshausen & Grier, Inc., 1959. Telex from Edgerton, Germeshausen & Grier, Inc., Boston, MA, to List, December 2. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-105.
- U.S. Atomic Energy Commission. Albuquerque Operations Office, 1959. "Special Provisions Involved in the Bureau of Mines Support to Project Pre-Vintage." Telex from U.S. Atomic Energy Commission, San Francisco Operations Office, to Russell Ball, December 9. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-105.

Frank, James, and John Nuckolls, 1959. "The Pre-Vintage Experiment." Memo from James Frank and John Nuckolls to Frank Adelman, December 17. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-105.

Edgerton, Germeshausen & Grier, Inc., 1959. Revised Pre-Vintage Operational Plan. Manuscript, Edgerton, Germeshausen & Grier, Inc., Boston, MA, December 29. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV.

Adelman, Frank L., 1960. "Pre-Vintage." Memo from Frank L. Adelman to Distribution, January 7. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-105.

Denton, Vern, 1960. "Pre-Pre-Vintage." Memo from Vern Denton, Lawrence Radiation Laboratory, to G. W. Johnson, January 28. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-105.

Johnson, Gerald W., 1960. Letter from Gerald W. Johnson, Lawrence Radiation Laboratory, to E. C. Shute, February 16. On file at: Archives and Records Office, Lawrence Berkeley National Laboratory, Berkeley, CA, File 434-900157, 7/18 and Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-105 [OUO].

Mansfield, R., 1960. "Adit No. 3, Plan and Profile, Project Pre-Vintage, Colorado." Drawing No. L-6-10894 from Lawrence Radiation Laboratory, March 2. On file at: Archives and Records Office, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-105 [OUO].

Lombard, David B., 1960. Plowshare Program, Peaceful Uses for Nuclear Explosives. University of California, Lawrence Radiation Laboratory, *Report UCRL-6081*, July 25. Livermore, CA. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV.

### **5.63 Pumped Storage Reservoirs**

Nuclear Excavation of Storage Reservoirs

Plowshare Program

Idaho, Washington

The project concept was to excavate water storage reservoirs along the lower Columbia and Snake Rivers in Idaho and Washington in conjunction with dams and reservoirs. Water would be pumped from the lower reservoirs to the upper reservoirs using power generated by the dams. The project summary proposed the use of nuclear cratering techniques for construction of the storage reservoirs; however, the project was not recommended as a demonstration project due to time constraints. The project, submitted to the U.S. Army Engineers Nuclear Cratering Group by the North Pacific Division, Walla Walla District, was not conducted.

Lawrence Radiation Laboratory. U.S. Army Engineer Nuclear Cratering Group, [1966]. Demonstration Project Summary. Manuscript. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-103 [OUO].

### **5.64 Radio Telescope Facility**

Nuclear Explosive to Create Crater for Radio Telescope Facility  
Plowshare Program  
Concept Only, No Location

In a letter dated November 27, 1963 to the Center for Radiophysics and Space Research at Cornell University, Louis J. Circeo from the Plowshare Division suggested that nuclear craters could be used to construct a fixed-dish radio telescope facility and requested comment on the idea. The project concept did not develop beyond this initial inquiry.

Circeo, Louis J., 1963. Letter from Louis J. Circeo, Lawrence Radiation Laboratory, to W. E. Gordon, November 27. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.

### **5.65 Radioactive Waste Disposal**

Nuclear Chimney for Radioactive Waste Disposal  
Plowshare Program  
Concept Only, No Location

The idea of storing high-level radioactive waste was explored by members of the Hansom Committee at the Lawrence Radiation Laboratory in 1964 (see Savannah River Plant – Chapter 5.75). In a July 19, 1967 Lawrence Radiation Laboratory memo, the disposal of radioactive waste was proposed as a possible Plowshare application. The proposal focused on the disposal of radioactive noble gases (such as Krypton-85) that result from nuclear power production in underground cavities formed by a nuclear explosion. However, it was not until the early 1970s that a method for storing radioactive waste was presented in a number of technical papers issued by Lawrence Radiation Laboratory. The disposal concept used nuclear explosives to construct underground chimneys beneath the sites of irradiated fuel processing plants. Radioactive waste in either slurry or liquid form would be discharged into the chimneys with minimal processing. In a 1971 paper by Cohen et al., a high-level radioactive waste disposal scheme was proposed. In this proposal, nuclear reactor wastes would be injected into a deep underground cavity and allowed to “boil.” The resulting steam would be processed at the ground surface and recycled. After waste disposal was terminated, the heat generated by the radioactive waste would melt the surrounding rock, dissolving the waste. When the rate of radioactive decay decreased sufficiently, the rock would solidify and radioactivity would eventually be trapped in an insoluble silicate rock matrix deep beneath the surface. The approach was eventually referred to as the “rock melt” concept.

In 1975, Lawrence Livermore Laboratory submitted a proposal for nuclear waste disposal that outlined a field program to demonstrate the waste disposal method. However, unlike previous reports that suggested nuclear explosives, the method for forming a deep underground cavity is not specified. The proposal recommended the Nevada Test Site for the field experiment. After 1975, the project concept no longer carried a Plowshare component, but research efforts on the rock melt concept continued into the 1980s,

funded by the U.S. Department of Energy and conducted under the Base Technology Program.

Cohen, Jerry J., 1967. "Disposal of Radioactive Waste Gases - A Possible Plowshare Application." Memo from Jerry J. Cohen, Lawrence Radiation Laboratory, to Distribution, July 19. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-109.

Lombard, David B., 1967. "Radioactive Waste Gases." Memo from D. B. Lombard, Lawrence Radiation Laboratory, to Distribution, July 28. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-109.

Gibson, T. A., 1970. "The Economic Constraints of Radioactive Waste Disposal with Nuclear Explosives --or: Is There a Place for Nuclear Explosives in Radioactive Waste Disposal?" Memo from T. A. Gibson, Lawrence Radiation Laboratory, to A. Lewis, May 4. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-109.

Cohen Jerry J. and T. A. Gibson, Jr., 1970. "Radioactive Waste Disposal: Appraisal of Plowshare Prospects and Recommendations for K-Division Actions." Memo from J. J. Cohen and T. A. Gibson, Jr., Lawrence Radiation Laboratory, to A. Holzer and G. C. Werth, July 10. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-109.

Cohen, Jerry J., and Terry L. Steinborn, [1970]. The Rock-Melt Approach to Nuclear Waste Disposal in Geological Media. Manuscript, Lawrence Livermore Laboratory, Livermore, CA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-109.

Cohen, Jerry J., Arthur E. Lewis, and Robert L. Braun, 1971. Use of a Deep Nuclear Chimney for the In-Situ Incorporation of Nuclear Fuel-Reprocessing Waste in Molten Silicate Rock. University of California, Lawrence Radiation Laboratory, *Report UCRL-51044*, May 4. Livermore, CA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-036 and PLO-109.

Werth, Glenn C., 1971. Status of Contained Nuclear Explosive Applications. University of California, Lawrence Radiation Laboratory, *Report UCRL-51074*, June 21. Livermore, CA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-103.

Gaberson, J. B., 1971. Press Release, Subject: Technology developed under the U.S. PNE program may be useful in disposing radioactive wastes, from Lawrence Radiation Laboratory, November 5. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.

Lawrence Livermore Laboratory, 1971. Press Release, Subject: Radioactive waste disposal. From Lawrence Livermore Laboratory, November 5. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.

- Livermore Herald and News, 1971. Rock Vaults May Be Nuclear Waste Tombs. *Livermore Herald and News*, November 6. Livermore, CA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.
- Lewis, A. E., J. J. Cohen, R. L. Braun, and A. J. Rothman, 1972. Placement and Self-Processing of Nuclear Fuel Reprocessing Wastes in Deep Underground Cavities. Paper prepared for presentation at the Symposium on the Management of Radioactive Wastes from Fuel Reprocessing, Paris, France, November 27 - December 1, 1972. University of California, Lawrence Radiation Laboratory, *Preprint UCRL-73818*, August. Livermore, CA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-109.
- Lewis, A. E., J. J. Cohen, and R. L. Braun, 1972. Disposal of Nuclear Waste by In-Situ Incorporation in Deep Molten Silicate Rock. *Underground Waste Management and Environmental Implications*, The American Association of Petroleum Geologists, Memoir 18. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-109.
- Toman, John, 1974. Letter with encl. (letter from the Tribune Printing Company, PA, to John Toman, March 22) from John Toman, Lawrence Livermore Laboratory, to Ralph Brown, April 1. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-109.
- Cohen, J. J., R. L. Braun, L. L. Schwartz, and H. A. Tewes, 1974. Economic and Environmental Evaluation of Nuclear Waste Disposal by Underground In Situ Melting. University of California, Lawrence Livermore Laboratory, *Report UCRL-51713*, November 30. Livermore, CA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-109.
- Batzel, Roger E., 1975. Letter with encl. (Proposal for Nuclear Waste Disposal, L. L. Schwartz, H. A. Tewes, and R. L. Braun, Lawrence Livermore Laboratory, July 21), from Roger E. Batzel, Lawrence Livermore Laboratory, to Frank Baranowski, July 22.
- Schwartz, Larry L., 1976. "Request for Information Relating to PNE Waste Disposal Activities." Telex from Larry L. Schwartz, Lawrence Livermore Laboratory, to Captain Alan R. Phillips, April 14. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.
- Schwartz, L., and H. Tewes, 1976. "Comments on High-Level Nuclear Waste Disposal Method Proposed by Pacific-Sierra Research Corporation." Memo from L. Schwartz and H. Tewes, Lawrence Livermore Laboratory, to Jeff Hodges, September 15. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.
- Tonnessen, K. A., and J. J. Cohen, 1977. Survey of Naturally Occurring Hazardous Materials in Deep Geologic Formations: A Perspective on the Relative Hazard of Deep Burial of Nuclear Wastes. University of California, Lawrence Livermore Laboratory, *Report UCRL-52199*, January 14. Livermore, CA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-109.

Ballou, L., M. Nordyke, and G. Werth, 1977. A Summary of U.S. PNE Experience. Report prepared for U.S. Energy Research & Development Administration from Lawrence Livermore Laboratory, *Report UCID-17649*, November 17. On file at: Defense Threat Reduction Information Analysis Center, Albuquerque, NM; and Technical Reports Library, Lawrence Livermore National Laboratory, Livermore, CA.

Davis, Clyde R., 1978. "Request for Comments Y/OW1/SUB-77/16504/1." Letter from Clyde R. Davis, State Oil and Gas Board, Jackson, Mississippi, to Rodney J. Davis, March 29. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-013.

Tewes, H. A., 1980. "Nuclear Waste Isolation: Rock Melt Concept Update." Memo with encl. (Isolation of High-Level Radioactive Waste by Incorporation into Silicate Rock, manuscript) from H. Tewes, Lawrence Livermore Laboratory, to L. Schwartz and R. Schock, December 22. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-109.

Tewes, H. A., 1981. "Review of Current and Past Experimental Work at LLNL Pertinent to the Rock Melt Concept; Recommendation for Future Work." Memo from H. A. Tewes, Lawrence Livermore National Laboratory, to Distribution, May 19. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-109.

Lawrence Livermore Laboratory, no date. "Artists Concept of Waste Disposal in a Typical Nuclear Chimney." Drawing from Lawrence Livermore Laboratory, no date. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.

## **5.66 Raymondville Harbor**

Nuclear Explosives to Remove a Sandbar  
Plowshare Program  
Texas

The use of nuclear explosives to remove a sandbar from a harbor near Raymondville, Texas, was proposed by Charles Johnson, the Port Director. The area is along the Texas Gulf Coast approximately 100 miles south of Corpus Christi. The project is included on a list of "possible" nuclear excavation projects in a U.S. Atomic Energy Commission, Division of Peaceful Nuclear Explosions document dated July 1964.

U.S. Atomic Energy Commission, 1964. Suggested Nuclear Excavation Projects and Possible Nuclear Excavation Projects. Manuscript, Division of Peaceful Nuclear Explosives, July. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.

### **5.67 Red Mountain Mineral Extraction**

Nuclear Mining Application

Plowshare Program

Colorado

Red Mountain Mineral Extraction was a proposal to use nuclear explosives to provide access, probably by removing overburden, to the mineral deposits in Red Mountain. Red Mountain is a set of three peaks in the San Juan Mountains of western Colorado, east of Telluride. H. C. Sprinkle, from Durham, North Carolina, proposed the project and the concept is listed in a U.S. Atomic Energy Commission, Division of Peaceful Nuclear Explosives July 1964 document as a "possible" nuclear excavation project.

U.S. Atomic Energy Commission, 1964. Suggested Nuclear Excavation Projects and Possible Nuclear Excavation Projects. Manuscript, Division of Peaceful Nuclear Explosives, July. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.

### **5.68 Runaway Gas or Oil Wells**

Nuclear Explosives to Shut Off a Gas or Oil Well

Plowshare Program

No Location

Following the successful Russian applications of using nuclear explosives to seal runaway gas wells, a memo from the Lawrence Radiation Laboratory, dated March 26, 1970, considers the use of nuclear explosives to stop offshore oil and gas well leaks in the United States. The memo points out that the Lawrence Radiation Laboratory did not have the experience to close a cased hole above a nuclear explosion and suggests implementing a program to study the subject. The program would include modeling studies, calculation of closure mechanisms, compilation of geologic data in offshore areas, and an add-on experiment at the Nevada Test Site. There is no documentation to suggest that a study program was ever developed.

Stephens, D. R., 1970. "Use of Nuclear Explosives to Shut Off an Oil or Gas Well." Memo from D. R. Stephens, Lawrence Radiation Laboratory, to E. H. Fleming, March 26. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-100.

### **5.69 Saline River Canal**

Nuclear Excavation of a Canal

Plowshare Program

Illinois

In 1965, the Saline Valley Conservancy District contacted the Lawrence Radiation Laboratory and members of the Illinois Congress, concerning the possibility of using nuclear explosives to build a canal along the Saline River, a tributary of the Ohio River in



southeastern Illinois. Approximately 11 miles of the river, between the town of Equality and the Ohio River, flowed over bedrock. The request argued that the location would provide an experimental site for a study of continuous row charge detonations in solid rock, data that would be useful for construction of a canal in Central America.

Rhodes, Juanita, 1965. Letter from Juanita Rhodes, Saline Valley Conservancy District, to Gerald W. Johnson, March 17. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.

Scherrer, George M., 1965. Letter from George M. Scherrer, Saline Valley Conservancy District, to Gerald W. Johnson, March 17. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.

Scherrer, George M., 1965. "Memorandum Presented at the Illinois Congressional Breakfast, Congressional Hotel, Washington, D.C." Memo from George M. Scherrer, Saline Valley Conservancy District, to Congressmen from Illinois, March 24. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.

## **5.70 San Diego – Imperial Valley Interstate/ Laguna Mountains Highway**

Nuclear Explosives for Highway Construction

Plowshare Program

California

On September 27, 1962, a paper from the Plowshare Division at the Lawrence Radiation Laboratory titled "Preliminary Investigation: The Use of Nuclear Excavation for the Construction of an Interstate Highway between San Diego and the Imperial Valley," was presented to the San Diego Industrial Development Council. The study examined a realignment of Highway 80 to provide a level grade through the Laguna Mountains and reduce travel distance by 22 miles. Nuclear excavation with approximately 105 devices and a total yield of 6,365 kts would be required to construct the level grade. The report concluded that immediate application of this project was not practical, but might be so in the future. An inquiry was made about this proposed project by the Farm Editor from the *Post and Press* in 1963. The project concept also appears on a list of "possible" projects compiled by the U.S. Atomic Energy Commission, Division of Peaceful Nuclear Explosives, dated July 1964.

Circeo, Louis J., 1962. Preliminary Investigation: The Use of Nuclear Excavation for the Construction of an Interstate Highway between San Diego and the Imperial Valley. Paper to be presented at the San Diego Industrial Development Council, San Diego, CA, September 27. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-100.

Huffman, Ira A., 1963. Letter from Ira A. Huffman, The Post and Press Newspapers, El Centro, CA, to U.S. Atomic Energy Commission, April 17. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.

Hamburger, Richard, 1963. Letter from Richard Hamburger, U.S. Atomic Energy Commission, Division of Peaceful Nuclear Explosives, to Ira A. Huffman, April 30. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.

### **5.71 San Luis Dam**

Nuclear Quarrying for Construction of a Dam  
Plowshare Program  
California

In the early 1960s, the Richard Peterson & Son Company was developing a bid for a project to drill and blast rock for the San Luis Dam. The San Luis Unit, West San Joaquin Division of the U.S. Army Corps of Engineers, was authorized to build the dam in 1960 as part of the Central Valley Project. The Peterson Company made a request to Lawrence Radiation Laboratory concerning the possible use of nuclear explosives to obtain the estimated 14 million tons of aggregate needed for the dam. The division chair for Plowshare replied that while the rock breaking application was technically feasible, the project could not be accomplished in the requested one year time frame due to the need for new legislation before industrial organizations could participate as well as technical uncertainties about the distribution of rock fragment sizes that would be created in a basalt medium. The use of nuclear explosives for this project was not advised. However, an undated document from Lawrence Radiation Laboratory concluded that the construction of aggregate for the San Luis Dam seemed technologically and economically feasible and advised further study. The San Luis Dam was built using conventional construction methods and was completed in 1967.

Peterson, Roy J., 1963. Letter from Roy J. Peterson, Richard Peterson & Son, Novato, CA, to Gary H. Higgins, February 6, and response from G. H. Higgins, April 22. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.

Higgins, Gary H., 1963. Letter from Gary H. Higgins, Lawrence Radiation Laboratory, to R. J. Peterson, April 22. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.

Lawrence Radiation Laboratory, [1963]. The Use of Nuclear Explosives for the Production of Aggregate for the San Luis Dam. Manuscript, Lawrence Radiation Laboratory, ca. 1963, Livermore, CA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-084.

Peterson, Roy J., 1964. Letter from Roy J. Peterson, Richard Peterson & Son, Novato, CA, to Gerald W. Johnson, December 3. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.

Rabb, David D., 1964. Memo from David D. Rabb, Lawrence Radiation Laboratory, for Record, December 4. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.

Peterson, Roy J., 1965. Nuclear Explosives for Peaceful Purposes. Manuscript, Richard Peterson & Son, Licensed Contractor Specializing in Drilling, Blasting, Novato, CA, April 22. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.

### **5.72 Santa Barbara Channel Oil Leakage**

Nuclear Explosives to Control Oil Leakage

Plowshare Program

California

An April 1, 1970 Lawrence Radiation Laboratory memo provides a detailed response to a query concerning the use of Plowshare techniques to control underground oil field leaks in the Santa Barbara Channel. The memo details information about the Dos Cuadras oil field, based on information from the Geological Survey Professional Paper #679, "Geology, Petroleum Development, and Seismicity of the Santa Barbara Channel Region, California." According to the memo the Dos Cuadras oil field covers nearly 1,000 acres and is productive at depths of up to 4,000 ft. The shallowest major reservoir lies below Platform A and is less than 300 ft from the sea surface. On January 28, well A-21, the fifth of 54 planned wells on Platform A, "blew out."

In the Dos Cuadras oil field, there are three major stratigraphic regions below Platform A. The uppermost deposit is a fossiliferous siltstone or shale with minor sandstone beds (capstone). The next is a permeable sandy deposit in which most of the pore space is saturated with oil (commercial zone). This in turn is underlain by a deposit of siltstone and shale. The formation is characterized by the somewhat unique properties of a porous, shallow and easily fractured capping rock in close proximity to the surface of the oil bearing beds. These properties taken together would make the use of Plowshare techniques in this particular oil field "extremely risky." The memo notes that evaluation of the use of Plowshare techniques in the area of oil leakage should focus on questions pertaining to the geology and material properties of the rock as well as issues regarding pipe closure.

Crowley, Barbara K., 1970. "Could Plowshare be Utilized to Stop Oil Leakage in the Santa Barbara Channel?" Memo from Barbara K. Crowley, Lawrence Radiation Laboratory, to Distribution, April 1. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-100.

### **5.73 Santa Rosa Canal**

Nuclear Excavation of a Canal

Plowshare Program

Florida

L. C. Simpler, the secretary of the Canal Commission for Santa Rosa County, Florida, inquired about the possibility of using nuclear explosives to build a canal across Santa Rosa Island. The February 3, 1965 letter mentions that the county was considering a

canal 1,500 ft long, 200 ft wide, and 9 ft deep to connect the Intercoastal Waterway and the Gulf of Mexico in the vicinity of Navarre, Florida.

Simpler, L. C., 1965. Letter from L. C. Simpler, First National Bank in Milton, FL, to Gerald W. Johnson, February 3. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-077.

#### **5.74 Santa Rosa Wash Basin**

Nuclear Excavation Application

Plowshare Program

Arizona

The Santa Rosa Wash Basin was a project submitted by the U.S. Army Corps of Engineers, Los Angeles District and is summarized in a Demonstration Project Summary document from the U.S. Army Engineer Nuclear Cratering Group at the Lawrence Radiation Laboratory. The project area lies within the Papago Indian Reservation, about 70 miles south of Phoenix, Arizona. The project, approved by Public Law 88-298 on October 27, 1965, was to provide flood control, water conservation, irrigation, ground water recharge, recreation, and fish and wildlife facilities. The nuclear excavation application for this project was not identified.

Lawrence Radiation Laboratory. U.S. Army Engineer Nuclear Cratering Group, [1966]. Demonstration Project Summary. Manuscript. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-103 [OUO].

#### **5.75 Savannah River Nuclear Plant Waste Disposal**

Nuclear Chimney for Storage of Radioactive Waste

Plowshare Program

South Carolina

During 1964, at the request of the U.S. Atomic Energy Commission, San Francisco Operations Office and the Division of Reactor Development, the Hansom Committee from Lawrence Radiation Laboratory began evaluating a Plowshare application for storing high-level radioactive waste in underground chimneys, created by nuclear explosions. An October 6, 1964 Lawrence Radiation Laboratory memo reports on discussions held during a visit to the Savannah River Plant which was operated by DuPont. DuPont was seeking a solution to storing high-level radioactive waste and one of the solutions proposed was to use a 30 kt nuclear explosive to create an underground storage cavity. However, a number of technological problems needed to be addressed. Among them were issues related to seismic damage, waste transport, heat generated from radioactive waste, and isolation of the aquifer. The memo provided a preliminary assessment of using nuclear explosives to create underground storage for radioactive waste at the Savannah Plant and recommended a detailed study of the concept (see also Radioactive Waste Disposal – Chapter 5.65).

Lombard, David B., 1964. "Trip Report: Radioactive Waste Disposal at the Savannah River Plant." Memo from David B. Lombard, Lawrence Radiation Laboratory, to Distribution, October 6. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-109.

Hamburger, Richard, 1967. Letter from Richard Hamburger, U.S. Atomic Energy Commission, to Clyde A. Hawley, February 3. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-109.

Lombard, David B., 1967. "Radioactive Waste Gases." Memo from D. B. Lombard, Lawrence Radiation Laboratory, to Distribution, July 28. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-109.

### **5.76 Shelter Cove Harbor**

Nuclear Excavation of a Small Craft Harbor

Plowshare Program

California

Shelter Cove Harbor was a proposal to use nuclear explosives to build a harbor on the northern Californian coast in Humboldt County. The project concept is discussed in a series of status reports from the U.S. Army Engineer Nuclear Cratering Group and described as a harbor on the northern California coast between Fort Bragg and Eureka. Between September 30, 1964 and December 31, 1967, the U.S. Army Corps of Engineers, San Francisco District, was conducting feasibility studies and preparation of a final report was underway by December 31, 1967. The feasibility study was issued in 1968, but a copy of the document has not been located. However, according to a 1969 document, the proposal was to detonate a 100 kt nuclear explosive in a sandstone medium at Shelter Cove. The goal was to create a mooring basin approximately 1,000 ft in diameter that would be surrounded by a breakwater. The 1969 document states that the final report for the project indicated the need for more data about the phenomenology of a nuclear detonation in a saturated sandstone medium.

Slazak, Walter J., 1964. "Status Report - Nuclear Explosives Studies for Civil Construction (Reports Control Symbol ENGCE-E-9)." Letter with encl. ("Status Report, Effective Date: 30 September 1964 - ENGCE-E-9") from Walter J. Slazak, Lawrence Radiation Laboratory, U.S. Army Engineer Nuclear Cratering Group, to Chief of Engineers, Department of the Army, October 26. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.

Slazak, Walter J., 1965. "Status Report - Nuclear Explosives Studies for Civil Construction (Reports Control Symbol ENGCE-E-9)." Memo with encl. ("Status Report, Effective Date: 31 December 1964 - ENGCE-E-9") from Walter J. Slazak, Lawrence Radiation Laboratory, U.S. Army Engineer Nuclear Cratering Group, to Chief of Engineers, Department of the Army, January 15. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.

Hughes, Bernard C., 1965. "Status Report - Nuclear Explosives Studies for Civil Construction (Reports Control Symbol ENGCW-E-9)." Letter with encl. ("Status Report, Effective Date: 31 March 1965 - ENCGW-P-6(R1)") from Bernard C. Hughes, U.S. Army Engineer Cratering Group, to Chief for Engineers, Department of the Army, April 13. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.

Hughes, Bernard C., 1968. "Status Report - Nuclear Explosives Studies for Civil Construction (RCS ENGCW-P-6 (R-1))." Letter with encl. ("Status Report, Effective Date: 31 December 1967") from Bernard C. Hughes, Lawrence Radiation Laboratory, U.S. Army Engineer Nuclear Cratering Group, to Chief of Engineers, Department of the Army, January 13. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.

U.S. Army Corps of Engineers. San Francisco District, 1968. "Shelter Cove Harbor, Humboldt County, California; Small Craft Harbor Nuclear Excavation, Feasibility Study." Document Not Available.

Hughes, Bernard C., 1969. History of the U.S. Army Engineer Nuclear Cratering Group, January. Lawrence Radiation Laboratory, January. Livermore, CA.

### **5.77 Smackover Formation Oil Stimulation**

Nuclear Explosives for Oil Stimulation

Plowshare Program

Mississippi

The project concept was to use nuclear explosives to enhance petroleum production in the Smackover Formation in Mississippi. The Smackover Formation is on the eastern Gulf Coast and is a calcareous hydrocarbon reservoir. In a letter dated January 2, 1963, Andrew Suttle, the Director of Defense Research and Engineering, introduced the concept. The Lawrence Radiation Laboratory responded in an April 25, 1963 letter, providing a rough estimate of oil availability from the formation and advising that the idea warranted further consideration.

Suttle, Andrew D., 1963. Letter from Andrew D. Suttle, Office of the Director of Defense Research and Engineering, Washington, D.C., to Edward Teller, January 2. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.

Knox, Joseph B., 1963. Letter from Joseph B. Knox, Lawrence Radiation Laboratory, to Andrew D. Suttle, Jr., April 25. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.

### **5.78 Southwest Water Reservoirs**

Nuclear Craters for Water Reservoirs

Plowshare Program

Southwestern U.S.

The proposal to construct surface reservoirs in the southwestern U.S. appears on a list of “possible” nuclear excavation projects, compiled by the U.S. Atomic Energy Commission, Division of Peaceful Nuclear Explosives, dated July 1964.

U.S. Atomic Energy Commission, 1964. Suggested Nuclear Excavation Projects and Possible Nuclear Excavation Projects. Manuscript, Division of Peaceful Nuclear Explosives, July. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.

### **5.79 Subway**

Nuclear Explosive Test for Canal or Harbor Construction

Plowshare Program

No Location

Subway was a proposal to detonate a 7 to 9 kt device to investigate the feasibility of using nuclear devices to develop canal and harbor projects. The project is included in a list of Plowshare Program projects in a U.S. Atomic Energy Commission, Albuquerque Operations Office memo dated March 17, 1961. The project did not proceed beyond the concept phase and a site was not selected.

Reeves, James E., 1961. "Glossary of Seismic Projects, Plowshare Program, and Reactor Programs." Memo from James E. Reeves, U.S. Atomic Energy Commission, Albuquerque Office, to List, March 17. On file at Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV [OUO].

U.S. Atomic Energy Commission, 1963. Long Range Plan, 1964-1973, Peaceful Uses of Nuclear Explosives Program (Plowshare). Report from U.S. Atomic Energy Commission, March 20. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV.

### **5.80 Synthetic Diamond**

Nuclear Explosives to Create Diamond Crystals

Plowshare Program

No Location

In a letter dated January 28, 1968, G. H. Bell from Tustin, California wrote to the U.S. Atomic Energy Commission, Sandia Laboratories, inquiring about the possibility of creating synthetic diamond during an underground nuclear explosion. Specifically, Bell asked if a nuclear explosion could be designed to produce large diamond crystals for industrial diamond and what impact the radioactive half-life would have on use of the

diamond crystals. Sandia Laboratory responded that the inquiry would be forwarded to the Lawrence Radiation Laboratory.

Bell, G. H., 1968. Letter from G. H. Bell to U.S. Atomic Energy Commission, January 22. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-027.

Stewart, Dixon, 1968. Letter from Dixon Stewart, Sandia Laboratories, to G. H. Bell, January 31. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-027.

### **5.81 Trinity River Canal**

Nuclear Explosives for Canal Construction

Plowshare Program

Texas

The Trinity River Watershed project was a proposal by the Texas River Authority to develop a canal between Fort Worth, Texas and the Gulf of Mexico. The proposed canal would run a distance of 380 miles with a depth of 12 ft. The project concept also called for building a number of locks and dams along the Trinity River for flood control and to support barge traffic. According to a November 4, 1962 *Fort Worth Star-Telegraph* news article, the U.S. Army Corps of Engineers submitted a proposal to Washington for the project based on a four-year study of the Trinity basin. An inquiry was made by Texas officials about the possible use of Plowshare excavation techniques to lower construction costs and time. There is no documentation available to indicate what response, if any, the Lawrence Radiation Laboratory had to this idea. The Trinity Canal project was approved by Congress in 1965, using conventional means, but the project was never funded. The U.S. Army Corps of Engineers finally abandoned the project in 1973.

Forrest and Cotton Consulting Engineers, 1960. "Watershed Map Showing Master Plan Reservoirs." Drawing from Forrest and Cotton Consulting Engineers, Dallas, TX, for Trinity River Authority, Trinity River, TX, November.

Richhart, C. L., 1962. Trinity May Play Heroic Role. *Fort Worth Star-Telegram*, p. 2, November 4.

Justin, John, 1962. Letter from John Justin, Mayor, The City of Fort Worth, Texas, to J. R. Maxfield, Jr., November 30. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-100.

Cabell, Earle, 1962. Letter from Earle Cabell, Mayor, City of Dallas, Texas, to J. R. Maxfield, Jr., December 7.



### **5.82 U.S. Navy Proposals**

Peaceful Applications of Nuclear Explosives for the U.S. Navy  
Plowshare Program  
Concept Only, No Location

In a January 28, 1971 Lawrence Radiation Laboratory memo, J. B. Green outlined a number of areas in which Plowshare technology might be beneficial to the U.S. Navy and suggested that these be discussed during an upcoming visit by Captain Pietrie. These included storage of liquid fuel (see Offshore Fuel Oil Storage – 5.57), the use of nuclear chimneys for offshore petroleum waste disposal, and ice engineering (see also Operation Breakup – Chapter 3.10). Other ideas were to use nuclear excavation techniques for tactical situations, such as, harbor construction, channel clearing and reef removal.

Green, J. B., Jr., 1971. "Possible Peaceful Applications of Nuclear Explosive by the U. S. Navy."  
Memo from J. B. Green, Jr., Lawrence Radiation Laboratory, to Glenn C. Werth, January 28.

### **5.83 Upper Midwest Geostorage Facility**

Nuclear Chimney for Gas Storage  
Plowshare Program  
Iowa, Minnesota, Wisconsin

The Northern Natural Gas Company of Omaha, Nebraska subcontracted Fenix & Scisson, Inc. together with the Dowell Corporation to conduct a preliminary investigation of the use of nuclear chimneys for underground gas storage. The gas company was interested in storing gas in the Minnesota, Wisconsin, Iowa region to provide a supply for the Minneapolis and St. Paul metropolitan areas. A Lawrence Radiation Laboratory memo, dated February 13, 1968, summarizes a meeting with a representative from Fenix & Scisson, Inc. who inquired about the extent of a technical program at Lawrence Radiation Laboratory for a nuclear gas storage project.

Holzer, Fred, 1968. "Visit of Milton Rex, Administrative Manager, Engineering Dept. Fenix & Scission, Inc." Memo from Fred Holzer, Lawrence Radiation Laboratory, to Record, February 13. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.

### **5.84 Vaquero**

High Explosive Seismic Monitoring Experiment  
Vela Uniform  
Louisiana

Vaquero was a proposed project to obtain data on seismic disturbances from contained underground explosions. The specific objectives were to obtain data on the seismic effect of lower peak pressure of a gas mixture detonation compared with a high explosive detonation, and to study the relationship between cavity size and yield by detonating variable amounts of gas in the cavity. The experiments were planned for the Carey Salt

Formation, Winnfield, Louisiana, the site of the Cowboy project. The Vaquero project is listed in a March 17, 1961 memo from the U.S. Atomic Energy Commission, Albuquerque, as a Plowshare Program project. At that time the project was "concept only."

Reeves, James E., 1961. "Glossary of Seismic Projects, Plowshare Program, and Reactor Programs." Memo from James E. Reeves, U.S. Atomic Energy Commission, Albuquerque Office, to List, March 17. On file at Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV [OUO].

### **5.85 Vintage**

Nuclear Explosives to Fracture Oil Shale  
Plowshare Program  
Colorado

Vintage was a proposed 10 kt nuclear experiment to fracture oil shale followed by an in situ combustion process to retort the oil. Planning for the project began in 1958 and a location in Garfield County, Colorado (U.S. Naval Reserve, T. 5 S., R. 95 W.) was selected. The project was to be a joint U.S. Atomic Energy Commission, Bureau of Mines, and industry effort. A high explosive experiment (see Pre-Vintage – Chapter 5.62) was planned as an initial step for the project (see Pinot – Chapter 3.11). The Vintage project was shelved by 1960.

Denton, Vern, 1958. "Notes Covering Trip to Rifle, Colorado, Nov. 11-15, 1958." Memo from Vern Denton, Lawrence Radiation Laboratory, to Distribution, November 17. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-105.

Denton, Vern, 1958. "Trip Report, 11/19/58, Laramie - Bureau of Mines." Memo from Vern Denton, Lawrence Radiation Laboratory, to Distribution, November 25. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-105.

Thorne, H. M., 1958. Letter from H. M. Thorne, U.S. Department of the Interior, Bureau of Mines, to Harold Fidler, November 25. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-105.

Stanfield, K. E., 1958. Letter with encl. ("Possible Sites for 'Vintage' Oil-Shale Test Under the Plowshare Project") from K. E. Stanfield, U.S. Department of the Interior, Bureau of Mines, to Charles E. Violet, December 9. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-105.

Violet, C. E., 1958. "Technical Steering Committee, Project Vintage." Memo from C. E. Violet, Lawrence Radiation Laboratory, to Distribution, December 11. On file at: Archives and Records Office, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-105.

- Murphy, Walter I. R., 1958. Memo from Walter I. R. Murphy, U.S. Department of the Interior, Bureau of Mines, to Rodney L. Southwick, December 22. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-105.
- U.S. Department of the Interior. Bureau of Mines, 1959. Application Nuclear Explosions to Oil-Shale Utilization. Report for Bureau of Mines - U.S. Atomic Energy Commission Industry Meeting, Dallas, TX, January. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-105.
- Shute, Ellison C., 1959. Remarks to U.S. Bureau of Mines - AEC - Petroleum Industry Meeting, Dallas, TX, from Ellison C. Shute, U.S. Atomic Energy Commission, San Francisco Operations Office, January 6. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-106.
- Gaskell, T. F., 1959. Atom Bombs to Free Oil? *The New Scientist*, January 15. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-106.
- Frank, Wilson J., 1959. Telex from Wilson J. Frank, Lawrence Radiation Laboratory, to U.S. Atomic Energy Commission, February 2. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-105.
- Savage, John W., and Henry W. Hough, 1959. *Rocky Mountain Oil Reporter*, pp. 18-23, March. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-105.
- U.S. Atomic Energy Commission, 1959. "For Shute - Info to Gerald Johnson - From Keto." Telex from U.S. Atomic Energy Commission to U.S. Atomic Energy Commission, San Francisco District, May 27. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-105.
- Johnson, Gerald W., 1959. Letter from Gerald W. Johnson, Lawrence Radiation Laboratory, to Fred C. Hartley, July 2. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-105.
- Johnson, Gerald W., 1959. "Ref: TWK Keto to Shute re Bureau of Mines Agreement for Vintage." Letter from Gerald W. Johnson, Lawrence Radiation Laboratory, to Russell Ball, August 21. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-105.
- Plowshare Advisory Committee, 1959. Oil Shale (Project Vintage). Report prepared for Plowshare Advisory Committee Briefing, November 12-13, October 30. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.
- Plowshare Advisory Committee, 1959. Plowshare Advisory Committee Briefing, November 12-13, 1959, Agenda. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.

Plowshare Advisory Committee, 1959. Report of the Plowshare Advisory Committee, November 12-13. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029 [OUO].

Rabb, David D., 1961. Letter from David D. Rabb, Plowshare Division, Lawrence Radiation Laboratory, to Russell J. Cameron, May 1. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-105.

Teller, Edward, 1963. Plowshare. University of California, Lawrence Radiation Laboratory *Report UCRL-7222*, February 4. Livermore, CA. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.

Hosmer, Craig, 1969. Remarks of Rep. Craig Hosmer to Joint Committee on Atomic Energy, Symposium on the Public Health Aspects of Peaceful Nuclear Explosives, Las Vegas, NV, April 8. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.

Starbird, Alfred D., [1958]. Letter from Alfred D. Starbird, Brigadier General, U.S. Atomic Energy Commission, to Edward Teller. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-105.

U.S. Atomic Energy Commission, [1958]. Letter from U.S. Atomic Energy Commission to Fred A. Seaton. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-105.

## **5.86 Wagon**

Nuclear Cratering Experiment

Plowshare Program

Nevada

Wagon was proposed as a 0.5 to 5 kt nuclear cratering experiment to provide data on the cratering capability of a nuclear explosion in a hard, dry, non-carbonate medium and the distribution of radioactivity. In a 1959 document, the Geological Survey identified several granite locations in the western U.S. as potential sites for the project. By 1960, the project was in the planning phase with a location either on or off the Nevada Test Site being considered, but a basalt formation at Buckboard Mesa in Area 18 at the Nevada Test Site was favored and eventually selected. The device for the Wagon experiment was scheduled for detonation in late spring 1962, but the test was never executed.

Alvord, D.C., W. J. Carr, P. M. Hanshaw, S. Pl Kanizay, C. S. Robinson, R. W. Schnabel, J. A. Sharps, and C. T. Wrucke, 1959. Possible Test sites in Granitic Rocks in the United States. U.S. Department of the Interior, Geological Survey, Trace Elements Memorandum Report TEM-1024, July.

Plowshare Advisory Committee, 1960. Report on Plowshare Advisory Committee Meeting, May 25-26. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029 [OUO].

- Lawrence Radiation Laboratory, 1960. The Wagon Experiment: A Nuclear Cratering/Radioactivity Experiment in Basalt. Manuscript. September 28. On file at: Archives and Records Office, Lawrence Berkeley National Laboratory, Berkeley, CA, File 434-900157, 7/18; and Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-066.
- Lawrence Radiation Laboratory, 1960. Letter from Lawrence Radiation Laboratory to E. C. Shute, October 26. On file at: Archives and Records Office, Lawrence Berkeley National Laboratory, Berkeley, CA, File 434-900157, 7/18.
- Bacigalupi, C. M., 1961. "Trip Report on Visit to NTS, 17 January through 20 January, 1961." Memo with encl. ("Proposed Dogsled Area," drawing, January 18) from C. M. Bacigalupi, Lawrence Radiation Laboratory, to Distribution, January 23. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-066.
- Lawrence Radiation Laboratory, 1961. Architect-Engineer's Scope of Work, Technical Program Construction, Project Wagon. Manuscript, January 30. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV [OUO].
- Reeves, James E., 1961. "Glossary of Seismic Projects, Plowshare Program, and Reactor Programs." Memo from James E. Reeves, U.S. Atomic Energy Commission, Albuquerque Office, to List, March 17. On file at Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV [OUO].
- Reynolds Electrical & Engineering Co., Inc., 1961. General Support Plan and Signal Facilities, Project Wagon. Report to U.S. Atomic Energy Commission (Contract AT 29-2-162), from Reynolds Electrical & Engineering Co., Inc., Las Vegas, NV, March 28. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV.
- Holmes & Narver, Inc., 1961. Engineering and Construction Plan, Project Wagon. Report to U.S. Atomic Energy Commission, Albuquerque Operations Office (Contract AT 29-2-20), from Holmes & Narver, Las Vegas, NV, April. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV.
- Black, R. A., and John C. Roller, 1961. Results of Resistivity Measurements, Project Wagon No. 1 Site, Buckboard Mesa, Nevada Test Site. U.S. Department of the Interior, Geological Survey, Technical Letter, No. Wagon-1, June 5. Washington, D.C.
- Plowshare Advisory Committee, 1961. Sixth Report of the Plowshare Advisory Committee. Meeting held at Los Alamos Scientific Laboratory, Los Alamos, New Mexico, June 7-8. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029 [OUO].
- Plowshare Advisory Committee, 1961. Seventh Report of the Plowshare Advisory Committee. Meeting held in Carlsbad, New Mexico, October 30-31. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029 [OUO].

Holmes & Narver, Inc., 1961. Engineering and Construction Plan, Project Wagon (Revised). Report to U.S. Atomic Energy Commission, Albuquerque Operations Office (Contract AT 29-2-20), from Holmes & Narver, Inc., Las Vegas, NV, December. On file at: Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV.

Reeves, James E., 1961. "Planning Directive (PL-5-12-61), Project Wagon and Buckboard II." Memo from James E. Reeves, U.S. Atomic Energy Commission, Albuquerque Office, to Those Listed Below, December 20. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-066.

U.S. Atomic Energy Commission, 1962. Plowshare Program. In *Annual Report to Congress of the Atomic Energy Commission*, pp. 208-219, January. Government Printing Office, Washington, D. C.

### **5.87 Wenaha Dam**

Nuclear Quarrying for Construction of a Dam  
Plowshare Program  
Washington

The project was a proposed demonstration project to use nuclear explosives to construct a quarry for the Wenaha Dam and Reservoir on the Grande River, Washington. In a letter from the Nuclear Cratering Group dated, September 20, 1966, the project was one of five projects considered for a nuclear quarrying demonstration (see also Project Travois – Chapter 3.21 and Etsel Dam – Chapter 5.29). The U.S. Army Corps of Engineers, Walla Walla District project required 14 million cubic yards of aggregate to construct the rock-fill dam. Nuclear explosion(s) with an estimated yield of 50 to 100 kt would be required. The dam site was located about 40 miles southwest of Clarkston in southwestern Washington. It was initially considered for a slide-dam application, but later revised to a quarry demonstration. The demonstration project summary states that the project was strongly opposed by the U.S. Fish and Wildlife Service. The dam was never built.

Slazak, Walter J., 1966. Letter with encl. ("Summary of Possible Quarrying Projects") from Walter J. Slazak, Lt. Colonel, Lawrence Radiation Laboratory, U.S. Army Engineer Nuclear Cratering Group, to Michael M. May, September 20. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-029.

### **5.88 West Kentucky Turnpike**

Nuclear Explosives for Highway Construction  
Plowshare Program  
Kentucky

The use of nuclear explosives to remove a hill in Caldwell County, Kentucky, for construction of the West Kentucky Turnpike (Parkway) was suggested by the Wasson Coal Mining Corporation of Boonville, Indiana. Bonds for the West Kentucky Parkway were issued in 1961 and construction on the original 127.9 mile route was completed in 1963. An extension from Princeton to Eddyville in Caldwell County is the likely location

proposed for use of nuclear explosives. The project is a “possible” project on a list compiled by the U.S. Atomic Energy Commission, Division of Peaceful Nuclear Explosives, dating to July 1964. However, the extension was completed using conventional methods in 1968.

U.S. Atomic Energy Commission, 1964. Suggested Nuclear Excavation Projects and Possible Nuclear Excavation Projects. Manuscript, Division of Peaceful Nuclear Explosives, July. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.

### **5.89 White Bird Hill**

Nuclear Explosives for Highway Construction

Plowshare Program

Idaho

The project idea was proposed by Russ Eldredge from Marsing, Idaho. He suggested using nuclear explosives to remove White Bird Hill to re-route U.S. Highway 95 in Idaho. White Bird Hill is part of the Clearwater Mountain Range southeast of Lewiston, Idaho. This project was listed as a “possible” Plowshare application on a July 1964 document from the U.S. Atomic Energy Commission, Division of Peaceful Nuclear Explosions.

U.S. Atomic Energy Commission, 1964. Suggested Nuclear Excavation Projects and Possible Nuclear Excavation Projects. Manuscript, Division of Peaceful Nuclear Explosives, July. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-030.

### **5.90 Wilkins Dam**

Nuclear Explosives to Construct a Dam

Plowshare Program

Arizona

A February 1966 draft public announcement and cover letter for a proposed visit to the Wilkins Dam site is the only documentation available for the Wilkins Dam project. The Wilkins Dam site on Clear Creek, 25 miles south of Winslow, Arizona, was studied by the Bureau of Reclamation for construction of a concrete dam by conventional methods. According to the draft public announcement, to be issued by the U.S. Atomic Energy Commission, Nevada Operations Office, field investigations were to be undertaken to compare the use of conventional versus nuclear construction techniques to build the dam. The announcement mentions that the Wilkins site investigation was part of the Aquarius study (see Aquarius – Chapter 4.1).

Curtis, Harold B., 1969. Letter with encl. (Joint AAEC-USAEC Wilkins Dam Site Study, manuscript, Nevada Operations Office) from Harold B. Curtis, U.S. Atomic Energy Commission, San Francisco Operations Office, to C. A. Pugh and Frank W. Stead, February 14.

### **5.91 Winnow**

Nuclear Seismic Monitoring Experiment

Vela Uniform

Louisiana

Winnow was a proposed decoupling experiment at the Cowboy project site, located at the Carey Salt Mine, Winnfield, Louisiana. The project is included in a "Glossary of Seismic Projects, Plowshare Program, and Reactor Program" memo distributed by the U.S. Atomic Energy Commission, Albuquerque Office on March 17, 1961, and is listed under the Plowshare Program. Winnow was proposed to study the seismic response of a cavity in a salt medium with emphasis on the following variables: cavity shape, fracture radius, orientation and size of fractures and cracks, fragment size, etc. The objective of the study was to provide data on close-in decoupling measurements for the Vela Uniform program. In the 1961 document Winnow was a "concept only" project.

Reeves, James E., 1961. "Glossary of Seismic Projects, Plowshare Program, and Reactor Programs." Memo from James E. Reeves, U.S. Atomic Energy Commission, Albuquerque Office, to List, March 17. On file at Technical Library, National Nuclear Security Administration, Nevada Site Office, Las Vegas, NV [OUO].

### **5.92 Wisconsin Lakes**

Nuclear Explosives to Create Lakes

Plowshare Program

Wisconsin

In a letter dated January 23, 1967, C. W. Threinen from the Fish and Management Division, State of Wisconsin Conservation Department, requested information about using Plowshare techniques for creating lakes. The U.S. Atomic Energy Commission responded with general information and forwarded the inquiry to the Lawrence Radiation Laboratory.

Threinen, C. W., 1967. Letter from C. W. Threinen, Fish Management Division, State of Wisconsin Conservation Department, to U.S. Atomic Energy Commission, January 23.

Hamburger, Richard, 1967. Letter from Richard Hamburger, U.S. Atomic Energy Commission, to C. W. Threinen, February 3.

### **5.93 Wyoming Oil Shale**

Nuclear Explosives to Fracture Oil Shale

Plowshare Program

Wyoming

A 1971 Lawrence Livermore Laboratory memo identifies three possible locations in Wyoming for using nuclear explosive techniques to fracture oil shale deposits for in situ retorting. These locations are north central Green River Basin, south central Green River



Basin, and the Washakie Basin. The project concept for in situ oil shale retorting had previously been explored by the Lawrence Radiation Laboratory (see Bronco – Chapter 3.1 and Utah – Chapter 3.25).

Lewis, A. E., [1971]. "Wyoming Oil Shale - Retorting Nuclear Chimneys." Memo from Art Lewis, Lawrence Livermore Laboratory, to Glenn Werth. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-105.

#### **5.94 Yaquina Bay and Harbor Improvement**

Nuclear Explosives for Bay and Harbor Improvement

Plowshare Program

Oregon

The U.S. Army Corps of Engineers Nuclear Cratering Group requested that the Portland District study the possible use of nuclear explosives for a bay and harbor improvement project at Yaquina Bay in Newport, Oregon. The improvement project was planned to widen the entrance and lengthen the previously constructed turning basin. However, the study effort was cancelled because the project had already been initiated using conventional techniques and was located near productive oyster beds. Also, a nearby multi-million dollar highway bridge would likely be impacted by a nuclear excavation project. Later the use of high explosives for inlet excavation was suggested for Drum Inlet on the Core Banks off the northern coast of North Carolina (see Chapter 3.5).

Hughes, Bernard C., 1969. History of the U.S. Army Engineer Nuclear Cratering Group, January. Lawrence Radiation Laboratory, January. Livermore, CA.

#### **5.95 Young Bay Channel**

Nuclear Explosives for Channel Excavation

Plowshare Program

Alaska

The excavation of a channel between Hawk Inlet and Young Bay on Admiralty Island was one of the projects submitted during the 1960s by the U.S. Army Corps of Engineers, Alaska District, to the Nuclear Cratering Group as a potential Plowshare demonstration project. The project concept was to use nuclear excavation techniques to cut a channel at the north end of Admiralty Island, about 13 miles southwest of Juneau, Alaska. The channel would shorten the route for inter-island ferries, operating out of Juneau, by about 40 miles. The project had previously been considered for study by the U.S. Army Corps of Engineers, Alaska District using conventional methods, but was not authorized.

Lawrence Radiation Laboratory. U.S. Army Engineer Nuclear Cratering Group, [1966]. Demonstration Project Summary. Manuscript. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-103 [OUO].

## **5.96 Yukon River Diversion**

Nuclear Explosives to Divert River Channel

Plowshare Program

Alaska

In a letter to the U.S. Atomic Energy Commission dated July 23, 1962, the District Engineer for the U.S. Army Corps of Engineers, Alaska District inquired about the possibility of a Plowshare water diversion project in Alaska, namely, the diversion of the Yukon River at Galena Air Force Base. The Alaska District had been conducting erosion control studies at the military base and proposed relocating the river channel, but this solution was not economically feasible using conventional means. The letter to the U.S. Atomic Energy Commission was forwarded to the Lawrence Radiation Laboratory for consideration and the Laboratory responded to the Alaska District with a brief evaluation of the project on December 11, 1962. The project concept called for diverting the river for a distance of 7.5 miles in a newly formed channel with an area of at least 120,000 square ft. A series of 65 devices with a yield of 35 kts each, presumably detonated in a row charge in the alluvium deposit, would be needed to excavate the channel. The cost estimate for the project was \$20 million. The Lawrence Radiation Laboratory remarked that they would undertake a more thorough investigation if the Alaska District felt the cost was justified, but other solutions such as dredging a nearby slough for a chute cutoff might be more practical.

Hanburger, Colonel C., 1962. Letter with encl. (Galena area map) from Colonel C. Hanburger, U.S. Army Engineer District, Alaska, to J. B. Sanders, July 23. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-074.

Philip, John F., 1962. "Yukon River Diversion." Letter from John F. Philip, U.S. Atomic Energy Commission, San Francisco Operations Office, to Colonel C. Hanburger, August 13. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-074.

Philip, John F., 1962. "Yukon River Diversion." Letter from John F. Philip, U.S. Atomic Energy Commission, San Francisco Operations Office, to Gary H. Higgins, August 14. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-074.

Philip, John F., 1962. "Yukon River Diversion." Letter from John F. Philip, U.S. Atomic Energy Commission, San Francisco Operations Office, to Gary Higgins, December 4. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-074.

Circeo, Louis J., 1962. "Yukon River Diversion." Letter from Louis J. Circeo, Lawrence Radiation Laboratory, to Colonel C. Hamburger, December 11. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-074.

## 5.97 Zinc Recovery

Nuclear Explosives for Mining Zinc

Plowshare Program

Montana

During 1964, personnel from the Lawrence Radiation Laboratory Hansom Committee visited the Anaconda Mining Company's Badger Mine at Butte, Montana, to investigate the possibility of using nuclear explosives to recover low grade zinc ore that was being mined by traditional block-caving techniques. They concluded that a large scale bulk underground mining method patterned after block-caving techniques would be beneficial, but a nuclear-caving technique would need to incorporate a number of design features unique from standard mining procedures. During the early 1960s, the investigation of nuclear cave mining schemes was underway and a paper on the subject was issued on June 15, 1965. The paper presents a preliminary mine design, outlining some of the characteristics of mine development and operation. A Zinc Recovery project did not proceed beyond a conceptual phase.

Lawrence Radiation Laboratory, 1963. "Appendix A to Purchase Order 6176305." Appendix to Purchase Order between Lawrence Radiation Laboratory and Anaconda Company, March 13. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-102.

Anaconda Company, 1963. "Copper Ore Body, Nuclear Feasibility Study." Report to Lawrence Radiation Laboratory from Anaconda Company, Mining Research Department, July 20. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-102.

Hurlbut, S. W., 1963. Letter from S. W. Hurlbut, Anaconda Company, Mining Research Department, to G. H. Higgins, December 9. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-102.

Lawrence Radiation Laboratory, 1963. Memo from Lawrence Radiation Laboratory, K-Division, to Distribution, January 3. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-102.

Lombard, D. B. and S. M. Hansen, 1964. "Tour of Anaconda Badger Mine." Memo from D. B. Lombard and S. M. Hansen, Lawrence Radiation Laboratory, to Hansom Committee, February 4. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-102.

Hansen, Spent M., and David B. Lombard, 1965. Mining by Caving with Nuclear Explosions. University of California, Lawrence Radiation Laboratory, *Report UCRL-14201*, June 15. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-102.

Springer, D. L., 1973. "Comments on the HE Detonations in Arizona." Memo from D. L. Springer, Lawrence Livermore Laboratory, to H. C. Rodean, June 27. On file at: Archives and Research Center, Lawrence Livermore National Laboratory, Livermore, CA, File PLO-100.

**THIS PAGE INTENTIONALLY LEFT BLANK**

## CHAPTER 6.0 RESULTS AND CONCLUSIONS

This investigation was an examination of domestic Plowshare and Vela Uniform projects outside the boundaries of the Nevada Test Site in order to identify potential environmental liabilities. Excluded from the study were the eight project locations where Plowshare and Vela Uniform nuclear tests were conducted off the Nevada Test Site in the 1960s and early 1970s. In addition, projects undertaken at established testing grounds, such as Lawrence Livermore National Laboratory's Site 300 and Sandia National Laboratory's Coyote Test Field were not part of this analysis. Finally, Project Chariot, a Plowshare project in northwestern Alaska, was omitted from consideration because the Chariot location was remediated in the early 1990s by the Department of Energy, Nevada Site Office, Environmental Management Program personnel. In order to be included in this study, a project had to be proposed for the United States and be affiliated with the Plowshare or Vela Uniform programs.

### 6.1 Identification of Projects

The Plowshare Program and the Vela Uniform Program were initiated within a few years of one another. The goal of the Plowshare Program was to develop peaceful uses for nuclear explosives, particularly for civil works and joint projects with industry. Vela Uniform's goal was to develop and refine a system capable of detecting nuclear detonations and delineating them from other seismic and acoustical waves. While the Plowshare Program was solely a U.S. Atomic Energy Commission effort, Vela Uniform was a joint U.S. Atomic Energy and Department of Defense responsibility. The programs did have some overlap when Plowshare projects could provide useful data to the Vela Uniform Program and, similarly, Vela Uniform projects sometimes provided information to the Plowshare Program. Early into the research discussed in this report, it was realized that the Vela Uniform Program's interest in off-site project locations was more restricted than the Plowshare Program.

Research began by conducting archival, internet, and bibliographic searches for the known off-site project names in order to obtain the information to evaluate the activities at these locations. During document review, other projects were sometimes mentioned and the research widened to include these projects. This cycle repeated again and again with the list of project names continually increasing in length. From the beginning, there was hope that a formal Plowshare project list would be found, but this document evidently does not exist. There also was no final summary report written at the end of the Plowshare Program and its scientists moved on to other research programs. When it was apparent that the program would not resume, disposal of records did occur. So the information presented here, in many cases, was put together in a piecemeal fashion.

For some projects, feasibility studies and technical reports were available. Primary documentation in the form of meeting notes, memos, and letters for various projects were archived at the Lawrence Livermore National Laboratory Archives and Research Center and the Lawrence Berkeley National Laboratory Archives and Records Office. There



## **6.2 Analysis of Field Activities**

Determining the level of field effort was critical to understanding whether or not a project might have potential environmental liabilities. Five categories reflecting differences in the intensity of field activities were established prior to the inception of this investigation and each project was evaluated according to these categories. Levels 1 and 2 were assigned to high activity projects. Level 1 is a location where radioactive materials were used for tracer experiments. Level 2 refers to a location where high explosives were used for the project. Projects that are Level 3 have a medium activity level. These are locations where geologic or hydrologic tests or other substantial work was conducted to evaluate a site for a project or in preparation for an experiment. Levels 4 and 5 have low or almost no activity. Fieldwork where existing facilities, such as mines, wells, and drill holes, were utilized for data collection is a Level 4. Level 5 projects have locations where activity was confined to conceptual designs, background research, and visual field inspections. In cases where there were structured field activities that exceeded casual visual inspections, the project was assigned to a Level 4. Some projects do not have an activity level assigned because no location was identified for the project.

The activity levels assigned to the 170 projects are divided as follows. Project Pinot is the only Level 1 project. There are 15 projects in Level 2 comprised of 12 Plowshare and 3 Vela Uniform projects. Of the 11 Level 3 projects, 10 are Plowshare and 1 is Vela Uniform. For Level 4, there are 23 projects. Sixteen are Plowshare projects and 7 are Vela Uniform. More than half the projects are in Level 5. The 104 Level 5 projects are separated into 101 Plowshare and 3 Vela Uniform. There are 16 projects and concepts that do not have an activity level assigned because no project location was identified.

## **6.3 Field Studies and Land Status Research**

Following the determination of an activity level, it was possible to make a decision as to whether or not the project location merited consideration for an on-site field study. Activity Levels 1, 2, and 3 projects were placed into review for fieldwork. Levels 4 and 5 projects were removed from further review with the caveat that if during a trip one of these locations was nearby, a location might be visited for photographic purposes only. Pinot, the only Level 1 project, was a priority for a field study. The other 26 projects in the medium to high activity categories were analyzed to determine the likelihood of evidence of project activities and the possibility of public concerns. As a result, projects that were done in mining locations that were either owned by a private company or leased by a private company were placed low on the list. If no claims by the company against the U.S. Atomic Energy Commission had been made in the intervening forty or so years, it was unlikely that there were any environmental concerns at these places. Also, documentation did not indicate potential issues and in some cases showed that agreements were worked out on the removal of equipment and restoration of some work areas.

Most of the high explosives Level 2 projects were conducted by the U.S. Army Engineer Nuclear Cratering Group and its successor. Some were directly related to on-going Plowshare research and others can be characterized as civil works projects that demonstrated technology developed as part of the Plowshare Program. At a practical level, only a select number of projects would be able to have field studies. So, decisions were based primarily on the extent of the high explosives activity with a need to look at as many examples as possible of different excavation applications. Lawrence Livermore National Laboratory conducted Pre-Schooner II, a high explosive cratering experiment, with assistance from the Nuclear Cratering Group. This project was on public land and also was prioritized for a field visit. On the other hand, CHASE high explosive experiments were conducted in the ocean and there was nothing to be gained by visiting one of these places. The Level 2 projects with field studies are Pre-Gondola, Pre-Schooner II, Trencher, Trinidad, and Tugboat.

Most Level 3 projects were joint projects between industry and the U.S. Atomic Energy Commission. Project Iki is the only Level 3 project that was conducted and it was a geothermal test. Joint industry projects were for coal extraction and gas and oil shale stimulation experiments. For some of these, extensive field activities were undertaken for the Plowshare Program and these locations were documented. Other Level 3 projects with less field activity but nearby to these were also recorded, including two for a civil works project that had preliminary work for the construction of a quarry as part of a dam construction project. Only two of the 11 Level 3 projects were not part of the field studies. These were the two Vela Uniform projects, Plowboy and Rufus, because they had no likelihood of having any remains from the projects' fieldwork activities.

There were 15 project locations with comprehensive field studies and all are related to the Plowshare Program. The projects are: Bronco, Dragon Trail, Excavator, Iki, Pinot, Pre-Gondola, Pre-Schooner II, Thunderbird, Travois, Trencher, Trinidad, Tugboat, Utah, Wagon Wheel, and WASP. There were no field studies conducted at Vela Uniform project locations. In addition, a field visit was made to the proposed Kaunakakai harbor project location, a Level 5 project, due to another opportunity to be in the vicinity. Only photographs were taken of this location.

Land status research was conducted for all locations that were included in the field studies. This research showed that these projects were conducted either on land under the jurisdiction of the Bureau of Land Management or the U.S. Army Corps of Engineers. Two land withdrawals were made by the U.S. Atomic Energy Commission from the Bureau of Land Management for projects Pre-Schooner II and Bronco. Both land withdrawals have been terminated with responsibility for the areas returned to the Bureau of Land Management.

#### **6.4 Evaluation of Environmental Liabilities**

A project with potential environmental liabilities is Pinot, the high explosives test with radioactive tracers. Although the radioactive tracer used in the Pinot test has a relatively short half-life, some people might consider the location to be of risk. At the time of the



test, the mine was within the Naval Oil Shale Reserve Nos. 1 and 3. However, the mine itself was controlled by the U.S. Bureau of Mines. Over the years, administrative control of the area has changed several times. Jurisdiction was transferred from the U.S. Navy to the U.S. Department of Energy in 1977. Twenty years later, in 1997, the responsibility for this land was transferred to the U.S. Department of the Interior. Access to the mine is very difficult and the mine is closed to the public. In 2003, a local person said that someone checks on the mine once a year. But this could not be confirmed and the mine is not on the list of locations in Colorado under the Department of Energy's Office of Legacy Management. Personnel that were contacted at the local Bureau of Land Management office also were not familiar with this mine, leading to the conclusion that no one may be monitoring this location currently, unless it is being done under the Bureau of Land Management Colorado State Office. Therefore, it is recommended that the Bureau of Land Management State Office be contacted to determine whether or not there is monitoring of this location, and if not, then arrangements may need to be made for the mine to be monitored for security and unauthorized access.

At the other 14 project locations, evidence of past Plowshare project activities include changes in the landscapes and the presence of equipment and debris. Projects Pre-Gondola, Pre-Schooner II, Trencher, Trinidad, and Tugboat were high explosives projects that were conducted and the landscapes were reconfigured by the high explosives detonations. Pre-Gondola was in Montana and activities involved crater tests and construction of a large trench. For Trencher, several dozen craters were created across the project area, located west of Pre-Gondola. Trinidad consisted of small test craters and railroad cuts in Colorado and Tugboat was the excavation of a harbor for small boats on the Big Island of Hawaii. These locations were cleaned up after use and in some cases there were efforts to level the landscape to pre-test conditions. Debris was rare and only noticeable at the Pre-Gondola site due to the continuing drought in the western United States. Fort Peck Reservoir has lost elevation, completely exposing the former lake area in front of Pre-Gondola. As a result, debris from some of the high explosives detonations that had landed in the lake and was submerged for many years now is visible. In addition, some debris can be found on the sides of the large trench. The debris includes fragments of charge casings, emplacement hole pipe, stemming material, rebar, concrete, wire, conduit, braided steel cable, and miscellaneous metal and rubber fragments along with rebar and mounting posts in the area that served as instrument stations to monitor the explosions. If there are future issues with the debris, the U.S. Army Corps of Engineers at Fort Peck would be the ones handling the situation. It would be expected that there would be minimal to no debris at the other civil works high explosives project locations that were not visited.

Pre-Schooner II was a different type of project. It was conducted to study cratering characteristics of basalt as a scaling test for the Schooner nuclear cratering project planned for a site near Pre-Schooner II in Idaho. The Pre-Schooner II area was not cleaned up after the test. Targets used in surface motion studies are scattered around the crater. Also visible are most of the explosive charge casing, drill pipe, stemming, and down-hole instrumentation that were ejected during the detonation and landed several hundred to nearly 2,000 ft from ground zero. At the control point, there is domestic and

industrial debris, such as food and beverage containers intermingled with cable spools, wood, wiring, metal strapping, conduit, wood, solvent and oilcans, nails, and broken glass. The trailers and other structures were removed from the location. However, several structures remain at the staging area including a large cylindrical fuel oil tank, a collapsed water tank, and a small bunker. Also in the general area are several low earthen berms, a trash pit, a trash burning area, and miscellaneous industrial debris such as iron pipe, wood, steel cable, and drill casing. At a location southwest of ground zero where a camera station used to be, there is debris. Materials recorded are sheet metal target fragments, drill casing, and unidentifiable metal fragments. Although the Bureau of Land Management has not expressed concern about these structures and materials, it is possible that someday the U.S. Department of Energy will be asked about this situation.

There were three gas stimulation projects included in the fieldwork studies: Dragon Trail, Wagon Wheel and WASP. There are seven existing drill holes in Colorado from the Dragon Trail project and they are located in bladed areas. Four wells are in the eastern area of the gas field. These are Douglas Creek No.1, DT-B, East Dragon Trail No. 2, and DTU 25-11. The first three are inactive and have been plugged. In all three cases, a 6-inch diameter casing extends more than 4 ft above the surface with the well designation welded onto the pipe. At DT-B, there is a concrete pad, remains of a wooden structure, and debris, such as lumber, plywood, wooden lath, braided steel cable, iron pipe sections, metal cable anchors, broken glass and a few cans. Minimal debris was observed at the other two locations. DTU 25-11 is in production and the area has some associated modern equipment and features. In the western area, there are three well sites. DT-EX is active and has been renamed to DTU #1303. The associated equipment is currently being used. However, along the edge of the dirt pad, there are galvanized steel eye-bolt anchors and debris that includes bailing wire, wooden lath, metal fragments, and a few pull-tab and pop-top aluminum beverage cans. DT-A test well is inactive and is marked by the same type of casing and welded well designation as noted above and only minimal debris exists there. DT-E emplacement hole, however, was not located. The information on this hole discusses the plans to drill but it was unclear if this drilling was performed. It appears that work on the Dragon Trail project was suspended before the beginning of this drilling effort. These drill holes are in gas fields that are actively being developed today. There are no anticipated environmental issues at the Project Dragon Trail locations because the project leases were held by Continental Oil Company and the debris observed is minimal.

The Project Wagon Wheel gas stimulation experiment in Wyoming was ready to be conducted when Congressional intervention closed down the project. The location is surrounded by a wire mesh and metal pole fence capped with barbed wire and entry is through a double metal gate with metal cattle guard. The emplacement hole is marked by a 4 ½-inch diameter pipe, extending 6 ft above the surface. The pipe is welded shut and has a welded label for Wagon Wheel #1. Concrete pads surround the drill hole. Water Well #1, to the south of the emplacement hole, is still active and the top of the water well casing is locked down with a plate and a pad lock. A flexible pipe extends from the well to a pair of holding tanks along the south boundary fence. This well is surrounded by a small wire fence enclosure. Two 8-ft diameter tanks are along the south fence line and are

connected to each other. A line leads from the bottom of the south tank to the troughs just outside the fenced compound. The troughs, however, are not associated with the Wagon Wheel project and were put in later to water cattle. The Loomix trough consists of three deep water-filled troughs connected to each other with pipes. They are sitting on railroad ties and are partially covered by a wooden frame made of poles and 2x4s. A second trough consisting of a pair of split 16 inch diameter iron pipes is just west of the Loomix trough. Just west of the troughs is an area labeled as a flare pit. This is a horizontal, twin tank dehydrator and flow regulator. Another well, possibly Water Well #2, is near the dehydrator and the watering troughs. It consists of a 6 1/2-inch diameter pipe that extends approximately 28 inches above the ground surface. The well is uncapped and did not appear to be active.

In addition to the structural remains and features, discarded drilling equipment, construction material, and miscellaneous debris are piled along the south fence line and in a large debris pit north of Wagon Wheel #1. The debris includes black PVC pipe, metal hose clamps, railroad ties and lumber of various sizes, wooden lath, plywood sheets, galvanized pipe, metal hose/pipe couplers, threaded pipe couplings, threaded pipe caps, iron pipe in various lengths and diameters, metal fence posts, galvanized corrugated pipe sections, empty 5-gallon gas cans, dehydrators, flow regulators, cardboard boxes, D-cell batteries, soda cans, solder cans, empty motor oil cans and paint cans, several empty 55-gallon drums, galvanized culvert, wooden pallets, and various components of flow regulators. With the exception of the recent activity by a survey crew, the site looks probably much as it did when the Wagon Wheel project was abandoned.

Unrelated to the Wagon Wheel project is a fenced enclosure consisting of posts and four strands of barbed wire, south of the Wagon Wheel compound. The enclosure surrounds a shallow depression lined its entire length with black poly-tarp weighted down by river cobbles and sand.

The Wagon Wheel project location was leased by the El Paso Natural Gas Company. The structural features, abundant construction debris, and discarded instrumentation materials indicate that when the location was abandoned, the tanks were left in place and materials of little use were left adjacent to and in the debris pit. No cleanup was conducted at the site. The Bureau of Land Management personnel were very familiar with this site and no one mentioned the Wagon Wheel project items still at the location. It is unlikely that this situation will ever be raised in the future because the location had been leased by a gas company shortly before the field study and it is probable that the area has already been cleaned up by the lessee.

The Merna site for the WASP project in Wyoming could not be accessed during the field studies. One gas well was drilled at this location and a group of industrial investors held the lease for the subsurface minerals. The surface is private and so, except for the Merna drill hole itself, remains from the WASP activities should be negligible.

The two oil shale stimulation experiments are Bronco and Utah. Three drill holes were completed for the Bronco project in Colorado. USBM Core Hole No. 1 is in an isolated

area. It is marked by a 9-inch diameter well casing that has been capped and extends about 3.5 ft above the ground surface. There are four heavy gauge, galvanized steel, eye-bolt anchors embedded in the ground surrounding the well, probably used to secure the drill rig. Associated debris included concrete chunks, wood fragments, metal banding, well casing sections, a few cans, and some broken glass bottle fragments. USBM Core Hole No. 2 is situated between two active oil and gas leases. It consists of a 4-inch diameter vertical iron pipe that extends approximately 4 ft above the ground surface. The casing is capped and locked. The casing is welded with the well designation in block lettering, "BM. AEC. HOLE #2." The only debris noted were a few lumber fragments, some wooden lath, a couple pieces of metal, a red rubber gasket, a steel-sided, soft-top pull-tab beverage can, and two more recent pop-top aluminum soft-drink cans. Access problems and time constraints prevented DRI personnel from reaching USBM Core Hole No. 3, but it is assumed that the physical setting and condition of this location would be similar to the other core holes. Given that the debris at these core hole locations is minimal, there are no apparent environmental issues at the Bronco sites.

The Project Utah experimental drill hole, WOSCO EX-1, was inactive at the time of the field visit and looked the same as it did in a 1969 photograph. The 10 3/4-inch well casing is capped with a "Rector" well head with a wheeled valve closure. Four galvanized steel eyebolt anchors that stabilized the drill rig remain embedded in the ground approximately 40 ft from the well head. Debris is scattered around the drill hole. There are 4 wood panels, probably from a box that enclosed the wellhead at one time. Other debris includes miscellaneous pieces of lumber, metal strapping, metal bottle caps (crown cap closures), clear glass fragments, and a clear glass jar.

A large drilling mud pit is located about 30 ft NNE of the drill hole. The pond is surrounded by an earthen berm on three sides. The fourth side is level with the ground surface at the well head. A metal T-post and wire mesh fence surrounds the entire pit. All four corner posts of the enclosure are anchored with rebar and barbed wire guy wires. The pit has been used for disposal of trash. Industrial debris within the pit includes two empty 55-gallon drums, several empty 1 gallon and 5 gallon paint cans, a tire, several heavy equipment air filters, well casing and drill pipe segments, black rubber hose, 1-inch diameter braided wire cable, welding rods, threaded bolts, metal flanges, rubber gaskets and O-rings, more than 20 one-quart motor oil cans (SAE 20/20), and miscellaneous metal and wood fragments. Personal gear or consumables discarded in the mud pit include pull tab aluminum cans, pull tab soft-top steel cans, discarded Pepsi Cola and Coca Cola bottles, assorted green, amber, and clear glass fragments, sanitary-type fruit and vegetable cans, cotton work gloves, and a rubber boot heel.

There are several other debris concentrations surrounding the well head and mud pit. Items noted in these areas include food and beverage cans, bottle glass, lumber, bailing wire, and miscellaneous metal fragments. A low knoll located approximately 100 ft southwest of the EX-1 drill hole, had been bladed and leveled. The knoll probably was the location of a small office or equipment shed as indicated by the plywood, lumber, and metal scattered across the area.

There are ample materials and debris at the Project Utah site. This site is on Utah state land and at the time of the project the land was leased by Western Oil Shale Corporation. It now is within an active oil and gas field and there is a current lease on file. With the on-going development in the area, it is not expected that an issue will be raised regarding the construction and other materials that were left at the location.

Thunderbird was a coal gasification project in Wyoming. There were 14 core holes drilled for this project on land under lease to Wold and Jenkins. With the exception of the well heads, no surface facilities associated with the Thunderbird project drill holes remain. Some of the locations are inactive and the recording/telemetry sheds and fencing surrounding the drill hole locations with active wells post-date the Project Thunderbird activities. There are no environmental liabilities associated with the Thunderbird project.

There are three projects where no evidence of the projects was identified during the field visits. Project Iki was on the Big Island of Hawaii. For this geothermal study, a hole was drilled into the Iki crater to obtain measurements and samples. The drilling equipment was long ago removed as required by the National Park Service. Projects Excavator and Travois were in Idaho. Excavator was the high explosives calibration test for the Project Travois nuclear quarrying experiment. During the field studies, the one or more drill holes for characterizing the area were not relocated and there were no other features or debris that could definitely be attributed to these projects. Projects Iki, Excavator and Travois have no environmental liabilities.

## **6.5 Other Possible Issues**

While this research focused on potential environmental liabilities at domestic Plowshare and Vela Uniform locations, two other Plowshare Program issues were identified during the course of this work. The first is the effect of the Internet on the availability of Plowshare information and perceptions regarding the Plowshare Program. In 2002, there were about 650 results when conducting a search for this Plowshare Program. In May 2005, there were almost 2,000 results. In September 2008, there were over 22,000 results. The exponentially increasing information on the web contains mostly accurate information. However, there are inaccuracies and, in a very few instances, there are unfounded claims that nuclear explosives were used when they were not. At least in one case, this is related to a proposed Plowshare project that did not take place. As more and more old newspapers come online, decades old articles that discuss proposed nuclear projects as future certainties will create more inquiries into the actions of the U.S. Atomic Energy Commission related to the Plowshare Program (Figure 6.5-1).

The second issue is the realization that there was a very active international Plowshare Program. A cursory look at this information indicated that more than 75 projects were considered in more than 40 countries (Table 6.5-1). For some of these projects, fieldwork was conducted and feasibility studies were completed. It is possible that at some time in the future, the United States could be asked what types of work were done for the feasibility studies and whether or not nuclear explosives were used at one or more of

these locations. In order to handle this situation, it may be important that a complete list of these projects be available, if ever needed.



Figure 6.5-1. Collage of newspaper articles that reported on proposed Plowshare projects.

Table 6.5-1. International Projects Considered for the Plowshare Program

<b>General Location</b>	<b>Description</b>
Africa	Niger-Upper Volta River Diversion Canal
Algeria	gas stimulation project
Angola	Cabinda, harbor
Antarctica	seismology experiments
Argentina	Parana River, navigation canal
Argentina/Chile	Excavation for road (three routes)
Argentina/Paraguay	Paraguay River Project, navigation improvements
Australia	Cape Keraudren Project, harbor excavation
Australia	Diamond Gorge, dam
Australia	Ord River Project, excavation for a reservoir/aqueduct on the Ord River
Australia	Mareenie, oil and gas field near Alice Springs oil and gas stimulation
Australia	west coast, crater lip dam
Australia	west coast, overburden removal for mineral development
Australia	Geraldton, deepening of channel and harbor improvement
Australia	in situ nickel leaching mining project
Australia	Project Pacoota Boost, oil stimulation
Australia	Wittenoom development, nuclear explosives to fracture iron ore mining
Bolivia	Titicaca Canal, diversion canal from Lake Titicaca
Bolivia	Beni River Project, removal of Beni Falls for water control
Brazil	Madeira River, navigation canal
Brazil	San Francisco River, water diversion
Canada	Mackenzie River Delta, navigation canal
Canada	Simpson Strait, navigation canal
Canada	NAWAPA, North American Water Power Alliance, water diversion
Canada	Project Oil Sand, oil sands stimulation project in Athabaska tar sand formation
Canada	Boothia Isthmus, navigation canal
Canada	Prince Edward Island to the mainland, tunnel
Canada	Hudson Bay, dam
Canada	Welland Canal Bypass, navigation canal

Table 6.5-1. International Projects Considered for the Plowshare Program (continued)

<b>General Location</b>	<b>Description</b>
Carolina Islands	Kapingamarangi Lagoon channel, navigation channel
Central America	Interoceanic Canal Project, Atlantic-Pacific transisthmanian canal
Central Pacific	Baker and Howland Islands, navigation channel
Chile	Arica Harbor Project
Chile	Rio Bio Bio Dam Project, slide dam
Chile	El Salvador, mining
Columbia	La Macarena, water diversion
Columbia	La Araracuara, navigation canal
Columbia	Buenaventura to Bogota, highway cut
Costa Rica	Rio Tempisque Project, flood diversion canal
Egypt	Qattara Canal, diversion canal from the Mediterranean to Qattara Depression
France	off shore oil storage
Greenland	Ezberg project, overburden removal
India	Ganges-Hooghly Canal, diversion canal between the Ganges and Hooghly Rivers
India	Indus River development, dams and canals
Indian Ocean	Diego Garcia Atoll, channel improvement
Israel	Elat-Dead Sea Waterway, canal
Israel	Mediterranean to Red Sea, alternate Suez canal
Japan	Kobe, harbor
Madagascar	overburden removal
Mexico	Yucatan Peninsula, harbor
Mexico	Yuma, harbor and navigation canal
Mexico	Baja, navigation canal
Micronesia	Marshall Islands, Taongi, harbor
North Sea	Netherland interest, gas storage project
Pakistan	Nari and Hab Rivers Project, dam
Pakistan	Tarbela Dam Project, dam construction on the Indus River
Peru	Salaverry Harbor Project



Table 6.5-1. International Projects Considered for the Plowshare Program (continued)

<b>General Location</b>	<b>Description</b>
Peru	Ilo, harbor
Peru	irrigation project
Philippines	Luzon Island, navigation canal
Philippines	Ambukalo Reservoir, silting basin
Somalia	harbor
Samoa Islands	Samoa, harbor
South America	Andes Mountains Canal, diversion canal from the east to west slope
South America	Trans-Andean Highway/Railway, highway/railroad cut from Chile to Argentina
South America	modification of Humboldt current
South America	Upper Amazon River, navigation improvements
South Korea	Seoul Canal, navigation canal from Seoul to Yellow Sea
South Korea	Swamp Drainage Project
South Pacific	Line Islands, Christmas Island harbor
South Pacific	Kapingamarangi Atoll, navigation improvements
Southeast Asia	Mekong River Project, reservoir and aqueduct
Sudan	Jonglei Canal, diversion canal
Thailand	Isthmus of Kra, Malay Peninsula, navigation canal
Thailand	Mekong River, navigation improvements
Tunisia and Algeria	Artemis Project, Chotts Canal, diversion canal from Chotts Depression to the Mediterranean
United Arab Republic	Alternate Suez Canal
Venezuela	La Paz, oil and gas stimulation
Venezuela	Rio Negro/Orinoco Waterway, navigation canal

## 6.6 Conclusions

The U.S. Atomic Energy Commission created and oversaw the Plowshare Program and worked in tandem with the U.S. Department of Defense on the Vela Uniform Program. The Lawrence Livermore National Laboratory was primarily responsible for implementation of the Plowshare Program. However, the contributions of the U.S. Army Engineer Nuclear Cratering Group usually have been overlooked. The Nuclear Cratering Group worked under an agreement between the U.S. Atomic Energy Commission and the

U.S. Army and had offices at the Lawrence Livermore National Laboratory. This research shows that they had an important role in the civil works and cratering projects and were the lead agency of some of these. The Plowshare and Vela Uniform projects most commonly discussed in the literature are the nuclear and high explosives studies conducted on the Nevada Test Site and the off-site nuclear projects. Some basic information is available for a couple of the high explosives tests conducted off-site and for a few of the off-site projects that were planned but not executed.

Prior to this research, it was known that there were 24 Plowshare and 2 Vela Uniform domestic projects either planned for off-site locations or executed as high explosives tests off-site. The results of this research have greatly expanded this knowledge with the number of projects increasing to 156 Plowshare projects and 14 Vela Uniform projects. As the research progressed, it was apparent that the Vela Uniform Program did not pursue many off-site locations for its research. On the other hand, the Plowshare Program was interested in a variety of civil and industrial applications in different geologic environments and the types of projects considered were much broader than is common knowledge. Proposed civil works projects were to quarry rock construction materials; to construct dams, spillways, harbors, canals, reservoirs, highways, and railroad lines; and conduct sea ice breakup, sandbar removal, dredging of deltas, and diverting river channels. Proposed industrial applications included excavating, fracturing, and leaching ore for mining operations; stimulating oil, gas, and coal recovery underground; forming storage chambers for oil, gas, water and even trash and sewage; developing geothermal power and desalinization systems; and pulverizing basalt for agricultural development. Also discussed was the utilization of nuclear explosives for the production of synthetic diamonds and radioactive isotopes, and even to excavate a crater for a radio telescope facility. Table 6.6-1 contains an alphabetical list of the projects, a reference to the place in the report where the project is discussed, project location by state, and the purpose of each project. Table 6.6-2 presents the same information, organized alphabetically by state.

After an analysis of the 170 projects in this report, it has been determined that there are two Plowshare projects with potential environmental liabilities, Pinot and Pre-Schooner II. Pinot was a high explosives oil shale stimulation experiment in which a radioactive tracer was used. The mine where Pinot was conducted is closed to the public. Although there are indications that the mine was monitored at one time, no current on-going site monitoring could be confirmed during the field studies. The other project, Pre-Schooner II, involved a land withdrawal by the U.S. Atomic Energy Commission. While the land withdrawal ended many years ago with jurisdiction returning to the Bureau of Land Management, the project is in a very isolated location with only grazing on-going in the area. The U.S. Department of Energy could possibly be contacted about the extensive testing debris that is left at the location. Other potential issues that might arise in the future are requests for information about projects that may or may not have been executed domestically and internationally. The inclusion in this report of many Plowshare and Vela Uniform projects that were not conducted or did not have extensive fieldwork will provide project information to respond to almost any query from the public or a federal or state agency regarding a domestic project.

Table 6.6-1. Alphabetical Listing of Proposed Nuclear Projects, High Explosive Experiments, and High Explosive Construction Activities for the Off-Site Plowshare and Vela Uniform Programs

Chapter	Name	Description	ST	Program	Activity
5.1	Alamo Dam Spillway	Nuclear Excavation for Dam Spillway	AZ	Plowshare	Level 5
5.2	Alaska Copper Leaching	Nuclear Explosives to Fracture Copper Ore for Underground Chemical Mining	AK	Plowshare	Level 5
5.3	Ammonia Production	Nuclear Explosives in Geothermal Formations for Synthesizing Ammonia	No Location Specified	Plowshare	--
5.4	Anderson Proposals	Suggested Nuclear Excavation Applications	Multiple Locations	Plowshare	Level 5
5.5	Appalachian Gas Storage	Nuclear Chimney for Underground Gas Storage	KY	Plowshare	Level 5
4.1	Aquarius	Nuclear Explosives for Water Management	AZ	Plowshare	Level 4
5.6	Argo Tunnel	Possible Location for Nuclear Explosive Experiments	CO	Plowshare	Level 5
5.7	Arizona Aqueduct	Nuclear Explosives for Water Redistribution System	AZ	Plowshare	Level 5
5.8	Atlantic Gas Storage	Nuclear Chimney for Gas Storage	No Location Specified	Plowshare	--
5.9	Basalt Fracturing	Nuclear Explosives to Pulverize Basalt	No Location Specified	Plowshare	--
5.10	Bering Strait	Nuclear Excavation to Deepen Waterway	AK	Plowshare	Level 5
4.2	Boca Bypass	Nuclear Excavated Railroad Cut	CA	Plowshare	Level 5
4.3	Bo-Peep	Nuclear Explosives for Petroleum Stimulation	CA	Plowshare	Level 5
3.1	Bronco	Nuclear Explosives for Fracturing Shale Underground	CO	Plowshare	Level 3
4.4	Bruneau Canyon Dam	Nuclear Explosives for Ejecta Dam Construction	ID	Plowshare	Level 5
5.11	Buchanan Dam	Nuclear Quarrying for Dam Construction	CA	Plowshare	Level 5
5.12	Butler Valley Dam	Nuclear Quarrying for Dam Construction	CA	Plowshare	Level 5

Table 6.6-1. Alphabetical Listing of Proposed Nuclear Projects, High Explosive Experiments, and High Explosive Construction Activities for the Off-Site Plowshare and Vela Uniform Programs (continued)

Chapter	Name	Description	ST	Program	Activity
5.13	Buttes Dam	Nuclear Explosives for Dam Construction and Quarry	AZ	Plowshare	Level 5
5.14	Buttes Reservoir Copper Recovery	Nuclear Explosives to Fracture Ore Deposits for In Situ Leaching of Copper	AZ	Plowshare	Level 5
5.15	Cactus Ore Copper Recovery	Nuclear Explosives to Fracture Ore Deposits for In Situ Leaching of Copper	AZ	Plowshare	Level 4
4.5	Caddo Pine Island	High Explosives Experiment for Oil Stimulation	LA	Plowshare	Level 5
5.16	California Water Plan	Nuclear Explosives for Water Management Project	CA	Plowshare	Level 5
5.17	Camelsback Dam	Nuclear Excavation of a Spillway and Quarrying for Dam Construction	AZ	Plowshare	Level 5
5.18	Cape Cod Canal	Nuclear Explosives to Dredge a Channel	MA	Plowshare	Level 5
4.6	Cape Darby Harbor	Nuclear Excavation of a Harbor	AK	Plowshare	Level 5
5.19	Carmel-San Simeon Harbor	Nuclear Excavation of a Harbor	CA	Plowshare	Level 5
4.7	Carryall	Nuclear Explosives Proposed for Highway and Railroad Construction	CA	Plowshare	Level 4
5.20	Catherine Creek	High Explosive Calibration Study and Nuclear Quarrying for Dam Construction	OR	Plowshare	Level 5
3.2	CHASE	High Explosive Long Range Seismic Monitoring Experiments	AK,CA,VA	Vela Uniform	Level 2
4.8	Chomly Cutoff	Nuclear Excavation of a Sea-Level Channel	AK	Plowshare	Level 5
4.9	Cochiti Dam	Nuclear Quarrying for Construction of a Dam	NM	Plowshare	Level 4
5.21	Coconino Dam	Nuclear Explosives to Construct a Slide Dam and Spillway	AZ	Plowshare	Level 5
4.10	Colona Earthquake	Earthquake Seismic Data	CO	Vela Uniform	Level 4
5.22	Colorado River Desalinization	Nuclear Craters for Desalinization Plant	AZ	Plowshare	Level 5
5.23	Columbia River Delta Clearance	Nuclear Explosives to Clear a Delta	OR	Plowshare	Level 5

Table 6.6-1. Alphabetical Listing of Proposed Nuclear Projects, High Explosive Experiments, and High Explosive Construction Activities for the Off-Site Plowshare and Vela Uniform Programs (continued)

Chapter	Name	Description	ST	Program	Activity
5.24	Copper Flat	Nuclear Explosives to Fracture Ore for In Situ Copper Leaching	NM	Plowshare	Level 4
4.11	Copper Ore Chemical Mining	Nuclear Explosives to Mine Primary Copper Ore Deposits	AK, AZ, CA, CO, ID, MT, NV, NM, UT, WA	Plowshare	Level 5
4.12	Copper Recovery	Nuclear Explosives for Fracturing Copper Ore Deposits for In Situ Leaching	AK, AZ, CA, CO, ID, MT, NV, NM, OR, UT, WA, WY	Plowshare	Level 4
3.3	Cowboy	High Explosive Seismic Monitoring Experiment	LA	Vela Uniform	Level 2
5.25	Cross-Continent Barge Canal	Nuclear Excavation for Canal Construction	Multiple Locations	Plowshare	Level 5
4.13	Dogsled	Nuclear Cratering Experiment in Sandstone	AZ, UT	Plowshare	Level 4
5.26	Dow Chemical Proposals	Various Plowshare Applications	No Location Specified	Plowshare	--
3.4	Dragon Trail	Nuclear Explosives for Gas Stimulation	CO	Plowshare	Level 3
3.5	Drum Inlet	High Explosives for Channel Excavation	NC	Plowshare	Level 2
5.27	Earth Furnace	Nuclear Explosives to Develop Mineral Resources	WV	Plowshare	Level 5
5.28	El Centro Canal	Nuclear Explosives for Canal Excavation	CA	Plowshare	Level 5
5.29	Etsel Dam	Nuclear Quarrying for Construction of a Dam	CA	Plowshare	Level 5
3.6	Excavator	High Explosive Calibration Experiment	ID	Plowshare	Level 3
5.30	Experiment	Nuclear Industrial Plowshare Experiment	WV	Plowshare	Level 5

Table 6.6-1. Alphabetical Listing of Proposed Nuclear Projects, High Explosive Experiments, and High Explosive Construction Activities for the Off-Site Plowshare and Vela Uniform Programs (continued)

Chapter	Name	Description	ST	Program	Activity
5.31	Fault Lines	Nuclear Explosives to Relieve Stress along Fault Lines	No Location Specified	Plowshare	--
5.32	Feather River Project	Nuclear Explosives for Water Redistribution	CA	Plowshare	Level 5
4.14	Galley	Row Charge Nuclear Cratering Experiment	ID	Plowshare	Level 5
5.33	Garden Valley Dam	Nuclear Explosives for Construction of a Slide Dam	ID	Plowshare	Level 5
5.34	Gas Hills Uranium Mine	Nuclear Explosives to Mine Uranium	WY	Plowshare	Level 5
4.15	Geothermal Power Plant	Nuclear Explosives for Geothermal Power	AK, AZ, CA, CO, ID, MT, NV, NM, OR, UT, WA, WY	Plowshare	Level 5
4.16	Gold Leaching	Nuclear Explosives to Fracture Ore for In Situ Leaching of Gold	AK, WY	Plowshare	Level 5
4.17	Gondola	Nuclear Cratering Experiment	MT, NV, SD	Plowshare	Level 5
4.18	Groundhog	High Explosive Seismic Monitoring Experiment	CA, NV, NM, MT, LA, MI, MS	Vela Uniform	Level 5
5.35	Hansom	Nuclear Explosives in Rock Breaking Applications	Multiple Locations	Plowshare	--
5.36	Hawaii Harbor for Inter-Island Ferries	Nuclear Excavated Harbor	HI	Plowshare	Level 5
4.19	Hebgen Lake Earthquake	Earthquake Seismic Data	MT	Vela Uniform	Level 4
5.37	Honokahau Small Craft Harbor	Nuclear Excavated Harbor	HI	Plowshare	Level 5
5.38	Idaho Phosphates	Use of Nuclear Explosives to Mine Phosphates	ID	Plowshare	Level 5

Table 6.6-1. Alphabetical Listing of Proposed Nuclear Projects, High Explosive Experiments, and High Explosive Construction Activities for the Off-Site Plowshare and Vela Uniform Programs (continued)

<b>Chapter</b>	<b>Name</b>	<b>Description</b>	<b>ST</b>	<b>Program</b>	<b>Activity</b>
3.7	Iki	Geothermal Energy Experiment	HI	Plowshare	Level 3
5.39	John Day River	Nuclear Construction of a Slide Dam	OR	Plowshare	Level 5
5.40	Kaalualu Harbor	High Explosive Cratering Tests for Small Craft Harbor	HI	Plowshare	Level 5
4.20	Katalla Harbor	Nuclear Construction of a Deep-Water Harbor	AK	Plowshare	Level 5
4.21	Kaunakakai Harbor	Nuclear Harbor Excavation Experiment	HI	Plowshare	Level 5
5.41	Keetch Plan for Water Conservation	Nuclear Explosives for Water Storage System	TX	Plowshare	Level 5
4.22	Ketch	Nuclear Explosives for Underground Natural Gas Storage	PA	Plowshare	Level 4
5.42	Lake Erie - Lake Ontario Waterway	Nuclear Explosives to Construct a Waterway	NY	Plowshare	Level 5
5.43	Lake Erie - Ohio River Canal	Nuclear Explosives to Excavate a Canal	OH	Plowshare	Level 5
4.23	Lake Tahoe Sewage	Nuclear Chimneys for Sewage Disposal	CA	Plowshare	Level 5
5.44	Laurel River Dam	Nuclear Quarrying for a Rock-Fill Dam	KY	Plowshare	Level 5
3.8	Libby	High Explosive Experiment for a Highway Cut	MT	Plowshare	Level 2
5.45	Livermore Valley Sewage Disposal	Nuclear Chimneys for Sewage Disposal	CA	Plowshare	Level 5
3.9	Lost Creek	High Explosive Experimental Mounding and Controlled Blasting Series	OR	Plowshare	Level 2
5.46	Magnesium Recovery	Nuclear Explosives for Mining Magnesium	GA, NC	Plowshare	Level 5
5.47	Megawatt	Underground Nuclear Explosions for Power Generation	WV	Plowshare	Level 5
5.48	Missouri River Reservoir	Nuclear Excavation for Reservoir Project	MT	Plowshare	Level 5
5.49	Modesto Waste Disposal	Nuclear Chimneys for Sewage Disposal	CA	Plowshare	Level 5
5.50	Molybdenite Recovery	Nuclear Explosives for Molybdenite Mining	CO	Plowshare	Level 5
5.51	Montana Silver Retarc	Nuclear Explosives for Silver Mining	MT	Plowshare	Level 5

Table 6.6-1. Alphabetical Listing of Proposed Nuclear Projects, High Explosive Experiments, and High Explosive Construction Activities for the Off-Site Plowshare and Vela Uniform Programs (continued)

Chapter	Name	Description	ST	Program	Activity
5.52	Mountain Lake	Nuclear Explosives for Water Resource Development	WV	Plowshare	Level 5
5.53	Mt. Snow	Nuclear Excavation of Mountainside	VT	Plowshare	Level 5
4.24	NAWAPA	Nuclear Explosives for Construction of a Water Containment and Distribution System	AK, AZ, CA, CO, ID, IL, MI, MN, MT, ND, NM, NV, OR, SD, WA	Plowshare	Level 5
4.25	New Madrid Earthquake	Earthquake Seismic Data	MO	Vela Uniform	Level 4
5.54	New York Plateau Excavation	Nuclear Excavation of a Rock Plateau	NY	Plowshare	Level 5
5.55	Newmont Project	Nuclear Explosives to Fracture Copper Ore for Underground Chemical Mining	AZ	Plowshare	Level 4
4.26	Nome Harbor	Nuclear Excavation of a Harbor	AK	Plowshare	Level 5
4.27	North Slope Harbor	Nuclear Construction of an Offshore Loading Facility	AK	Plowshare	Level 4
5.56	Nuclear Explosive Power Generation	Underground Nuclear Explosions for Power Generation	AL, CO, LA, MS, NM, TX, UT	Plowshare	Level 5
5.57	Offshore Fuel Oil Storage	Nuclear Chimneys for Undersea Storage of Fuel Oil	GUAM	Plowshare	Level 5
4.28	Old Reliable Mine	High Explosives Seismic Study	AZ	Plowshare	Level 4
3.10	Operation Breakup	High Explosive Ice Cratering Experiment	AK	Plowshare	Level 2
5.58	PACER	Underground Nuclear Explosions for Power Generation	No Location Specified	Plowshare	--
5.59	Payette	Construction of a Cavity for a Nuclear Mining Experiment	MS	Vela Uniform	Level 4



Table 6.6-1. Alphabetical Listing of Proposed Nuclear Projects, High Explosive Experiments, and High Explosive Construction Activities for the Off-Site Plowshare and Vela Uniform Programs (continued)

Chapter	Name	Description	ST	Program	Activity
4.29	Phaeton	Nuclear Excavation	AK, CA, NV	Plowshare	Level 5
3.11	Pinot	High Explosives for Oil Shale Stimulation Research	CO	Plowshare	Level 1
3.12	Plowboy	High Explosives Salt Fracture Research	LA	Plowshare	Level 3
5.60	Plowshare Emergency Capability Program	Nuclear Explosives for Use in National and World Emergencies	No Location Specified	Plowshare	--
4.30	Point Barrow Harbor	Nuclear Excavation of a Harbor	AK	Plowshare	Level 5
4.31	Port Moller Canal	Nuclear Explosives for Canal Construction	AK	Plowshare	Level 5
5.61	Pre-Dogsled	High Explosive Cratering Experiment	AZ, UT	Plowshare	Level 5
3.13	Pre-Dribble	High Explosive Seismic Effects Research	MS	Vela Uniform	Level 2
3.14	Pre-Gnome	High Explosives Seismic Experiment	NM	Plowshare	Level 2
3.15	Pre-Gondola	High Explosives for Waterway Construction	MT	Plowshare	Level 2
3.16	Pre-Schooner II	High Explosive Cratering Experiment	ID	Plowshare	Level 2
5.62	Pre-Vintage	High Explosive Tests	CO	Plowshare	Level 5
5.63	Pumped Storage Reservoirs	Nuclear Excavation of Storage Reservoirs	ID, WA	Plowshare	Level 5
3.17	R. D. Bailey	High Explosive Experiment for Dam Spillway Excavation	WV	Plowshare	Level 2
5.64	Radio Telescope Facility	Nuclear Explosive to Create Crater for Radio Telescope Facility	No Location Specified	Plowshare	--
5.65	Radioactive Waste Disposal	Nuclear Chimney for Radioactive Waste Disposal	No Location Specified	Plowshare	--
4.32	Rampart Canyon Dam	Nuclear Excavation for Dam Construction and Quarry	AK	Plowshare	Level 5
5.66	Raymondville Harbor	Nuclear Explosives to Remove a Sandbar	TX	Plowshare	Level 5

Table 6.6-1. Alphabetical Listing of Proposed Nuclear Projects, High Explosive Experiments, and High Explosive Construction Activities for the Off-Site Plowshare and Vela Uniform Programs (continued)

Chapter	Name	Description	ST	Program	Activity
4.33	Red Lake Gas Storage	Nuclear Excavation for Underground Gas Storage	AZ	Plowshare	Level 4
5.67	Red Mountain Mineral Extraction	Nuclear Mining Application	CO	Plowshare	Level 5
3.18	Rufus	Surface Detonation of Nuclear Explosives	AK	Vela Uniform	Level 3
5.68	Runaway Gas or Oil Wells	Nuclear Explosives to Shut Off a Gas or Oil Well	No Location Specified	Plowshare	--
5.69	Saline River Canal	Nuclear Excavation of a Canal	IL	Plowshare	Level 5
4.34	San Clemente Island	Development of Underground Aquifer Using Nuclear Explosives	CA	Plowshare	Level 4
5.70	San Diego - Imperial Valley Interstate/ Laguna Mountains Highway	Nuclear Explosives for Highway Construction	CA	Plowshare	Level 5
5.71	San Luis Dam	Nuclear Quarrying for Construction of a Dam	CA	Plowshare	Level 5
4.35	Sand	Nuclear Explosive Seismic Monitoring Experiment	MS, TX	Vela Uniform	Level 4
5.72	Santa Barbara Channel Oil Leakage	Nuclear Explosives to Control Oil Leakage	CA	Plowshare	Level 4
5.73	Santa Rosa Canal	Nuclear Excavation of a Canal	FL	Plowshare	Level 5
5.74	Santa Rosa Wash Basin	Nuclear Excavation Application	AZ	Plowshare	Level 5
5.75	Savannah River Nuclear Plant Waste Disposal	Nuclear Chimney for Storage of Radioactive Waste	SC	Plowshare	Level 5
3.19	Sergius Narrows	Explosive Studies for Channel Improvement	AK	Plowshare	Level 2
5.76	Shelter Cove Harbor	Nuclear Excavation of a Small Craft Harbor	CA	Plowshare	Level 5
4.36	Shemya Island	Nuclear Harbor Excavation	AK	Plowshare	Level 5
4.37	Sloop	Nuclear Cratering Experiment for Leaching Copper Ore	AZ	Plowshare	Level 4

Table 6.6-1. Alphabetical Listing of Proposed Nuclear Projects, High Explosive Experiments, and High Explosive Construction Activities for the Off-Site Plowshare and Vela Uniform Programs (continued)

<b>Chapter</b>	<b>Name</b>	<b>Description</b>	<b>ST</b>	<b>Program</b>	<b>Activity</b>
5.77	Smackover Formation Oil Stimulation	Nuclear Explosives for Oil Stimulation	MS	Plowshare	Level 5
4.38	South Point Harbor	Nuclear Excavation of a Military Harbor	HI	Plowshare	Level 5
5.78	Southwest Water Reservoirs	Nuclear Craters for Water Reservoirs	No Location Specified	Plowshare	--
4.39	Spiridon Lake	Nuclear Explosives to Construct a Slide Dam	AK	Plowshare	Level 5
5.79	Subway	Nuclear Explosive Test for Canal or Harbor Construction	No Location Specified	Plowshare	--
4.40	Surrey	Isotope Production	LA, TX	Plowshare	Level 5
4.41	Swan Lake Dam	Nuclear Construction of a Rock-Fill Dam	AK	Plowshare	Level 5
5.80	Synthetic Diamond	Nuclear Explosives to Create Diamond Crystals	No Location Specified	Plowshare	--
4.42	Tar	Nuclear Explosive Seismic Monitoring Experiment	MS, TX	Vela Uniform	Level 4
4.43	Tennessee-Tombigbee Waterway	Nuclear Excavation of a Canal	MS	Plowshare	Level 5
3.20	Thunderbird	Nuclear Explosives for Coal Extraction	WY	Plowshare	Level 3
3.21	Travois	Nuclear Quarrying for Dam Construction	CA, ID, OR	Plowshare	Level 3
3.22	Trencher	High Explosive Excavation Experiment	MT	Plowshare	Level 2
3.23	Trinidad	High Explosives for Railroad Construction	CO	Plowshare	Level 2
5.81	Trinity River Canal	Nuclear Explosives for Canal Construction	TX	Plowshare	Level 5
3.24	Tugboat	High Explosive Excavation for Harbor Construction	HI	Plowshare	Level 2

Table 6.6-1. Alphabetical Listing of Proposed Nuclear Projects, High Explosive Experiments, and High Explosive Construction Activities for the Off-Site Plowshare and Vela Uniform Programs (continued)

Chapter	Name	Description	ST	Program	Activity
5.82	U.S. Navy Proposals	Peaceful Applications of Nuclear Explosives for the U.S. Navy	No Location Specified	Plowshare	--
5.83	Upper Midwest Geostorage Facility	Nuclear Chimney for Gas Storage	IA, MN, WI	Plowshare	Level 5
3.25	Utah	Nuclear Explosives to Fracture Oil Shale for Underground Retorting	UT	Plowshare	Level 3
5.84	Vaquero	High Explosive Seismic Monitoring Experiment	LA	Vela Uniform	Level 5
5.85	Vintage	Nuclear Explosives to Fracture Oil Shale	CO	Plowshare	Level 5
5.86	Wagon	Nuclear Cratering Experiment	NV	Plowshare	Level 5
3.26	Wagon Wheel	Nuclear Explosives for Stimulation of Underground Natural Gas Reservoirs	WY	Plowshare	Level 3
3.27	WASP	Nuclear Explosives for Stimulation of Underground Natural Gas Reservoirs	WY	Plowshare	Level 3
5.87	Wenaha Dam	Nuclear Quarrying for Construction of a Dam	WA	Plowshare	Level 5
5.88	West Kentucky Turnpike	Nuclear Explosives for Highway Construction	KY	Plowshare	Level 5
4.44	West Virginia Earthquake	Earthquake Seismic Data	WV	Vela Uniform	Level 4
4.45	Wheelbarrow	Limestone Chemical Experiment for Mining and Petroleum Recovery	WV	Plowshare	Level 5
5.89	White Bird Hill	Nuclear Explosives for Highway Construction	ID	Plowshare	Level 5
4.46	Whitstone Narrows	Nuclear Explosives to Remove Navigation Hazards	AK	Plowshare	Level 5
5.90	Wilkins Dam	Nuclear Explosives to Construct a Dam	AZ	Plowshare	Level 5
5.91	Winnow	Nuclear Explosive Seismic Monitoring Experiment	LA	Vela Uniform	Level 5
5.92	Wisconsin Lakes	Nuclear Explosives to Create Lakes	WI	Plowshare	--
5.93	Wyoming Oil Shale	Nuclear Explosives to Fracture Oil Shale	WY	Plowshare	Level 4

Table 6.6-1. Alphabetical Listing of Proposed Nuclear Projects, High Explosive Experiments, and High Explosive Construction Activities for the Off-Site Plowshare and Vela Uniform Programs (continued)

<b>Chapter</b>	<b>Name</b>	<b>Description</b>	<b>ST</b>	<b>Program</b>	<b>Activity</b>
5.94	Yaquina Bay and Harbor Improvement	Nuclear Explosives for Bay and Harbor Improvement	OR	Plowshare	Level 5
5.95	Young Bay Channel	Nuclear Explosives for Channel Excavation	AK	Plowshare	Level 5
5.96	Yukon River Diversion	Nuclear Explosives to Divert River Channel	AK	Plowshare	Level 5
5.97	Zinc Recovery	Nuclear Explosives for Mining Zinc	MT	Plowshare	Level 5

Table 6.6-2. Listing by State of Proposed Nuclear Projects, High Explosive Experiments, and High Explosive Construction Activities for the Off-Site Plowshare and Vela Uniform Programs

State(s)	Name	Description	Chapter	Program	Activity
Alaska	Alaska Copper Leaching	Nuclear Explosives to Fracture Copper Ore for Underground Chemical Mining	5.2	Plowshare	Level 5
Alaska	Bering Strait	Nuclear Excavation to Deepen Waterway	5.10	Plowshare	Level 5
Alaska	Cape Darby Harbor	Nuclear Excavation of a Harbor	4.6	Plowshare	Level 5
Alaska	Chomly Cutoff	Nuclear Excavation of a Sea-Level Channel	4.8	Plowshare	Level 5
Alaska	Katalla Harbor	Nuclear Construction of a Deep-Water Harbor	4.20	Plowshare	Level 5
Alaska	Nome Harbor	Nuclear Excavation of a Harbor	4.26	Plowshare	Level 5
Alaska	North Slope Harbor	Nuclear Construction of an Offshore Loading Facility	4.27	Plowshare	Level 4
Alaska	Operation Breakup	High Explosive Ice Cratering Experiment	3.10	Plowshare	Level 2
Alaska	Point Barrow Harbor	Nuclear Excavation of a Harbor	4.30	Plowshare	Level 5
Alaska	Port Moller Canal	Nuclear Explosives for Canal Construction	4.31	Plowshare	Level 5
Alaska	Rampart Canyon Dam	Nuclear Excavation for Dam Construction and Quarry	4.32	Plowshare	Level 5
Alaska	Rufus	Surface Detonation of Nuclear Explosives	3.18	Vela Uniform	Level 3
Alaska	Sergius Narrows	Explosive Studies for Channel Improvement	3.19	Plowshare	Level 2
Alaska	Shemya Island	Nuclear Harbor Excavation	4.36	Plowshare	Level 5
Alaska	Spiridon Lake	Nuclear Explosives to Construct a Slide Dam	4.39	Plowshare	Level 5
Alaska	Swan Lake Dam	Nuclear Construction of a Rock-Fill Dam	4.41	Plowshare	Level 5
Alaska	Whitestone Narrows	Nuclear Explosives to Remove Navigation Hazards	4.46	Plowshare	Level 5
Alaska	Young Bay Channel	Nuclear Explosives for Channel Excavation	5.95	Plowshare	Level 5
Alaska	Yukon River Diversion	Nuclear Explosives to Divert River Channel	5.96	Plowshare	Level 5

Table 6.6-2. Listing by State of Proposed Nuclear Projects, High Explosive Experiments, and High Explosive Construction Activities for the Off-Site Plowshare and Vela Uniform Programs (continued)

State(s)	Name	Description	Chapter	Program	Activity
Arizona	Alamo Dam Spillway	Nuclear Excavation for Dam Spillway	5.1	Plowshare	Level 5
Arizona	Aquarius	Nuclear Explosives for Water Management	4.1	Plowshare	Level 4
Arizona	Arizona Aqueduct	Nuclear Explosives for Water Redistribution System	5.7	Plowshare	Level 5
Arizona	Buttes Dam	Nuclear Explosives for Dam Construction and Quarry	5.13	Plowshare	Level 5
Arizona	Buttes Reservoir Copper Recovery	Nuclear Explosives to Fracture Ore Deposits for In Situ Leaching of Copper	5.14	Plowshare	Level 5
Arizona	Cactus Ore Copper Recovery	Nuclear Explosives to Fracture Ore Deposits for In Situ Leaching of Copper	5.15	Plowshare	Level 4
Arizona	Camelsback Dam	Nuclear Excavation of a Spillway and Quarrying for Dam Construction	5.17	Plowshare	Level 5
Arizona	Coconino Dam	Nuclear Explosives to Construct a Slide Dam and Spillway	5.21	Plowshare	Level 5
Arizona	Colorado River Desalinization	Nuclear Craters for Desalinization Plant	5.22	Plowshare	Level 5
Arizona	Newmont Project	Nuclear Explosives to Fracture Copper Ore for Underground Chemical Mining	5.55	Plowshare	Level 4
Arizona	Old Reliable Mine	High Explosives Seismic Study	4.28	Plowshare	Level 4
Arizona	Red Lake Gas Storage	Nuclear Excavation for Underground Gas Storage	4.33	Plowshare	Level 4
Arizona	Santa Rosa Wash Basin	Nuclear Excavation Application	5.74	Plowshare	Level 5
Arizona	Sloop	Nuclear Cratering Experiment for Leaching Copper Ore	4.37	Plowshare	Level 4
Arizona	Wilkins Dam	Nuclear Explosives to Construct a Dam	5.90	Plowshare	Level 5
California	Boca Bypass	Nuclear Excavated Railroad Cut	4.2	Plowshare	Level 5
California	Bo-Peep	Nuclear Explosives for Petroleum Stimulation	4.3	Plowshare	Level 5

Table 6.6-2. Listing by State of Proposed Nuclear Projects, High Explosive Experiments, and High Explosive Construction Activities for the Off-Site Plowshare and Vela Uniform Programs (continued)

State(s)	Name	Description	Chapter	Program	Activity
California	Buchanan Dam	Nuclear Quarrying for Dam Construction	5.11	Plowshare	Level 5
California	Butler Valley Dam	Nuclear Quarrying for Dam Construction	5.12	Plowshare	Level 5
California	California Water Plan	Nuclear Explosives for Water Management Project	5.16	Plowshare	Level 5
California	Carmel-San Simeon Harbor	Nuclear Excavation of a Harbor	5.19	Plowshare	Level 5
California	Carryall	Nuclear Explosives Proposed for Highway and Railroad Construction	4.7	Plowshare	Level 4
California	El Centro Canal	Nuclear Explosives for Canal Excavation	5.28	Plowshare	Level 5
California	Etsel Dam	Nuclear Quarrying for Construction of a Dam	5.29	Plowshare	Level 5
California	Feather River Project	Nuclear Explosives for Water Redistribution	5.32	Plowshare	Level 5
California	Lake Tahoe Sewage	Nuclear Chimneys for Sewage Disposal	4.23	Plowshare	Level 5
California	Livermore Valley Sewage Disposal	Nuclear Chimneys for Sewage Disposal	5.45	Plowshare	Level 5
California	Modesto Waste Disposal	Nuclear Chimneys for Sewage Disposal	5.49	Plowshare	Level 5
California	San Clemente Island	Development of Underground Aquifer Using Nuclear Explosives	4.34	Plowshare	Level 4
California	San Diego - Imperial Valley Interstate/ Laguna Mountains Highway	Nuclear Explosives for Highway Construction	5.70	Plowshare	Level 5
California	San Luis Dam	Nuclear Quarrying for Construction of a Dam	5.71	Plowshare	Level 5
California	Santa Barbara Channel Oil Leakage	Nuclear Explosives to Control Oil Leakage	5.72	Plowshare	Level 4
California	Shelter Cove Harbor	Nuclear Excavation of a Small Craft Harbor	5.76	Plowshare	Level 5
Colorado	Argo Tunnel	Possible Location for Nuclear Explosive Experiments	5.6	Plowshare	Level 5



Table 6.6-2. Listing by State of Proposed Nuclear Projects, High Explosive Experiments, and High Explosive Construction Activities for the Off-Site Plowshare and Vela Uniform Programs (continued)

State(s)	Name	Description	Chapter	Program	Activity
Colorado	Bronco	Nuclear Explosives for Fracturing Shale Underground	3.1	Plowshare	Level 3
Colorado	Colona Earthquake	Earthquake Seismic Data	4.10	Vela Uniform	Level 4
Colorado	Dragon Trail	Nuclear Explosives for Gas Stimulation	3.4	Plowshare	Level 3
Colorado	Molybdenite Recovery	Nuclear Explosives for Molybdenite Mining	5.50	Plowshare	Level 5
Colorado	Pinot	High Explosives for Oil Shale Stimulation Research	3.11	Plowshare	Level 1
Colorado	Pre-Vintage	High Explosive Tests	5.62	Plowshare	Level 5
Colorado	Red Mountain Mineral Extraction	Nuclear Mining Application	5.67	Plowshare	Level 5
Colorado	Trinidad	High Explosives for Railroad Construction	3.23	Plowshare	Level 2
Colorado	Vintage	Nuclear Explosives to Fracture Oil Shale	5.85	Plowshare	Level 5
Florida	Santa Rosa Canal	Nuclear Excavation of a Canal	5.73	Plowshare	Level 5
Hawaii	Hawaii Harbor for Inter-Island Ferries	Nuclear Excavated Harbor	5.36	Plowshare	Level 5
Hawaii	Honokahau Small Craft Harbor	Nuclear Excavated Harbor	5.37	Plowshare	Level 5
Hawaii	Iki	Geothermal Energy Experiment	3.7	Plowshare	Level 3
Hawaii	Kaalualu Harbor	High Explosive Cratering Tests for Small Craft Harbor	5.40	Plowshare	Level 5
Hawaii	Kaunakakai Harbor	Nuclear Harbor Excavation Experiment	4.21	Plowshare	Level 5
Hawaii	South Point Harbor	Nuclear Excavation of a Military Harbor	4.38	Plowshare	Level 5
Hawaii	Tugboat	High Explosive Excavation for Harbor Construction	3.24	Plowshare	Level 2
Idaho	Bruneau Canyon Dam	Nuclear Explosives for Ejecta Dam Construction	4.4	Plowshare	Level 5

Table 6.6-2. Listing by State of Proposed Nuclear Projects, High Explosive Experiments, and High Explosive Construction Activities for the Off-Site Plowshare and Vela Uniform Programs (continued)

State(s)	Name	Description	Chapter	Program	Activity
Idaho	Excavator	High Explosive Calibration Experiment	3.6	Plowshare	Level 3
Idaho	Galley	Row Charge Nuclear Cratering Experiment	4.14	Plowshare	Level 5
Idaho	Garden Valley Dam	Nuclear Explosives for Construction of a Slide Dam	5.33	Plowshare	Level 5
Idaho	Idaho Phosphates	Use of Nuclear Explosives to Mine Phosphates	5.38	Plowshare	Level 5
Idaho	Pre-Schooner II	High Explosive Cratering Experiment	3.16	Plowshare	Level 2
Idaho	White Bird Hill	Nuclear Explosives for Highway Construction	5.89	Plowshare	Level 5
Illinois	Saline River Canal	Nuclear Excavation of a Canal	5.69	Plowshare	Level 5
Kentucky	Appalachian Gas Storage	Nuclear Chimney for Underground Gas Storage	5.5	Plowshare	Level 5
Kentucky	Laurel River Dam	Nuclear Quarrying for a Rock-Fill Dam	5.44	Plowshare	Level 5
Kentucky	West Kentucky Turnpike	Nuclear Explosives for Highway Construction	5.88	Plowshare	Level 5
Louisiana	Caddo Pine Island	High Explosives Experiment for Oil Stimulation	4.5	Plowshare	Level 5
Louisiana	Cowboy	High Explosive Seismic Monitoring Experiment	3.3	Vela Uniform	Level 2
Louisiana	Plowboy	High Explosives Salt Fracture Research	3.12	Plowshare	Level 3
Louisiana	Vaquero	High Explosive Seismic Monitoring Experiment	5.84	Vela Uniform	Level 5
Louisiana	Winnow	Nuclear Explosive Seismic Monitoring Experiment	5.91	Vela Uniform	Level 5
Massachusetts	Cape Cod Canal	Nuclear Explosives to Dredge a Channel	5.18	Plowshare	Level 5
Mississippi	Payette	Construction of a Cavity for a Nuclear Mining Experiment	5.59	Vela Uniform	Level 4
Mississippi	Pre-Dribble	High Explosives Seismic Effects Research	3.13	Vela Uniform	Level 2
Mississippi	Smackover Formation Oil Stimulation	Nuclear Explosives for Oil Stimulation	5.77	Plowshare	Level 5

Table 6.6-2. Listing by State of Proposed Nuclear Projects, High Explosive Experiments, and High Explosive Construction Activities for the Off-Site Plowshare and Vela Uniform Programs (continued)

State(s)	Name	Description	Chapter	Program	Activity
Mississippi	Tennessee-Tombigbee Waterway	Nuclear Excavation of a Canal	4.43	Plowshare	Level 5
Missouri	New Madrid Earthquake	Earthquake Seismic Data	4.25	Vela Uniform	Level 4
Montana	Hebgen Lake Earthquake	Earthquake Seismic Data	4.19	Vela Uniform	Level 4
Montana	Libby	High Explosive Experiment for a Highway Cut	3.8	Plowshare	Level 2
Montana	Missouri River Reservoir	Nuclear Excavation for Reservoir Project	5.48	Plowshare	Level 5
Montana	Montana Silver Retarc	Nuclear Explosives for Silver Mining	5.51	Plowshare	Level 5
Montana	Pre-Gondola	High Explosives for Waterway Construction	3.15	Plowshare	Level 2
Montana	Trencher	High Explosive Excavation Experiment	3.22	Plowshare	Level 2
Montana	Zinc Recovery	Nuclear Explosives for Mining Zinc	5.97	Plowshare	Level 5
Nevada	Wagon	Nuclear Cratering Experiment	5.86	Plowshare	Level 5
New Mexico	Cochiti Dam	Nuclear Quarrying for Construction of a Dam	4.9	Plowshare	Level 4
New Mexico	Copper Flat	Nuclear Explosives to Fracture Ore for In Situ Leaching Copper	5.24	Plowshare	Level 4
New Mexico	Pre-Gnome	High Explosives Seismic Experiment	3.14	Plowshare	Level 2
New York	Lake Erie - Lake Ontario Waterway	Nuclear Explosives to Construct a Waterway	5.42	Plowshare	Level 5
New York	New York Plateau Excavation	Nuclear Excavation of a Rock Plateau	5.54	Plowshare	Level 5
North Carolina	Drum Inlet	High Explosives for Channel Excavation	3.5	Plowshare	Level 2
Ohio	Lake Erie – Ohio River Canal	Nuclear Explosives to Excavate a Canal	5.43	Plowshare	Level 5
Oregon	Catherine Creek	High Explosive Calibration Study and Nuclear Quarrying for Dam Construction	5.20	Plowshare	Level 5

Table 6.6-2. Listing by State of Proposed Nuclear Projects, High Explosive Experiments, and High Explosive Construction Activities for the Off-Site Plowshare and Vela Uniform Programs (continued)

State(s)	Name	Description	Chapter	Program	Activity
Oregon	Columbia River Delta Clearance	Nuclear Explosives to Clear a Delta	5.23	Plowshare	Level 5
Oregon	John Day River	Nuclear Construction of a Slide Dam	5.39	Plowshare	Level 5
Oregon	Lost Creek	High Explosive Experimental Mounding and Controlled Blasting Series	3.9	Plowshare	Level 2
Oregon	Yaquina Bay and Harbor Improvement	Nuclear Explosives for Bay and Harbor Improvement	5.94	Plowshare	Level 5
Pennsylvania	Ketch	Nuclear Explosives for Underground Natural Gas Storage	4.22	Plowshare	Level 4
South Carolina	Savannah River Nuclear Plant Waste Disposal	Nuclear Chimney for Storage of Radioactive Waste	5.75	Plowshare	Level 5
Texas	Keetch Plan for Water Conservation	Nuclear Explosives for Water Storage System	5.41	Plowshare	Level 5
Texas	Raymondville Harbor	Nuclear Explosives to Remove a Sandbar	5.66	Plowshare	Level 5
Texas	Trinity River Canal	Nuclear Explosives for Canal Construction	5.81	Plowshare	Level 5
Utah	Utah	Nuclear Explosives to Fracture Oil Shale for Underground Retorting	3.25	Plowshare	Level 3
Vermont	Mt. Snow	Nuclear Excavation of Mountainside	5.53	Plowshare	Level 5
Washington	Wenaha Dam	Nuclear Quarrying for Construction of a Dam	5.87	Plowshare	Level 5
West Virginia	Earth Furnace	Nuclear Explosives to Develop Mineral Resources	5.27	Plowshare	Level 5
West Virginia	Experiment	Nuclear Industrial Plowshare Experiment	5.30	Plowshare	Level 5
West Virginia	Megawatt	Underground Nuclear Explosions for Power Generation	5.47	Plowshare	Level 5
West Virginia	Mountain Lake	Nuclear Explosives for Water Resource Development	5.52	Plowshare	Level 5

Table 6.6-2. Listing by State of Proposed Nuclear Projects, High Explosive Experiments, and High Explosive Construction Activities for the Off-Site Plowshare and Vela Uniform Programs (continued)

State(s)	Name	Description	Chapter	Program	Activity
West Virginia	R. D. Bailey	High Explosive Experiment for Dam Spillway Excavation	3.17	Plowshare	Level 2
West Virginia	West Virginia Earthquake	Earthquake Seismic Data	4.44	Vela Uniform	Level 4
West Virginia	Wheelbarrow	Limestone Chemical Experiment for Mining and Petroleum Recovery	4.45	Plowshare	Level 5
Wisconsin	Wisconsin Lakes	Nuclear Explosives to Create Lakes	5.92	Plowshare	--
Wyoming	Gas Hills Uranium Mine	Nuclear Explosives to Mine Uranium	5.34	Plowshare	Level 5
Wyoming	Thunderbird	Nuclear Explosives for Coal Extraction	3.20	Plowshare	Level 3
Wyoming	Wagon Wheel	Nuclear Explosives for Stimulation of Underground Natural Gas Reservoirs	3.26	Plowshare	Level 3
Wyoming	WASP	Nuclear Explosives for Stimulation of Underground Natural Gas Reservoirs	3.27	Plowshare	Level 3
Wyoming	Wyoming Oil Shale	Nuclear Explosives to Fracture Oil Shale	5.93	Plowshare	Level 4
Alabama, Colorado, Louisiana, Mississippi, New Mexico, Texas, Utah	Nuclear Explosive Power Generation	Underground Nuclear Explosions for Power Generation	5.56	Plowshare	Level 5
Alaska, Arizona, California, Colorado, Idaho, Illinois, Michigan, Minnesota, Montana, North Dakota, New Mexico, Nevada, Oregon, South Dakota, Washington	NAWAPA	Nuclear Explosives for Construction of a Water Containment and Distribution System	4.24	Plowshare	Level 5

Table 6.6-2. Listing by State of Proposed Nuclear Projects, High Explosive Experiments, and High Explosive Construction Activities for the Off-Site Plowshare and Vela Uniform Programs (continued)

State(s)	Name	Description	Chapter	Program	Activity
Alaska, Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, Wyoming	Geothermal Power Plant	Nuclear Explosives for Geothermal Power	4.15	Plowshare	Level 5
Alaska, Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, Washington	Copper Ore Chemical Mining	Nuclear Explosives to Mine Primary Copper Ore Deposits	4.11	Plowshare	Level 5
Alaska, Arizona, California, Colorado, Idaho, Nevada, New Hampshire, New Mexico, Texas, Utah, Virginia, Washington, Wyoming	Copper Recovery	Nuclear Explosives for Fracturing Copper Ore Deposits for In Situ Leaching	4.12	Plowshare	Level 4
Alaska, California, Nevada	Phaeton	Nuclear Excavation	4.29	Plowshare	Level 5
Alaska, California, Virginia	CHASE	High Explosive Long Range Seismic Monitoring Experiments	3.2	Vela Uniform	Level 2
Alaska, Wyoming	Gold Leaching	Nuclear Explosives to Fracture Ore for In Situ Leaching of Gold	4.16	Plowshare	Level 5
Arizona, Utah	Dogsled	Nuclear Cratering Experiment in Sandstone	4.13	Plowshare	Level 4
Arizona, Utah	Pre-Dogsled	High Explosive Cratering Experiment	5.61	Plowshare	Level 5
California, Idaho, Oregon	Travois	Nuclear Quarrying for Dam Construction	3.21	Plowshare	Level 3

Table 6.6-2. Listing by State of Proposed Nuclear Projects, High Explosive Experiments, and High Explosive Construction Activities for the Off-Site Plowshare and Vela Uniform Programs (continued)

State(s)	Name	Description	Chapter	Program	Activity
California, Nevada, New Mexico, Montana, Louisiana, Michigan, Mississippi	Groundhog	High Explosive Seismic Monitoring Experiment	4.18	Vela Uniform	Level 5
Georgia, North Carolina	Magnesium Recovery	Nuclear Explosives for Mining Magnesium	5.46	Plowshare	Level 5
Idaho, Washington	Pumped Storage Reservoirs	Nuclear Excavation of Storage Reservoirs	5.63	Plowshare	Level 5
Iowa, Minnesota, Wisconsin	Upper Midwest Geostorage Facility	Nuclear Chimney for Gas Storage	5.83	Plowshare	Level 5
Louisiana, Texas	Surrey	Isotope Production	4.40	Plowshare	Level 5
Mississippi, Texas	Sand	Nuclear Explosive Seismic Monitoring Experiment	4.35	Vela Uniform	Level 4
Mississippi, Texas	Tar	Nuclear Explosive Seismic Monitoring Experiment	4.42	Vela Uniform	Level 4
Montana, Nevada, South Dakota	Gondola	Nuclear Cratering Experiment	4.17	Plowshare	Level 5
Multiple Locations	Anderson Proposals	Suggested Nuclear Excavation Applications	5.4	Plowshare	Level 5
Multiple Locations	Cross-Continent Barge Canal	Nuclear Excavation for Canal Construction	5.25	Plowshare	Level 5
Multiple Locations	Hansom	Nuclear Explosives in Rock Breaking Applications	5.35	Plowshare	--
Guam	Offshore Fuel Oil Storage	Nuclear Chimneys for Undersea Storage of Fuel Oil	5.57	Plowshare	Level 5
No Location Specified	Ammonia Production	Nuclear Explosives in Geothermal Formations for Synthesizing Ammonia	5.3	Plowshare	--
No Location Specified	Atlantic Gas Storage	Nuclear Chimney for Gas Storage	5.8	Plowshare	--
No Location Specified	Basalt Fracturing	Nuclear Explosives to Pulverize Basalt	5.9	Plowshare	--
No Location Specified	Dow Chemical Proposals	Various Plowshare Applications	5.26	Plowshare	--

Table 6.6-2. Listing by State of Proposed Nuclear Projects, High Explosive Experiments, and High Explosive Construction Activities for the Off-Site Plowshare and Vela Uniform Programs (continued)

<b>State(s)</b>	<b>Name</b>	<b>Description</b>	<b>Chapter</b>	<b>Program</b>	<b>Activity</b>
No Location Specified	Fault Lines	Nuclear Explosives to Relieve Stress along Fault Lines	5.31	Plowshare	--
No Location Specified	PACER	Underground Nuclear Explosions for Power Generation	5.58	Plowshare	--
No Location Specified	Plowshare Emergency Capability Program	Nuclear Explosives for Use in National and World Emergencies	5.60	Plowshare	--
No Location Specified	Radio Telescope Facility	Nuclear Explosive to Create Crater for Radio Telescope Facility	5.64	Plowshare	--
No Location Specified	Radioactive Waste Disposal	Nuclear Chimney for Radioactive Waste Disposal	5.65	Plowshare	--
No Location Specified	Runaway Gas or Oil Wells	Nuclear Explosives to Shut Off a Gas or Oil Well	5.68	Plowshare	--
No Location Specified	Southwest Water Reservoirs	Nuclear Craters for Water Reservoirs	5.78	Plowshare	--
No Location Specified	Subway	Nuclear Explosive Test for Canal or Harbor Construction	5.79	Plowshare	--
No Location Specified	Synthetic Diamond	Nuclear Explosives to Create Diamond Crystals	5.80	Plowshare	--
No Location Specified	U.S. Navy Proposals	Peaceful Applications of Nuclear Explosives for the U.S. Navy	5.82	Plowshare	--