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Preliminary Feasibility Study

**Injection of
Radioactive Waste by
Hydraulic Fracturing at
West Valley, New York**

Volume 1 - Executive Summary

MAY 1978

by
Acres American Incorporated
Buffalo, New York
in association with
Terra Tek Incorporated
Salt Lake City, Utah

Argonne National Laboratory

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**INJECTION OF
RADIOACTIVE WASTE BY
HYDRAULIC FRACTURING AT
WEST VALLEY, NEW YORK**

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The information in this document, prepared in support of a study concerning the Western New York Nuclear Service Center, does not present all the data from which conclusions were drawn. The report, TID-28905, Vols. 1 & 2, Western New York Nuclear Service Center Study, was prepared after reviewing and evaluating this and other studies.

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EXECUTIVE SUMMARY

1 - INTRODUCTION

This report presents the results of a preliminary study, undertaken by Acres American Incorporated, of the technical feasibility of the disposal of radioactive waste by hydraulic fracturing and injection into shale formations below the West Valley, New York site. The waste to be disposed of comprises approximately 600,000 gallons of high level neutralized Purex waste, including both the supernate (liquid) and sludge and a further 12,000 gallons of acidic Thorex waste, currently stored in tanks at the West Valley facility. The study has assessed the possibility of incorporating these wastes in a suitable grout mixture and injecting it into deep shale formations beneath the West Valley site as a means of permanent disposal.

In the hydraulic fracturing and injection process the liquid waste would be diluted, and mixed with cement, clay and other additives to form a stable solid matrix after injection. The waste could be injected into the shale beds, 800 to 1,500 feet below the existing site in zones suitable for horizontal fracturing and to provide satisfactory long term isolation.

Hydraulic fracturing of rock is commonly used by the oil and gas industry to improve the yield of reservoirs; the technique involves the injection of water and sand at high pressure to crack the rock (hydraulic fracture). The injected sand "props" the fractures open after the pressure is reduced allowing an increased flow of oil or gas to the well. Hydraulic fracturing has been in use for the disposal of radioactive waste at Oak Ridge National Laboratory (ORNL), Tennessee since the mid 1960's. To date, over 1.8 million gallons of grout containing radioactive waste have been successfully injected at that site.

The basic requirements for satisfactory disposal of radioactive waste by hydraulic fracturing are:

1. The site should be in a stable geological area with extensive successions of impermeable or nearly impermeable rock above and below the injected horizons.
2. The site should have rock and in situ stress conditions such that fractures can be formed horizontally and can be controlled in extent.
3. There should be no significant possibility of transport of radionuclides to the biosphere in concentrations that could adversely affect health and safety.

4. The design and operation of a hydraulic fracturing waste disposal facility should utilize proven technology.

In this study the West Valley site has been assessed in terms of the above requirements on the basis of currently available information. A program of research and development, required to confirm or reject this means of disposal at the West Valley site, has been outlined.

2 - REQUIREMENT 1: STABLE GEOLOGICAL AREA WITH IMPERMEABLE ROCK

West Valley lies approximately 30 miles SSE of Buffalo, New York in the north central portion of Cattaraugus County (see Figure 1). The town of West Valley is at an approximate elevation of 1,500 feet. Geologically, the West Valley site lies within the Appalachian Basin. Although the basin has undergone a number of complex orogenic and tectonic events since the Precambrian era (approximately 600 million years ago), the western part of the basin, which includes the West Valley site, has experienced only minor structural deformation.

Since the early Mesozoic era (270 million years ago), the Western New York region has remained stable with only minor crustal uplift and subsidence.

The West Valley site is underlain by up to 5,000 feet of relatively undeformed Paleozoic age sedimentary carbonates, sandstones, shales and evaporites which dip 1 to 2 degrees to the south. The upper 2,000 to 3,000 feet of rock is predominantly shales, sandstones and siltstones. A continuous boring drilled to over 1,500 feet in depth at West Valley during an early hydraulic fracturing test program conducted by the United States Geologic Society showed a thick series of impermeable shales.

A seismic refraction survey and borings done by others in the vicinity of the site show a preglacial buried valley cut in to the bedrock surface of the eastern and northeastern parts of the site. This valley is filled with up to 550 feet of glacially derived silts, clays and sands and extends to at least 350 feet below the present level of Buttermilk Creek (Figures 2 and 3).

The nearest mapped fault to the site is the Clarendon-Linden fault approximately 25 to 30 miles east of the site. This fault considered a major tectonic feature in Western New York, trends north-south for over 60 miles from Lake Ontario to the New York - Pennsylvania border. Based on stratigraphic offsets of subsurface units, the last movement along this fault appears to be younger than the most recent rock units in the area (post middle Devonian, 370 million years ago).

Seismic records of the Western New York area show a high frequency of occurrence of earthquakes in close proximity to the Clarendon-Linden fault. The intensity of these earthquakes range from microseismic events to the 1929 intensity VIII Attica earthquake. With the exception of these

localized occurrences, the natural seismicity in Western New York as a whole, appears to be low to moderate.

Drilling for natural gas has been extensive throughout Western New York. Gas drilling is most active west of West Valley in Chataugua County and along the shores of Lake Ontario: the primary producing unit is the Medina Group, a series of Lower Silurian shales, sandstones and siltstones. This unit, which lies approximately 3,500 feet below the West Valley site is capped by a thick series of Middle and Upper Silurian shales and carbonates of the Clinton and Lockport Groups; these in turn are overlain by the evaporite series of the Salina Group. Although West Valley is not considered a high gas production area, the actual gas resources of this area are currently unknown. Recent electric and geophysical logging performed in wells in Chautauga and Cattaraugus Counties have shown gas flows and/or porous zones within the Upper Devonian Shales. It is understood that a proposal has been submitted by a Western New York gas company to the New York State ERDA, to massively hydrofracture the Upper Devonian Shales in Chautauga County for gas production. If this scheme is accepted and proves feasible then additional hydrofracturing of the Devonian Shales might be performed throughout the area possibly also including Cattaraugus County.

In summary, the West Valley area was found to be geologically stable with a thick series of impermeable or nearly impermeable shales extending to several thousand feet in depth. Aspects requiring further investigation and/or resolution are:

- (1) Accurate definition of the extent and composition of the buried valley along the east and northeast portions of the site.
- (2) More accurate definition of the stratigraphic horizons for potential waste injection.
- (3) Assessment of the oil and gas potential in proximity to the site and, if required, defining necessary exclusion areas.

The above tasks are included in the general development program presented in Section 6.

3 - REQUIREMENT 2: THE ACHIEVEMENT OF CONTROLLED HORIZONTAL HYDRAULIC FRACTURES

For the purpose of injection of radioactive waste, it must be shown that any induced fractures initiate and propagate essentially horizontally since vertical fractures could provide potential leakage paths to the surface. The areal extent of the induced fracture and the waste contained within it should be controllable and remote from significant groundwater flow paths or possible drilling sites and mines.

The initiation of a fracture in a horizontal direction at the borehole can be ensured with the use of downhole jet cutting equipment.

The propagation direction and orientation of hydraulic fracturing is controlled principally by two factors; the presence of directions of weakness in the rock such as, joints or bedding planes, and the in situ state of stress of the rock at the injection depth. These factors were assessed using fracture mechanics theories, presently available site data and preliminary fracture toughness test data. Since the theory of hydraulic fracturing is still under development, two analytical approaches were used to provide a basis for confidence in the predictions of crack propagation direction. These were classical solutions for isotropic material properties and a finite element, linear elastic fracture mechanics computer program for anisotropic materials. These were used to compare results for various fracture criteria and for parametric studies of input data.

For the purpose of this study, two stratigraphic horizons (850 and 1,250 feet below ground surface) were chosen for the analysis to confirm the preference for horizontal hydrofracturing. These horizons were selected after a review of the physical description of the previous drillhole cores and the associated electric and geophysical logging.

In order to provide site specific data on fracture toughness, laboratory tests were made on shale samples collected from the drilled core. The tests on the shale were made both along and across the bedding surface. The tests showed a strong preference for fracturing parallel to the bedding planes.

Generally, a higher horizontal stress (due to regional tectonic pressures) than vertical stress (pressure from the overlying rocks) will also give a preference for horizontal propagation.

In situ stress measurements have not been performed at West Valley and therefore, the in situ stress parameters used for the analyses were based on a review of stress measurements in the general region. This data from northeast and north-central United States and southeast Canada showed that although the magnitude of the stresses vary, the horizontal stress is generally higher than the vertical stress to the depths of interest.

The ranges of horizontal stresses considered were 1,500 to 2,000 psi at both 850 and 1,250 feet and the vertical stresses were 935 and 1,375 psi respectively.

The results of the analyses at the 850 and 1,250 horizons showed that, once horizontal fractures had been initiated by jetting, then the fracture would certainly propagate horizontally. This conclusion was shown to be essentially independent of the particular fracture theory and material properties for the range of in situ stresses considered. The existence of horizontal bedding planes gives extra confidence in this conclusion.

The total volume of injected grout was estimated to be approximately 3 million gallons. Several schemes to determine the radial extent of injection(s) for single and multiple levels were assessed for West Valley. It was found that any combination of multiple fracture and injection at both levels (850 to 1,250 feet) was feasible and would result in a grout sheet located within a radius of 1,200 to 2,000 feet from the injection well.

In conclusion, although the analyses confirmed that controlled horizontal fracturing would be achieved at West Valley, further sampling and testing of the West Valley rock must be performed as part of the general development and verification program discussed in Section 6. As part of that general program studies must:

- (1) define actual injection horizons,
- (2) obtain site specific rock properties, and
- (3) define the in situ stresses at the injection horizons.

4 - REQUIREMENT 3: NO TRANSPORT OF RADIONUCLIDES
FROM THE GROUT SHEET TO THE
BIOSPHERE IN CONCENTRATIONS
THAT COULD ADVERSELY AFFECT
HEALTH AND SAFETY

The isolation of nuclides in shale beds following grout injection requires:

- slow leach rates of radionuclides from the grout,
- very slow groundwater movement,
- retardation (retention) of radionuclides within the shale.

The rate of release of radionuclides is determined by the leach rates of the nuclides from the grout. Subsequently the extent of the transport of the radionuclides is substantially limited by slow groundwater movement and retardation within the shale. Consequently, these three processes provide almost independent mechanisms for containment of radionuclides.

The leach rates of various radionuclides from grout have been measured in the laboratory at Oak Ridge National Laboratory (ORNL). It was found that a satisfactory grout mix with a low leach rate can be developed using readily available materials comprising cement, clay, fly ash and additives.

In the current study, groundwater movement in the bedrock at the West Valley site has been simulated using a generalized cross section computerized finite element water flow model. Modeled permeability and porosity values were based on data for similar rock types in Northwestern New York State. These analyses have shown that, as expected, groundwater movement around the grout sheet would be extremely slow with groundwater passing the injection zone flowing towards Buttermilk Creek (Figure 3).

Retardation of any leached radionuclides relative to the groundwater velocity will occur in the shale due to adsorption and ion-exchange effects with the fine grained mineral constituents. The degree of retardation will depend upon the radionuclide, the groundwater chemistry and the mineral composition of the shales, but is expected to be very significant.

Additional data about the groundwater regime and rock mass permeability will be required to accurately define the groundwater flow as affected by the buried valley at the site.

Other factors that may potentially affect the groundwater flow, such as domestic and industrial use and hydrofracturing for gas and oil production must also be assessed. In addition, laboratory tests to develop a grout mix suitable for the West Valley waste and to define the retardation characteristics of the shale bedrock at the injection horizon will be required. The extent and time requirements for an exclusion zone to prevent drilling for water, oil and gas or other minerals must also be determined.

5 - REQUIREMENT 4: PROVEN TECHNOLOGY IS
AVAILABLE FOR THE DESIGN
AND OPERATION OF A HY-
DRAULIC DISPOSAL FACILITY

The technology for the design and operation of a hydraulic fracturing waste disposal facility has been developed at ORNL where a successful fracturing facility has been in operation since the mid 1960's. A new fracture facility has been designed and is presently under construction at ORNL to inject an additional 14 million gallons of intermediate radioactive waste material.

These facilities have been approved for the storage, mixing and injection of waste material. The technology used at ORNL is directly applicable for a West Valley facility. Although the particular case of an injection facility at West Valley would have to be evaluated for its safety and environmental impacts, the actual injection process does not require a state-of-the-art design and evaluation.

Once a detailed design concept has been developed for West Valley, accident scenarios, such as waste pipe rupture, well head rupture, surface breakout of radioactive grout mix, and backup equipment and safety procedures can be examined within the context of the work done at ORNL.

In summary, the design, and operation of a hydrofracture facility at West Valley is readily achievable with current technology and experience.

6 - CONCLUSIONS AND RECOMMENDED RESEARCH AND DEVELOPMENT PROGRAM

This preliminary study yields the following general technical conclusions for hydraulic fracturing and injection of radioactive waste at West Valley:

- (1) The theoretical analyses using the limited site data presently available and a review of the previous West Valley hydraulic fracturing test indicate that horizontal fracturing can be achieved in the shale beds at the depths of 850 and 1,250 feet.
- (2) Multiple injections will probably be required at the selected horizon(s). The areal extent of the grout sheets is likely to be a radius of 600 to 1,000 feet from the injection points. The quantity of the waste/grout mixture to be injected has been estimated at 3 million gallons.
- (3) The deep shales have low permeability and hence, probably very low groundwater velocity which offers excellent isolation properties for the retention of injected radionuclides.
- (4) The technology of hydraulic fracturing and injection of liquid radioactive wastes and the design of a suitable grout mix has been proven at ORNL and is applicable to the waste at West Valley.
- (5) The principal sources of uncertainty regarding the extent and orientation of fractures and overall isolation, are the general in situ stress field and the effects of the buried valley on the east side of the site which may cause changes in the local stress field and influence groundwater flow patterns.

In summary, it appears from a technical standpoint, the concept of hydraulic fracturing and injection of radioactive waste material is feasible at West Valley. A detailed site investigation, laboratory and analysis program will be required to confirm the safety of the concept using site specific data. Other factors to be resolved include the potential conflicts with gas and water supply interest.

A generalized seven phase development program through to injection and facility decommissioning is presented in Figure 4. The proposed program assumes that a period of approximately five years is available prior to completion of the injection program. The program is an orderly development

with minimal financial and safety risks applying previously proven techniques, largely based on ORNL operation. The principal phases of this program are:

Phase 1 - Prefeasibility Studies (FY78)

Objective - Determination of the general feasibility of the West Valley area for hydraulic fracturing for injection based on general data and experience elsewhere to a level of detail and reliability for overall program planning.

Duration - 9 months.

Cost - \$60,000.

Phase 2 - Research and Development (FY79)

Objective - Field, laboratory and analytical studies, to confirm the feasibility of the concept using site specific data and provide the information required for design and location of the proof test and injection facility.

Duration - 12 months.

Cost - \$1,000,000 approximately.

Phase 3 - Proof Test and Design (FY80)

Objective - A hydraulic fracturing and grout injection test in the designated facility configuration to verify the acceptability of the facility location and injection operations. Preparation of the detailed design for the production injection facility, and its decommissioning including bid packages. The test is scheduled for warm weather operation.

Duration - 12 months.

Cost - \$1,000,000 approximately.

Phase 4 - Licencing

Objective - Obtain licence from regulatory agencies for handling and injection of radioactive materials based on PSAR, EIS, etc. The requirements for licencing have not been clearly defined at this stage and consequently, this phase will be subject to major review.

Duration - Unknown (assumed 20 months in the program).

Cost - \$250,000 (unsubstantiated estimate).

Phase 5 - Injection Facility Construction

Objective - To assemble the necessary batch storage tanks, pumps, piping, grout and water supplies, standby facilities, operating crews, training and general preparation prior to FSAR and production injection.

Duration - 9 months (depends on mobilization time and awaits spring season).

Cost - See Supplement 1.

Phase 6 - Injection Operation

Objective - Injection of 630,000 gallons of waste in a grout mixture involving a total injection volume of approximately 3 million gallons.

Duration - Two summer seasons. This schedule is based on the injection of approximately 200,000 gallon batches at monthly intervals. This schedule is based on the ORNL schedule for the new facility. It may prove possible to compress this schedule to a more continuous type of operation at West Valley. However, in order to provide a conservative basis for planning, the proven ORNL schedule is suggested.

Cost - See Supplement 1.

Phase 7 - Decommissioning

Objective - To restore the surface site to as close as possible to its initial state in requiring only minimal monitoring and security. This will involve disposal of pumps, tanks and other surface equipment together with sealing of drilling tubes.

Duration - 9 months (approximately, but this may be coordinated with other site decommissioning activities).

Cost - \$500,000 (unsubstantiated).

The phases in which time could possibly be saved if necessary are, Phase 4 - Licencing, depending on regulatory requirements; Phase 5 - Construction, if this was to be carried out in parallel with the proof test; Phase 6 - Injection, if a more continuous injection program could be justified. If all of these compressions could be made thus it may be possible to complete injection and decommissioning by early 1982, a saving of two years off the basic program.

The cost estimates are based on general consulting and contractor rates applicable in spring 1978. The prices are not firm quotations or offers of services, but are intended for planning purposes only.

FIGURES

FIG. 1

FIG. 2

PLAN OF SITE AREA

FIG. 3

PREGLACIAL BURIED VALLEY

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PROPOSED HIGH - LEVEL RADIOACTIVE WASTE INJECTION PROGRAM
AT WEST VALLEY , NEW YORK

FIG. 4