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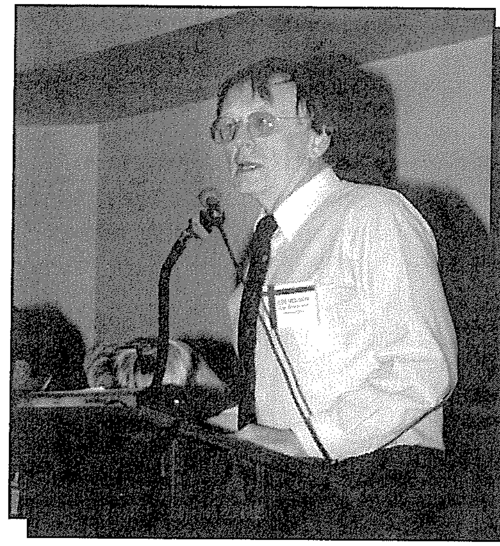

Lee Esparza is a 1972 graduate of the University of New Mexico with a bachelor's degree in geology. He has done graduate study at the University of Wyoming, Eastern Washington University and the University of Minnesota. He has been with the federal government since 1973 working for the Atomic Energy Commission, Department of Energy, Bureau of Mines and presently at the Bureau of Reclamation. Lee currently is the project director for the Lake Meredith Salinity Control Project. He is a Society of Economic Geologists Fellow.

LAKE MEREDITH SALINITY CONTROL PROJECT

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ABSTRACT

The U.S. Bureau of Reclamation and the Canadian River Municipal Water Authority (CRMWA) are completing the final engineering design for reducing chloride concentration in the Canadian River before it enters Lake Meredith. The lake, located north of Amarillo, Texas, is a major source for municipal and industrial water for eleven Texas High Plain communities with a combined population of about 500,000 people. Those communities are members of the CRMWA.

The lake was designed to yield 103,000 acre-feet per year of acceptable quality water but in practice has a firm yield of only 76,000 acre-feet per year, with chloride levels typically 350-450 mg/l. The elevated chlorides are caused by inflow of natural brines, most notably near Logan, New Mexico where about 0.7 cfs of brine contributes about 0.45 kg/second of chloride.

Early studies suggested that the brine originates from dissolution of Permian salt deposits and flows upward to the river from an artesian "brine aquifer" in the Triassic Tecovas Formation. Recent analyses suggest a more regional, lateral flow of brine from the south, through the Tecovas and then the younger Trujillo Formation, with complex interactions with freshwater inflow from the north. Because of density and other factors, brine both discharges to the river and passes beneath it, to discharge further downstream.

Characterization of brine flow and siting of the brine control wells has been based on extensive surface water quality data, test drilling, aquifer sampling, resistivity surveys, seismic surveys, fracture analyses, three-dimensional flow and solute transport modes, and a two-dimensional density-dependent flow and solute transport model.

The design calls for eleven production wells to be drilled to depths varying from about 120 to 260 feet adjacent to the Canadian River, south of Logan, New Mexico. Saltwater brine from these wells will be transferred by buried pipeline about 3/4 of a mile south of the river to an injection well facility. The brine will be pumped into holding tanks prior to being injected into a high angle/horizontal drill hole completed in the Pennsylvania Sangre de Cristo Formation, at a depth of about 3,100 feet. The injection rate is anticipated to be about 300 gallons per minute.

INTRODUCTION

This paper is in three parts. The first part will provide the background information for the project. The second will discuss the hydrogeotechnical aspects of the project and the third will discuss the engineering design. The purpose of the Lake Meredith Salinity Control Project is to capture saltwater entering the Canadian River, south of Logan, New Mexico before it enters Lake Meredith. Lake Meredith is located north of Amarillo, Texas. It serves as a major drinking water source for 500,000 inhabitants, in eleven West Texas communities.

The goal for the project is ultimately to reduce salt concentrations of the lake. This will be done by drilling eleven production wells and transporting the captured saltwater (brine) by pipeline to a point south of the Canadian River and disposing of it by deep injection well (Figure 1).

The project is a cooperative effort with the U.S. Interior Department, Bureau of Reclamation (BOR), the Canadian River Municipal Water Authority (CRMWA), and the Texas Water Development Board (TWDB). Reclamation involvement with the project is authorized under Public Law 102-575. The project is anticipated to cost approximately $9.5 million and BOR will pay up to one-third of the total project cost. TWDB and CRMWA will pay the remainder. Construction is targeted to begin in late February 1998, following the acquisition of all required federal, state, and local permits and the awarding of the construction contract. Construction is anticipated to take about twelve months. An Environmental Assessment-Finding of No Significant Impact for the Salinity Control Project was issued in 1986 and updated in 1995.

HYDROGEOTECHNICAL ASPECTS

Figure 2 shows how the chloride concentrations in Lake Meredith have increased over time. For reference, the secondary drinking water standard established by the State of Texas is 300 mg/l and the standard set by the U.S. Environmental Protection Agency is 250 mg/l. These standards have been exceeded since the mid-1970s, except for a period in the early 1980s when the reservoir received a large inflow of fresh water. Chloride concentrations of about 475 mg/l were observed in the mid-1990s. Levels of sulfate and total dissolved solids also are high. Anyone

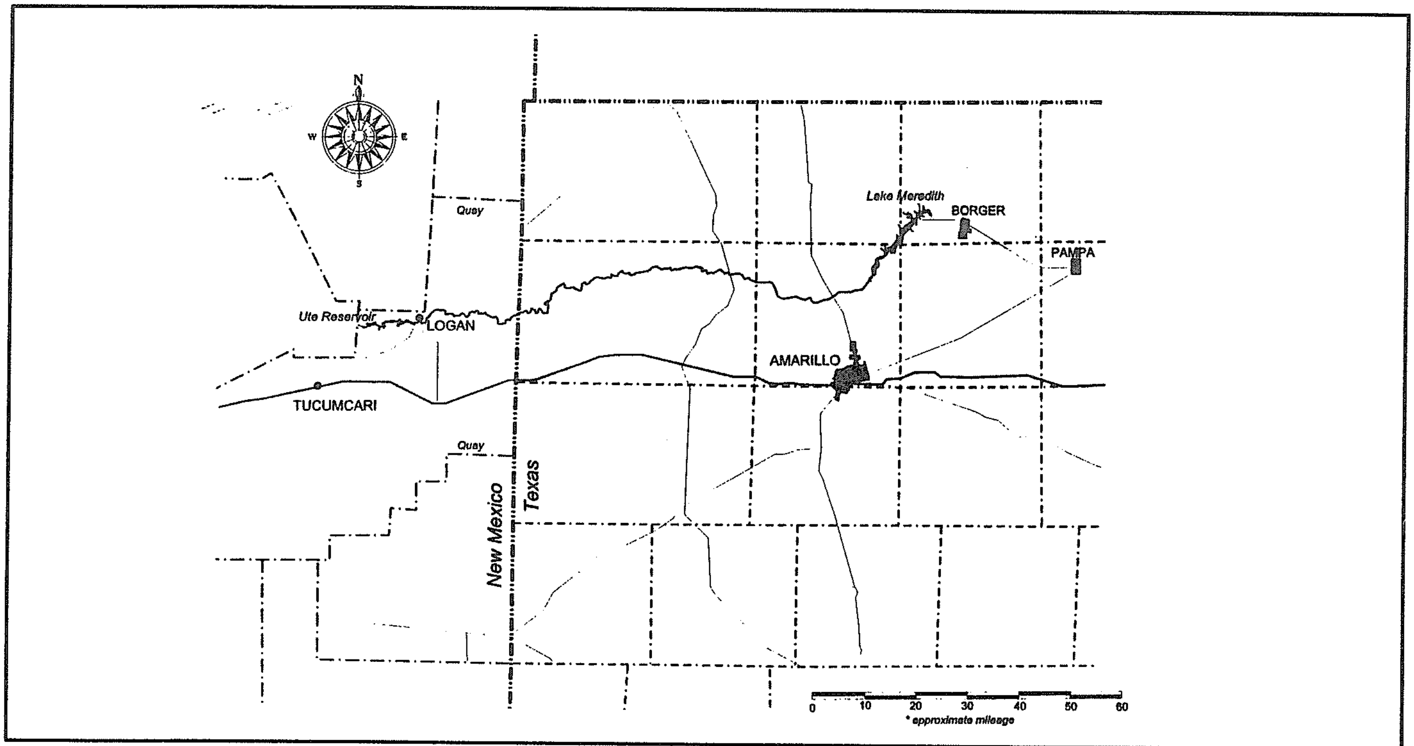

Figure 1. Location of the Lake Meredith Salinity Control Project.

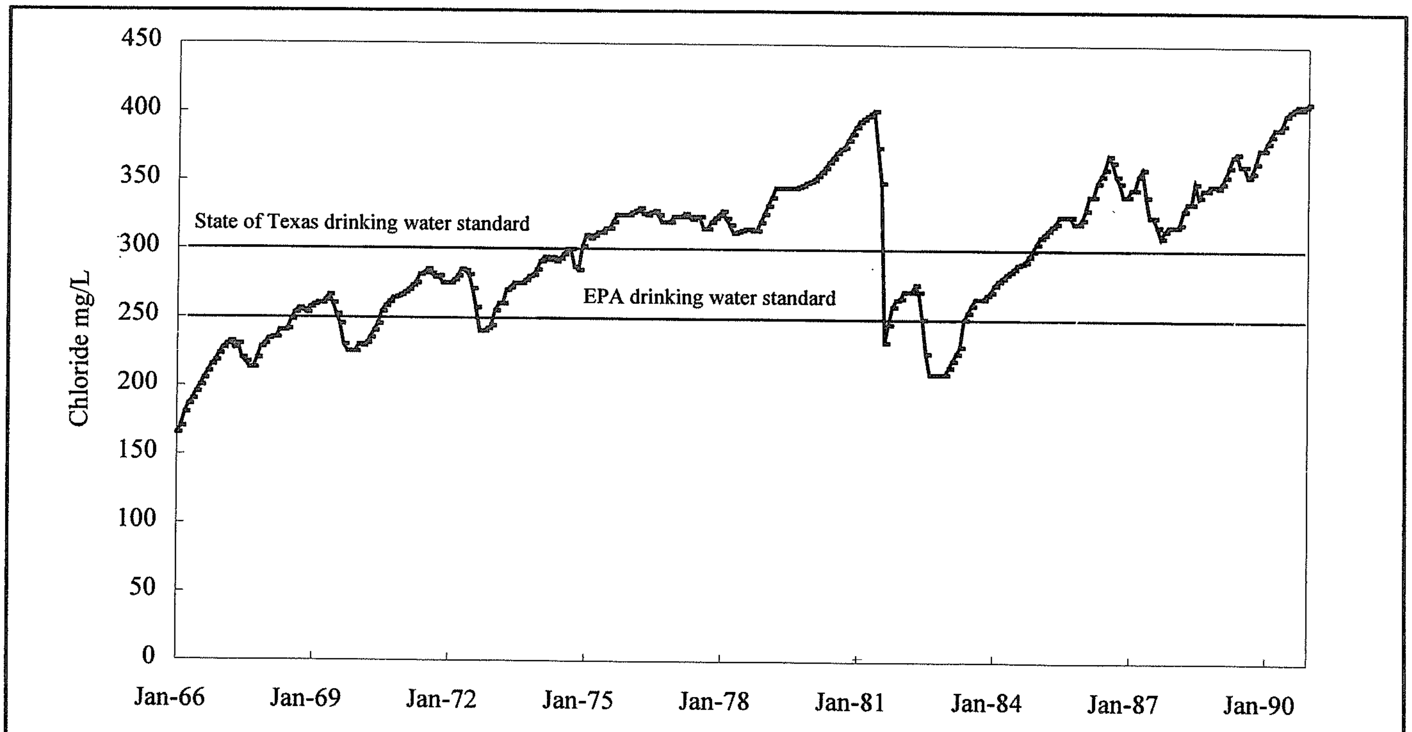

Figure 2. Lake Meredith salt concentration variation over time.

who has had a cup of coffee in Lubbock is well aware of the excessive salt content in Lake Meredith water.

Over the years, and especially since 1992, there have been many stream surveys to measure salt load and thereby determine where the salt is entering the river. Figure 3 shows results from a number of surveys in recent years. The chloride concentrations at the New Mexico-Texas state line are typically in the range 25,000-40,000 tons/year, which represents roughly 80% of the total chloride to Lake Meredith. As the figure indicates, most of this salt enters the Canadian River Project near Logan, New Mexico, in the six-mile long reach from Ute Reservoir to Revuelto Creek. As discussed below, salt inflows in this reach have been extensively studied. On Figure 3, note a second inflow at about mile 26; there have been no detailed studies of this second area.

Canadian River Project Components

To meet the water supply needs of its member cities, CRMWA is proposing conjunctive management of three different projects. First, there is the Canadian River Project itself, which supplies Lake Meredith water to Amarillo, Lubbock and the other members of CRMWA. The Project was designed for a firm yield of 103,000 acre-feet per year, but in practice has produced no more than 76,000 acre-feet per year. The low yield results from the construction of Ute Reservoir, and from the fact that regional runoff has been less than projected for both Ute and Lake Meredith. There are two consequences to the reduced yield of Lake Meredith: the reservoir has never filled and spilled, and so salts have simply accumulated by evaporation with no flushing (except in deliveries to the cities); and most member cities have developed supplemental groundwater supplies in the over-drafted Ogallala aquifer.

The second project, now in final design, is a large well field to withdraw groundwater from an undeveloped part of the Ogallala in Roberts County, Texas, where chloride concentrations are generally less than 20 mg/l. Thirty thousand acre-feet per year or more of this groundwater will be pumped for blending with Lake Meredith water, thus

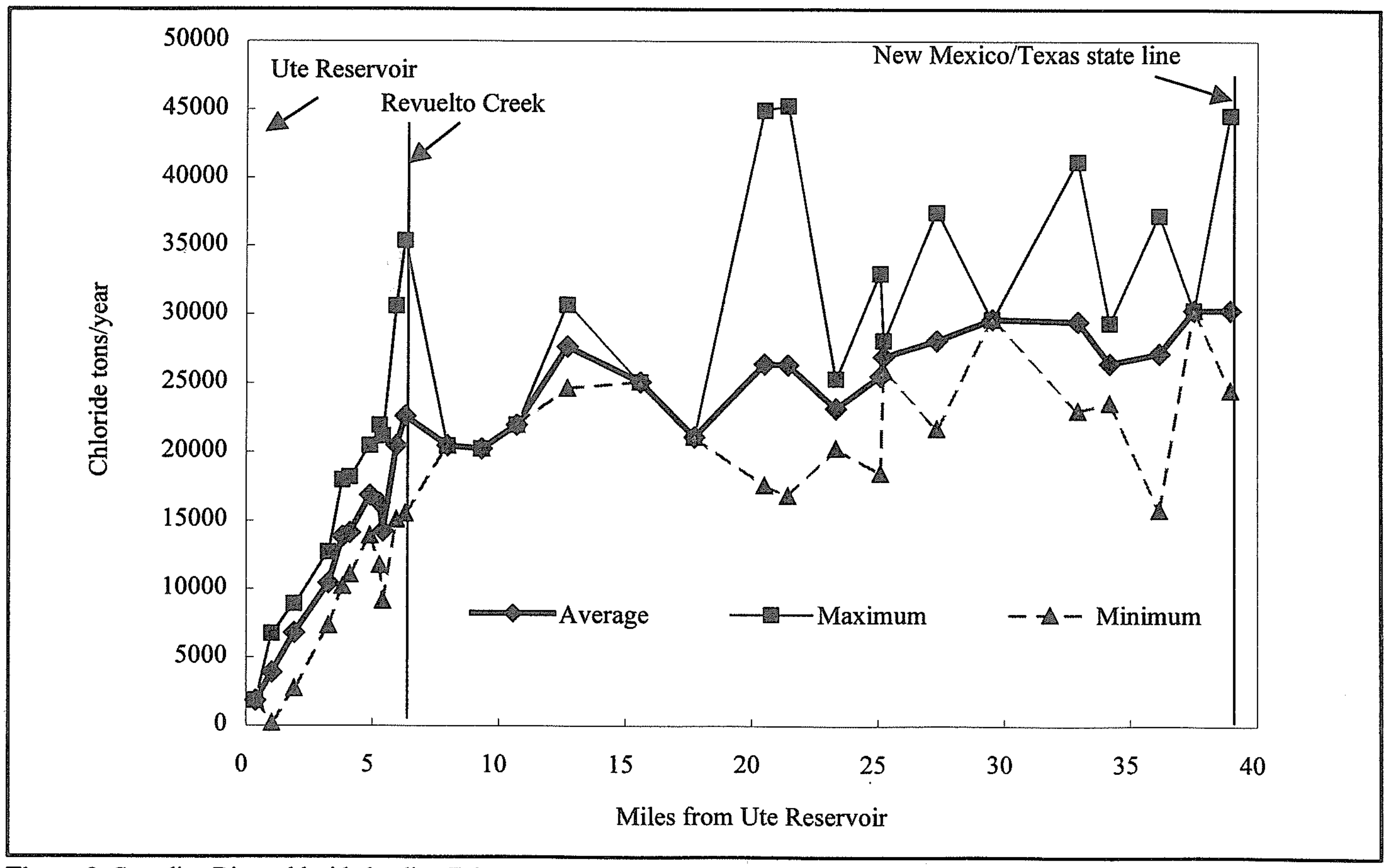

Figure 3. Canadian River chloride loading February 1992 to March 1996 - Ute Reservoir to state line.

simultaneously increasing the quantity of Project supply and decreasing its chloride content. The third project is the Lake Meredith Salinity Control Project, which is the subject of this paper. Salinity control will not increase the total supply of Lake Meredith water, but it will combine with the groundwater project to greatly improve water quality, especially in drought periods.

Brine Control Considerations

The keys to the salinity control project are brine control and brine disposal. Design of the brine control system has required extensive studies into geologic and hydrologic, both surface and groundwater, conditions in the area. Information has been obtained from the extensive literature on the geology of the Palo Duro Basin, and from localized data sources which include: stream surveys as discussed above, including very closely spaced measurements of specific conductance; surface geophysics (seismic and resistivity); drilling of many test holes, with associated geologic and borehole geophysical logs; completion of some of these tests as observation wells for long-term water-level monitoring; aquifer tests of selected wells; geologic mapping, with an emphasis on fractures; sampling and chemical analysis of surface and groundwater; and development of computer models to simulate flow conditions, including a conventional three-dimensional model, a 2-D cross-section model which accounts for brine density, and a flow-path model.

Salient Study Results

The Canadian River is located near the northern margin of a geologic basin where major salt beds are undergoing dissolution. The location of the river is probably controlled by surface collapse and subsidence along the salt solution zone. The Canadian River is entrenched into the regional topographic surface and thus represents the major natural discharge point for groundwater over a large area. Groundwater inflow from the south is dominantly saline, and that from the north is fresh.

Many factors influence the location and rates of groundwater inflow. As just one example, there is strong evidence that construction and enlargement of Ute Reservoir increased the rate of groundwater inflow, including brine inflow. Under current conditions, the baseflow near Logan is now a steady 3 cfs, of which about 1 cfs is brine.

The Tecovas Sandstone, of the Triassic Santa Rosa Formation, is the "brine aquifer," that is, the shallowest geologic unit where brine is found on a regional scale. As illustrated in Figure 4, near Logan the brine flows up through a confining horizon into the Trujillo Sandstone, also part of the Santa Rosa Formation, and from there through alluvium to the river. The flow schematic shown in Figure 4 was developed by Lee Wilson & Associates and is markedly different from earlier interpretations.

A typical brine sample contains 40,000 to 100,000 mg/l of total dissolved solids, with sodium and chloride by far the dominant ions. Brine inflow varies over time and space. A particularly important factor affecting this inflow is the relative head in the fresh and brine inflow systems and in the river: these heads vary in response to regional recharge patterns, and with changes in Ute storage. Two other important factors are: the topographic position of the river (e.g., the river gets more fresh water at locations where its channel is relatively north, and more saltwater where its channel is relatively south) and the location of fractures.

The fact that brine is denser than fresh water has important implications to assessment of the flow system. Computer modeling demonstrates that substantial errors are made if piezometric data from brine areas are not adjusted for density.

Salinity Control Design Considerations

The following chart illustrates differences between the brine control system that was envisioned in the mid-1980s, and that which is about to be built.

Prior concept	Current concept
One large well	Many small wells
Pump from Tecovas (deep)	Pump from Trujillo (shallow)
Locate near Ute Reservoir	Locate downstream

For both systems, pumping would be very near the river.

Figure 5 was generated by the density-adjusted cross-sectional model, and shows chloride isohalines for current flow conditions and conditions with the projected control system in place. Note that today only the upper part of the brine flow intercepts the river; the remainder flows underneath the freshwater wedge north of the river. The predicted effect of the project is to draw down the brine flow in the area just south of the river, so that virtually all the brine will pass beneath the river.

Combining the groundwater models with surface water models indicates that in the absence of the control system, future chloride concentrations in Lake Meredith would likely average at least 350 mg/l with values to 550 mg/l in droughts. A reasonable-case estimate is that, with brine control, these values will be reduced to about 290 mg/l and

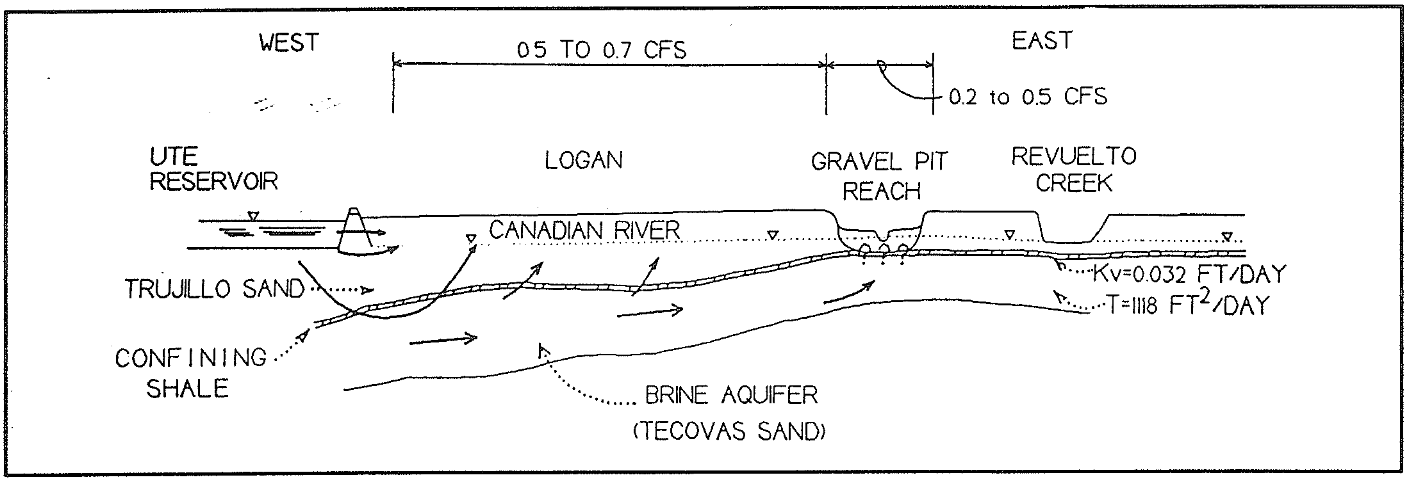

Figure 4. Hydrogeologic cross-section for the area of Logan, New Mexico.

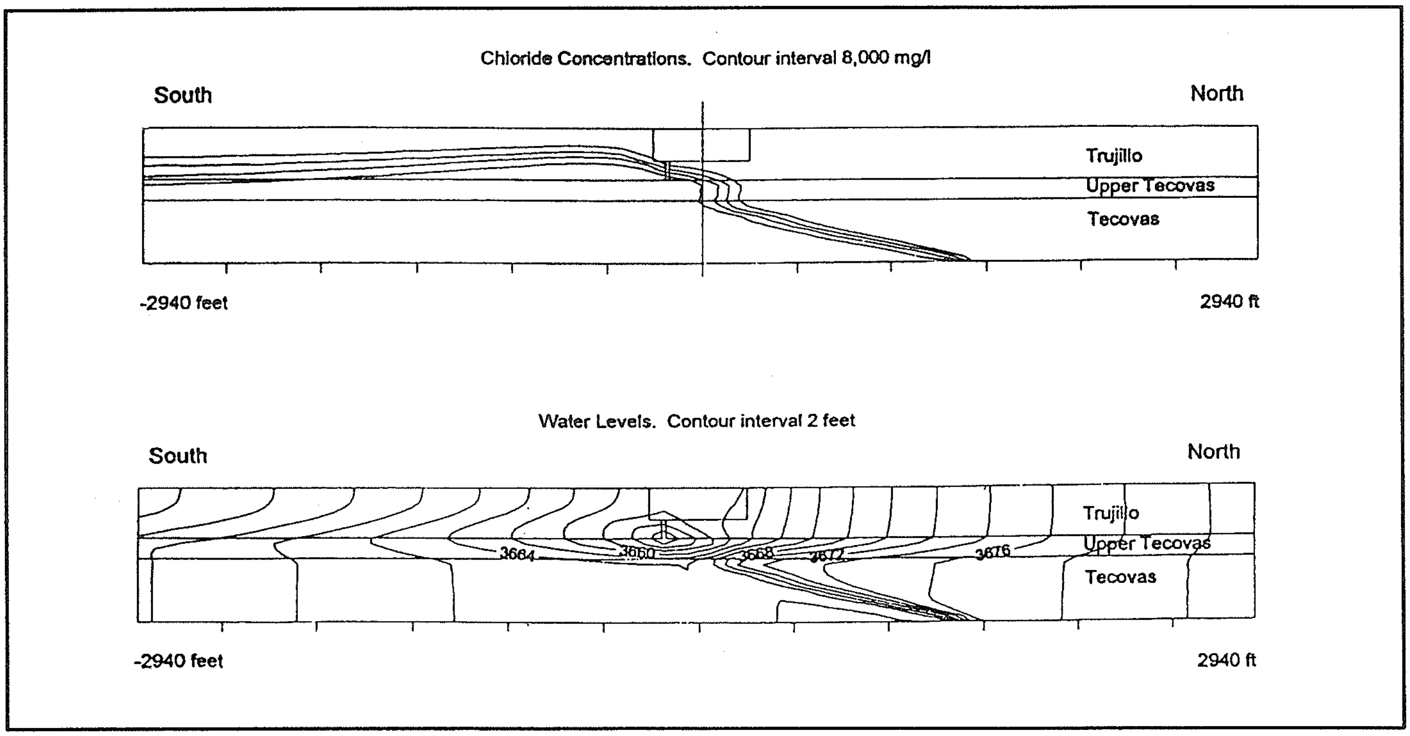

Figure 5. Conditions after pumping 30 years.

420 mg/l, respectively, and there is cautious optimism that the benefits of control may prove to be substantially better.

ENGINEERING DESIGN

A project engineering design is near completion by J.F. Sato Associates, Texas World Operations, Inc., RMH Group, and the Bureau of Reclamation. The basic design for the project will include eleven production wells, one injection well, a pumping plant and operations building, three miles of buried pipeline, power supply and distribution system, and an instrumentation and control system. Figure 6 is a map showing the project area and the location of wells and pipeline. Production wells will be drilled about ten feet into the Tecovas Sandstone. The wells will be completed for production from the lowermost part of the Trujillo Sandstone, with a screened interval of about 50 feet. Wells in the Canadian River, will be drilled to depths

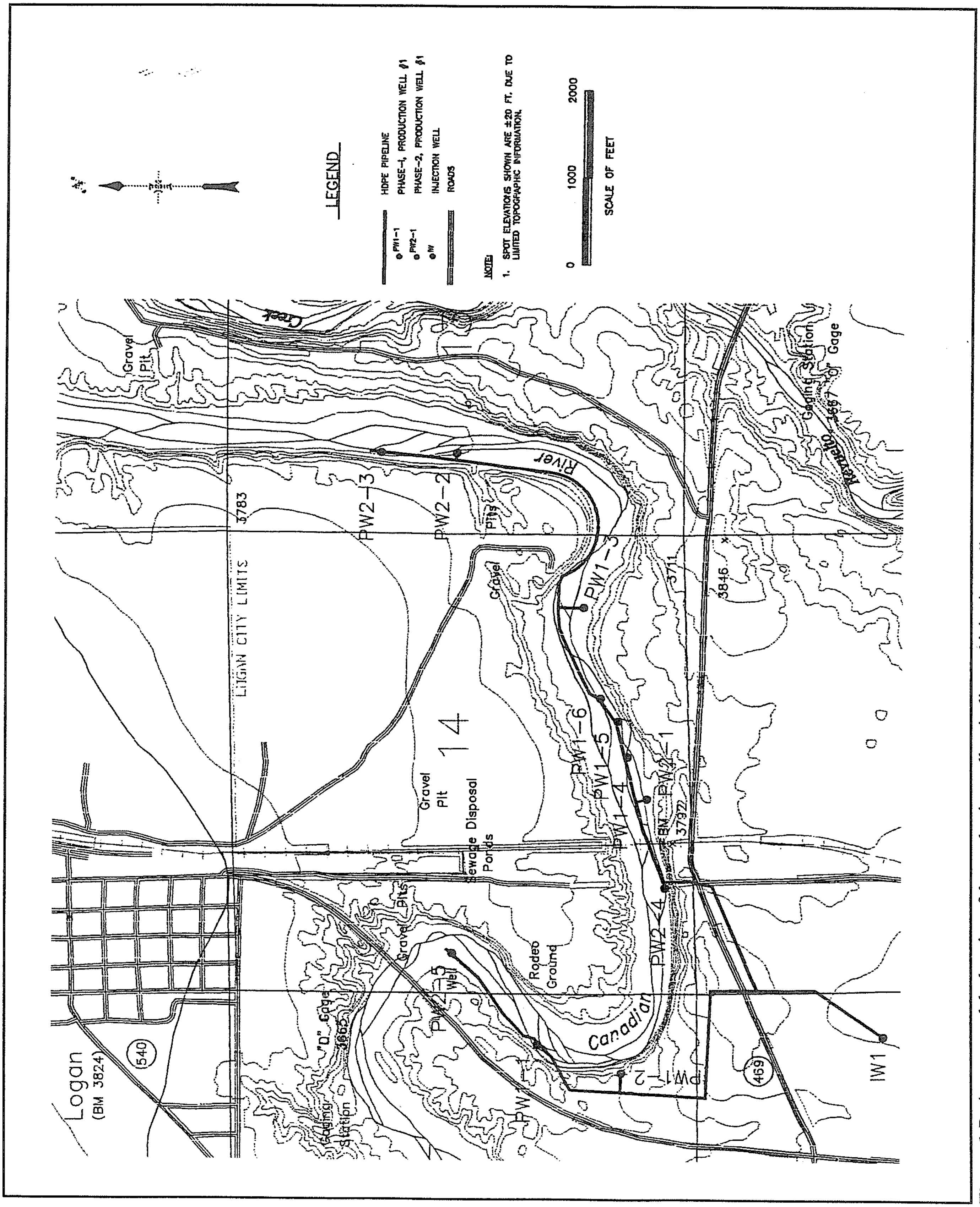

Figure 6. Project area and the location of the production wells, pipeline and injection wells.

ranging from 120 to 160 feet deep. Wells on the bluff, south of the river, will be about 260 feet deep. Production wells will be drilled to reduce the effects of pumping on river flow and to create as broad a cone of depression as possible from each well. The intent is to capture the highest concentrations of saltwater before it enters the river. Each well is expected to produce at least 30 gallons per minute (gpm) with rates of 50 to 90 gpm the most desirable. Conductivity of the water must be at least 30 millisiemens per centimeter, corrected to 25°C or about 20,000 milligrams per liter of dissolved solids. Submersible multistage pumps will be used with a remote control switching system to regulate flow rate, starting and stopping. Figure 7 illustrates a typical design for the injection wells.

The pipeline system will use high density polyethylene pipe. It will have a six-inch inside diameter and be butt welded in the field and tested for leaks. A leak detection system will be incorporated with the system with a link to the SCADA system. The pipeline will be buried at least 3 feet deep, with depths varying depending on the need to maintain a constant grade throughout the alignment. There will be east and west branches with a total pipeline length to the injection well of about three miles. The pipeline alignment as shown in Figure 6 was chosen to avoid cultural resource areas and considered topography, rock excavation and river crossing factors. It will be routed under State Highway 469 via two angled drill holes; one for each branch. The two branches will join south of the highway and be integrated into an eight-inch inside diameter pipeline.

The injection well will be a high angle/horizontal design as shown in Figure 8. It will be completed to a depth of about 3,100 feet and have a horizontal bore length of about 1,700 feet. It will be completed in the Pennsylvanian Sangre de Cristo Formation. The injection rate goal is 300 gpm. Operational injection pressure is anticipated to be about 875 psi to prevent development of new fractures or propagation of existing fractures in the injection interval.

It is expected the high angle/horizontal injection will greatly increase the surface area available for fluid injection. The probability of accessing secondary porosity and natural fractures or vugular porosity is expected to be increased. The upper and lower portions of the well will be vertical. The horizontal portion will be drilled beginning about 500 feet from the total depth using directional tools. This will be accomplished using a down hole mud pump operated by fluids pumped down the drill string. Fluid pumped through the mud motor turns a rotor attached to a drill bit. Orientation, direction, and angle of the hole is continuously monitored during drilling. The angle of the hole is determined by a bent sub, a short pipe joint with a built-in angle, installed above the mud motor.

The angle and hole direction is controlled by the angle of the bent sub used, orientation of the sub and amount of weight applied to the drill bit.

Power Supply and Distribution

Power will be purchased from the Farmers Electric Cooperative of New Mexico via a 10-year contract. Farmers will install a 25-KV overhead transmission line. An underground conduit will follow the pipeline down the canyon wall to the valley. All electrical equipment will be housed in watertight cabinets. A 150-horsepower (HP) pump will be used for the injection pumping plant. Additionally, a 20-HP filter pump will be used at the pumping plant and a 480-volt motor control center will be installed in the injection well pump house.

Instrumentation and Controls

A state of the art SCADA system will be used to control production and injection well operations. The system will be linked to the main computer in the operations building. Well production will be monitored by magnetic flow meter and well pressure measured by pressure transducers. Salinity is to be measured by a conductivity meter installed in each well discharge pipe. Well operation signals will be transmitted by radio modem to the main computer. Injection well operations are to be monitored for flow rate, annulus pressure and well pressure. A leak detection system will be incorporated as part of the pipeline. A backup emergency alarm with automatic shutdown and a dialup modem linked to the main computer and CRMWA headquarters at Sanford, Texas will be installed.

SUMMARY

- The intent of the project is to reduce the salinity of Lake Meredith by capturing saltwater brine before it enters the Canadian River near Logan, New Mexico. The water is to be disposed of by deep well injection.
- The project will benefit eleven West Texas communities, with 500,000 inhabitants.

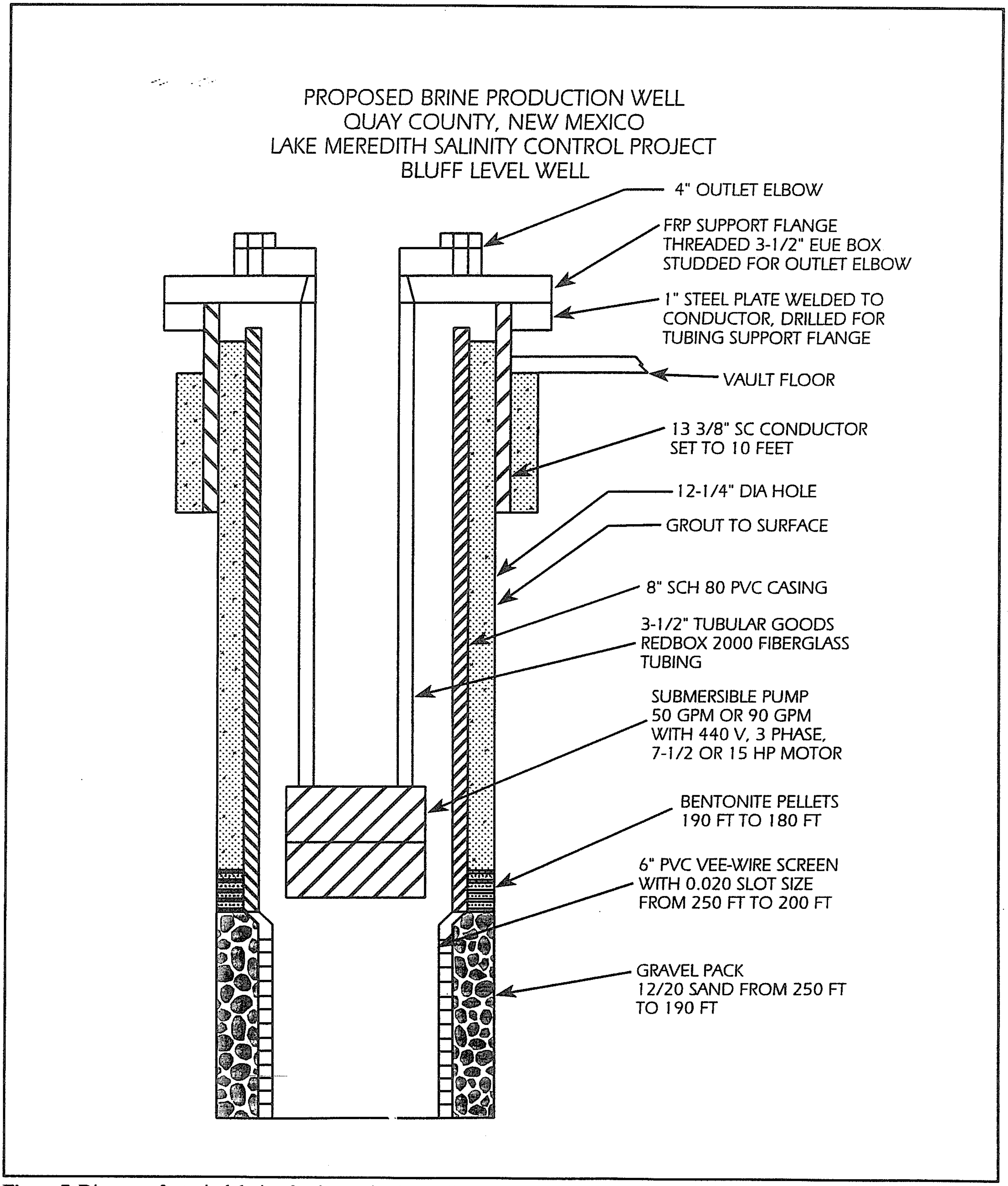

Figure 7. Diagram of a typical design for the production wells.

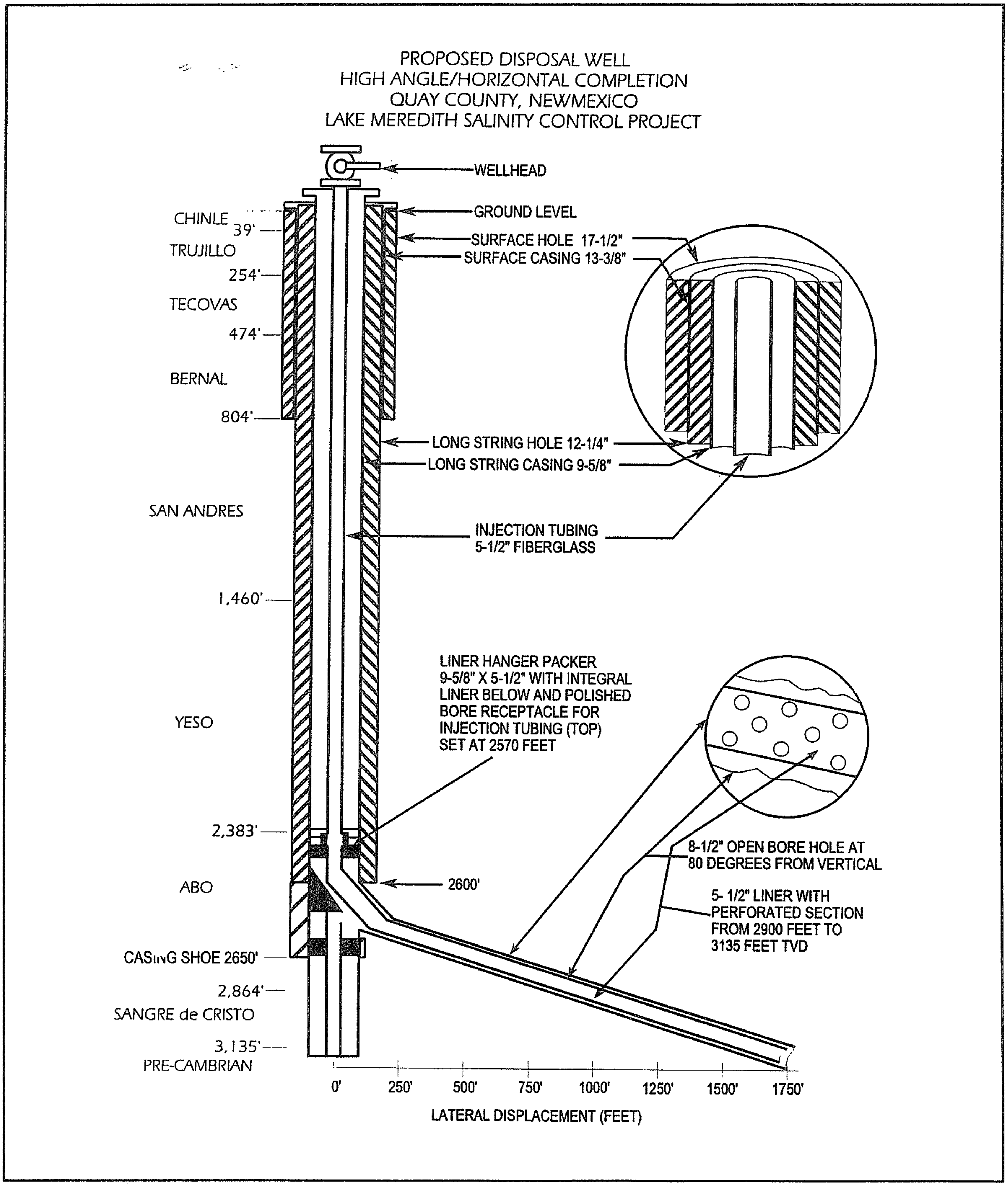

Figure 8. Diagram of the high angle/horizontal injection well.

- The project is a cooperative effort with the Bureau of Reclamation, the Canadian River Municipal Water Authority, and the Texas Water Development Board.
- Project costs are anticipated to be about $9.5 million.
- The brine typically contains 40,000 to 100,000 mg/l of total dissolved solids, with sodium and chloride, the dominant ions.
- The predicted effect of the project is to draw down the brine flow in the area just south of the river, so that virtually all the brine will pass beneath the river.
- Combining surface and groundwater models indicates that without a control system, future chloride concentrations in Lake Meredith could average at least 350 mg/l with values up to 550 mg/l in droughts. It is estimated that with brine control, these values could be reduced to about 290 mg/l and 420 mg/l, respectively.
- There will be up to 11 production wells in the Trujillo Sandstone drilled to depths ranging from 120 to 260 feet.
- About three miles of pipeline will transport the brine to a high angle/horizontal injection well for disposal at depths of about 3,100 feet.
- Construction is expected to begin in early 1998, following acquisition of all required federal, state, and local permits.

Acknowledgments

We acknowledge contributions to this presentation from John Williams and Kent Satterwhite (CRMWA); Dennis McDonough (BOR); J.F. Sato Associates, Inc., Littleton, Colorado; Texas World Operations Inc., Houston, Texas; and RMH Group, Lakewood, Colorado. Lee Wilson & Associates (LWA) serve as a consultant to the CRMWA. Roger Miller and Tom Parker of the LWA staff have had primary responsibility for the geologic/hydrologic studies discussed in this report.

Project stakeholders include the eleven-member cities of the CRMWA, the Texas Water Development Board, Texas State Legislature, New Mexico Environment Department, State Historical Preservation Office, New Mexico Interstate Stream Commission, City of Logan, Eastern New Mexico citizens and businesses, the Bureau of Reclamation, U.S. Army Corps of Engineers, and U.S. Environmental Protection Agency.