***SUMMARY OF WATER WELL CONSTRUCTION***

# WASHOE LAKE WETLANDS MITIGATION AREA

## Washoe County, Nevada

April 1997

*prepared for*

NEVADA DEPARTMENT OF TRANSPORTATION

Reno/Sparks, Nevada
Las Vegas, Nevada
Phoenix, Arizona

sea

S E A, INCORPORATED
CONSULTING ENGINEERS
950 INDUSTRIAL WAY
SPARKS, NEVADA 89431-6092
(702) 358-6931
FAX: 358-6954

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*Reno/Sparks, Nevada*
*Las Vegas, Nevada*
*Phoenix, Arizona*

April 16, 1997
Project No. 0990-27-1

Mr. Daryl James
Environmental Services Division
**NEVADA DEPARTMENT OF TRANSPORTATION**
1263 South Stewart Street
Carson City, Nevada 89712

**RE: Summary of Water Well Construction; Washoe Lake Wetlands Mitigation Area; Washoe County, Nevada**

Dear Mr. James:

This report summarizes water well construction at the Washoe Lake Wetlands Mitigation Area. The drilling contractor for this project was Zim Industries from Fresno, California. A 14-inch-diameter, 600-feet-deep well has been constructed at the site. The water well was test pumped up to a maximum flow rate of 1,300 gallons per minute (gpm). The optimum (highest efficiency) pumping rate was determined to be 850 gpm, however, for purposes of occasional water supply during drought conditions, the well could be equipped to pump at a rate greater than the optimum rate.

Prior to construction of the production well, exploration was conducted after a failed attempt at well construction on the east side of the wetlands mitigation area in the fall of 1995. A brief summary of this previous drilling and exploration is included in this report.

It has been a pleasure working with NDOT on this portion of the wetlands project. Please contact us if you have any questions regarding the production well or hydrogeologic exploration performed at the site.

Sincerely,

**SEA, INCORPORATED**
Consulting Engineers

PROFESSIONAL ENGINEER-STATE OF NEVADA
DWIGHT L. SMITH
4/18/97
GEOLOGICAL
No. 11906

Dwight L. Smith, P.E.
Hydrogeologist

Larry J. Johnson
Vice President, Geotechnical

DLS:vjr

cc: Mr. Reid Kaiser, NDOT
Mr. Matt Lorne, NDOT

Enclosures

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*SUMMARY OF WATER WELL CONSTRUCTION*

# WASHOE LAKE WETLANDS MITIGATION AREA

## Washoe County, Nevada

## PRODUCTION WELL DRILLING, CONSTRUCTION, AND TESTING

### Drilling and Well Construction

The Nevada Department of Transportation (NDOT) entered into contract with Zim Industries, Incorporated for construction and testing of one production well at the Washoe Lake Wetlands Mitigation area, located at the south side of Washoe Lake, Washoe County, Nevada. Production well drilling commenced on October 5, 1996. Full-time drilling and construction monitoring was provided by NDOT staff. Mr. Glen Geiger performed a majority of this inspection for NDOT. Mr. Dwight Smith, P.E., Hydrogeologist, of SEA, Incorporated performed routine observation and supervision throughout the drilling and construction process.

A bucket auger rig was used to drill a 36-inch diameter borehole to a depth of 46 feet. A 30-inch outside diameter (O.D.) conductor casing was centered in the borehole, and cement grout was placed in the void between the conductor casing and the borehole wall. The conductor casing was placed to prevent sloughing of near-surface soils into the borehole during the remainder of drilling.

A 24-inch-diameter borehole was then advanced down to 620 feet, using reverse circulation drilling methods. Drilling was conducted 24 hours per day until well construction was completed. Artesian conditions were encountered during drilling, which necessitated use of high yield bentonite and minor amounts of barite additives to increase the density of the drilling fluid. On October 19, 1996, 14-inch-O.D. well casing was installed in the 24-inch-diameter borehole, to a depth of 610 feet. Fourteen-inch-O.D., continuous slot well screen was placed between 120 to 240 feet and 280 to 600 feet. Screen slot size is 0.060-inch. Solid steel pipe ("blank casing") was placed from ground surface to 120 feet, 240 to 280 feet, and 600 to 610 feet. A steel plate was welded on the bottom of the well casing, at 610 feet. Steel used to fabricate the blank casing was ASTM A 53, Grade B, with 5/16 wall thickness. Centering guides were placed with 90° offsets and 60-foot spacing along the entire length of well casing. A 2-inch diameter water level sounding pipe was attached to the outside of the well casing to a depth of 245 feet, where it was welded to an opening into the 14-inch-O.D. blank casing.

Shortly after installation of the well casing and before gravel pack installation, the lower portions of the borehole collapsed onto the well casing. Zim Industries spent the next ten days attempting to remove the collapsed formation. Formation collapse occurred between the depths of 400 to 620 feet. Air and drilling fluid jetting was performed along the outside of the well casing, and the bottom of the well casing was drilled through in an attempt to flush caved formation from around the casing. Zim Industries efforts to remove this material were partially successful; however, the borehole could not be maintained open long enough for gravel pack installation. On October 30, 1996, gravel pack material was placed in the remaining open area between the well casing and borehole wall from 100 feet down to approximately 460 feet. A 3-inch-diameter gravel make-up pipe was placed from ground surface to 110 feet in depth. Gravel pack material was Colorado Silica Sand No. 6x16 and was placed by pumping through a tremie pipe. Approximately 25 cubic yards of gravel pack material were placed around the well casing. The estimated quantity of gravel which would have been placed if the borehole had not collapsed in the lower sections was approximately 50 cubic yards.

Before the 100-foot sanitary seal could be placed in the remainder of the annulus between the well casing and borehole, formation caved again, filling the annulus between 56 to 100 feet in depth. Zim Industries was successful in removing this material using jetting methods. On November 4, 1996, Type II cement grout was pumped into the upper annulus to form the sanitary seal from ground surface to 100 feet in depth. Mr. Robert Brown of Washoe County District Health Department was present to witness placement of the sanitary seal. Approximately 9.25 cubic yards of cement grout was placed.

After placement of the sanitary seal, approximately 3/4 cubic yard of cement grout was pumped to the bottom of the well casing to plug the bottom of the well, which had been drilled through during previous efforts to remove caved formation. The well plug was placed from 555 feet to approximately 580 feet in depth. Aquifer formation material had heaved into the lower 30 feet of the well casing after the bottom plate had been drilled through. This material was not removed prior to placement of the bottom plug, due to concerns of potential heaving formation even higher into the well casing.

On December 19, 1996, a video log of the inside of the production well was performed by Welenco to document the final condition of the constructed well, and in particular to inspect for possible damage which may have occurred while drilling through the bottom of the well casing. Mr. Jim Murdock of NDOT was present to witness video logging. No visible damage was observed. However, it was determined that the cement plug had been placed up to 555 feet in depth, approximately 20 feet above the planned plug depth. Following video logging, the well was capped with a welded steel plate. Artesian water level in the well was above the top of the casing, and a flow/pressure release valve was installed in the side of the casing so that the top cap could be welded. The top of the well casing was completed at approximately 4 feet above natural ground surface.

As-built details of the completed production well are summarized below.

| | |
|---|---|
| • Total depth drilled: | 620 feet. |
| • Cased well depth to top of bottom plug: | 555 feet. |
| • Continuous slot screen (14-inch O.D.): | 120 feet to 240 feet and 280 feet to 600 feet, 0.060-inch slot size, 2 percent copper-bearing, low carbon steel. |
| • Blank casing (14-inch O.D.): | 4 feet above ground surface to 120 feet; 240 to 280 feet; and, 600 to 610 feet; ASTM A 53 Grade B, low carbon steel, 5/16-inch wall thickness. |
| • Gravel pack material: | Colorado Silica Sand, 6 x 16. |
| • Gravel makeup pipe: | 3-inch diameter; 2-feet above ground surface to 110 feet. |
| • Water level sounding pipe: | 2-inch diameter; 2-feet above ground surface to 245 feet. |
| • Bottom plug: | Type II cement grout 555 feet to 580 feet (estimated). |
| • Cement sanitary seal: | Type II cement grout ground surface to 100 feet. |
| • Conductor casing (30-inch O.D.): | 2 feet above ground surface to 46 feet in depth; 3/8-inch wall thickness; cement grouted into 36-inch diameter borehole. |

## Development and Pumping Tests

### Development

On November 6, 1996, well development was commenced using the drill rig and swabbing and air-lifting techniques. Two days of swabbing and air-lifting development was performed, with water clarity improving throughout the process. On November 13, 1996, further development was commenced using a diesel-powered turbine pump and pumping and surging methods. Sediment content was measured in the discharged water using a Rossum sand meter. Pumping and surging development was performed at increasing production rates with the final sand and silt content measured at below 1 part per million (ppm) for a production rate of approximately 1,300 gallons per minute (gpm).

## Step Drawdown Test

On November 15, 1996, a step drawdown pumping test was performed. During this test the well was pumped at four progressively increasing rates. Discharge rates were measured using a totalizing flow meter. During pumping at each production rate, water levels were recorded using a wire-lined water level sounder. Pumped rates during the step drawdown test were approximately 409, 745, 950, and 1,286 gpm. During this test, water level decline in the well is allowed to stabilize at each pumped rate. A plot of the depth to stabilized water level versus pumped rate is presented as Plate 3. From this plot, it is observed that pumping at rates greater than approximately 850 gpm, a greater unit water level drawdown per unit increase in water production occurs (steeper slope). The break in slope occurs at approximately 850 gpm and indicates that flow into the well is starting a transition from laminar to turbulent flow. The optimum (or most efficient) pumping rate, as determined from the step drawdown test, is, therefore, approximately 850 gpm. Because this well is planned to be used only occasionally, during periods of drought, pumping at rates above the optimum rate could be performed without significant detrimental effects to the well or pump. Based on the performance testing of the well, we would not recommend equipping the well to pump over 1,200 gpm in order to maintain a sufficient height of water above the pump intake. The blank well casing set at 240 to 280 feet in depth has been installed specifically for pump intake placement.

## Constant Rate Pumping Test

On November 17, 1996, a 72-hour constant rate pumping test was commenced at a rate of approximately 950 gpm. During this test, water level drawdown in the well was recorded using a digital data recorder (In-Situ Troll). The pumping rate was maintained at 950 gpm by Zim Industries pump crew. After pumping continuously for 72 hours, pumping was terminated, and water level recovery in the well was measured for approximately 72 hours. A plot of the constant rate pumping test data is presented as Plates 4a through 4c. As noted in these plates, a stable rate of drawdown with time was observed after approximately one day of pumping. Static water level in the well recovered to within approximately two feet of the static water level recorded at commencement of the test, indicating no dramatic aquifer storage depletion.

The transmissivity of the aquifer was calculated using the constant rate pumping test data and the Copper-Jacob method. Transmissivity is an indication of aquifer permeability and is defined as the rate of water yielded through a unit width of an aquifer, under a unit hydraulic gradient. Transmissivity was calculated using both the pumping and recovery data and was determined to range from 10,000 to 17,000 gallons per day per foot (gpd/ft). This range of transmissivity is considered to represent moderate to good permeability.

**Water Chemistry Testing**

Near the conclusion of the 72-hour constant rate pumping test, a water sample was collected for analysis of general chemistry, including major ionic compounds, pH, total dissolved solid content (TDS), arsenic, iron, manganese, nitrate, and boron. The water sample was delivered to High Desert Laboratories in Sparks, Nevada. Water quality was determined to be good with a TDS concentration of 116 milligrams per liter (mg/L, equal to parts per million). Boron is below the detection limit of 0.05 mg/L. Arsenic was present at 0.005 mg/L, which is substantially below the current state and federal drinking water standard of 0.05 mg/L. The pH was measured at 7.7. Iron and manganese are slightly elevated above current secondary drinking water standards. Manganese was measured at 0.17; the current standard is 0.10 mg/L. Iron was measured at 0.78; the current secondary drinking water standard is 0.6 mg/L. Neither of these constituents should pose significant problems for use in the wetlands area. In agricultural applications, significantly elevated iron has been noted to cause soil porosity plugging problems. Using the water chemistry, the sodium absorption ratio (SAR) is calculated to be 1.0, indicating a low sodium toxicity hazard to plants. In summary, the water chemistry appears excellent for uses in the wetlands mitigation area.

## SUMMARY OF PREVIOUS DRILLING EFFORTS AND EXPLORATION

### Eastern Abandoned Well - 1995

In November of 1995, Zim Industries mobilized a reverse circulation drilling rig in an attempt to construct a production well on the east side of the Washoe Lake Wetlands Mitigation Area. Drilling commenced using a reverse circulation drill rig and a 17-inch-diameter pilot hole. Drilling specifications for this project were prepared by SEA, Incorporated. Well siting was performed by Harding Lawson Associates (HLA) using geologic interpretations and a geophysical (resistivity) survey of the site (see Appendix C). Unfortunately, geologic interpretations made by HLA were not correct, and volcanic bedrock was encountered at 135 feet below ground surface. Fractured or vesicular volcanic rock formations have the potential to yield significant quantities of water, so drilling of the 17-inch diameter pilot hole was continued to a depth of 322 feet. The borehole was electric logged, and SEA interpreted the potential for production quantities of water being available from the penetrated alluvium (below 100 feet) and volcanic bedrock. Based on review of hydrogeologic data, it was felt that a well constructed at this location would not produce significant quantities of water. The geologic log and electric log of this borehole are presented in Appendix A. The drilling effort was abandoned, and the borehole was filled with cement grout, in accordance with state regulations.

## Borehole Exploration - 1996

After the failed well construction effort, SEA, Incorporated formulated an exploration plan based on review of existing hydrogeologic data which included reinterpretation of the HLA resistivity data, review of Washoe County aerial electro-magnetic geophysical survey data, review of State Engineer's office well logs for the vicinity, and review of regional geologic mapping. Two exploration locations were recommended on the east side of the Washoe Lake Wetlands Mitigation Area (see SEA memorandums dated November 16 and 17, 1995 - included in Appendix B).

In September of 1996, Zim Industries advanced an 8-inch-diameter borehole to a depth of 600 feet at the north exploration location and to a depth of 680 feet at the south exploration location. Mud rotary drilling methods were utilized. Formation samples (drilled cuttings) were collected at 5-foot depth intervals and geologically logged (see Appendix A). Directly following drilling of each borehole, an electric log was performed by Welenco (see Back Pocket). NDOT personnel provided full-time monitoring of drilling operations. SEA, Incorporated provided periodic supervision and hydrogeologic interpretations of materials penetrated. Once hydrogeologic data had been collected, both boreholes were abandoned with cement grout, in accordance with state regulations.

A summary of the geology encountered at each exploration boring is presented below.

<u>North Exploration Borehole</u>

| | |
|---|---|
| 0 - 120 feet: | Interbedded silty sands and sandy silts, and occasional clay. |
| 120 - 270 feet: | Silty sands, with 15-20% low plastic fines. |
| 270 - 320 feet: | Poorly graded sand. |
| 320 - 500 feet: | Silty sands, becoming denser with depth and clayey at 420 - 500 feet. |
| 500 - 600 feet: | Weathered granitic bedrock. |

<u>South Exploration Borehole</u>

| | |
|---|---|
| 0 - 330 feet: | Silty sands with occasional interbedded sandy silts, 15-35% low plastic fines, and occasional shallow clay. |
| 330 - 360 feet: | Poorly graded sands. |
| 360 - 590 feet: | Silty sand, 20-40% low plastic fines increasing with depth. |
| 590 - 680 feet: | Sandy silts with estimated 55% low plastic fines. |

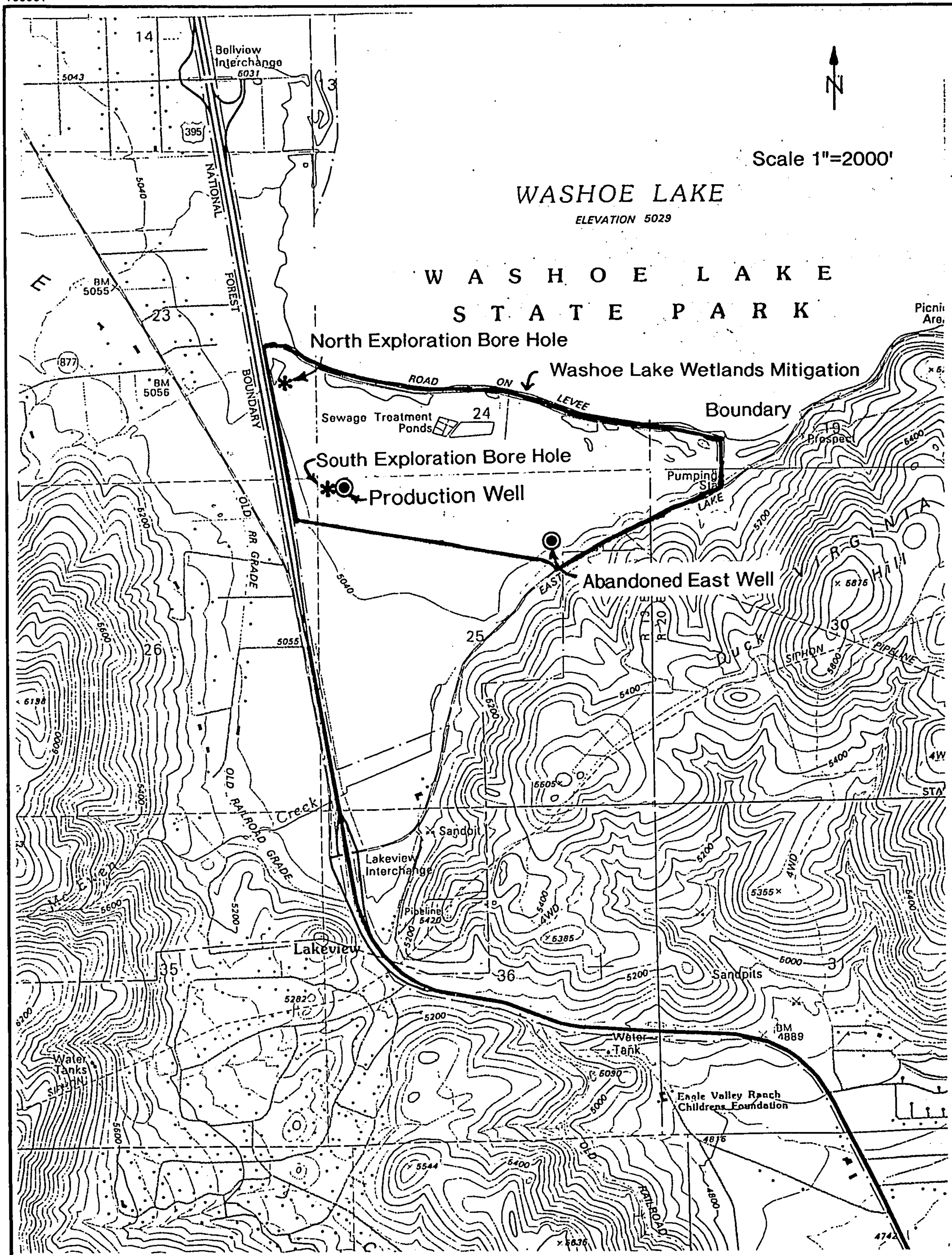
The silty sands encountered were noted to have a granitic origin with abundant quartz and feldspar grains, along with biotite flakes. At the northern borehole, weathered granitic bedrock was encountered at a depth of approximately 500 feet. Drilling became moderately difficult at this depth with the small mud rotary drill rig being used for exploration drilling.

The electric log for the north borehole indicates favorable formations at 100 to 155 feet, thin layers at 170 and 195 feet, 220 to 330 feet, and thin layers between 360 to 425 feet. At the southern exploration borehole, hydrogeologically favorable formations are interpreted at 100 to 210 feet, 310 to 420 feet, with thin layers at 525, 565, and 600 feet. Electric logs are very useful for interpreting the stratigraphy and water-bearing potential of materials encountered. Of primary importance in the electric logs is the resistivity traces, where shifts to the right represent higher permeability materials (i.e. sands) with increased water-bearing potential.

In comparison of geologic and electric log data from both exploration boreholes, the South exploration borehole is interpreted to have the more favorable hydrogeologic characteristics for development of a production well.

The production well constructed at the Washoe Lake Wetlands Mitigation Area in the fall of 1996 is located approximately 20 feet east of the South exploration hole. The aquifer materials encountered contained a high percentage of silt and fine sand. The production well screen slot-size was reduced to 0.060 inch, and a finer gravel pack material was specified to correspond with the geologic materials encountered.

166061

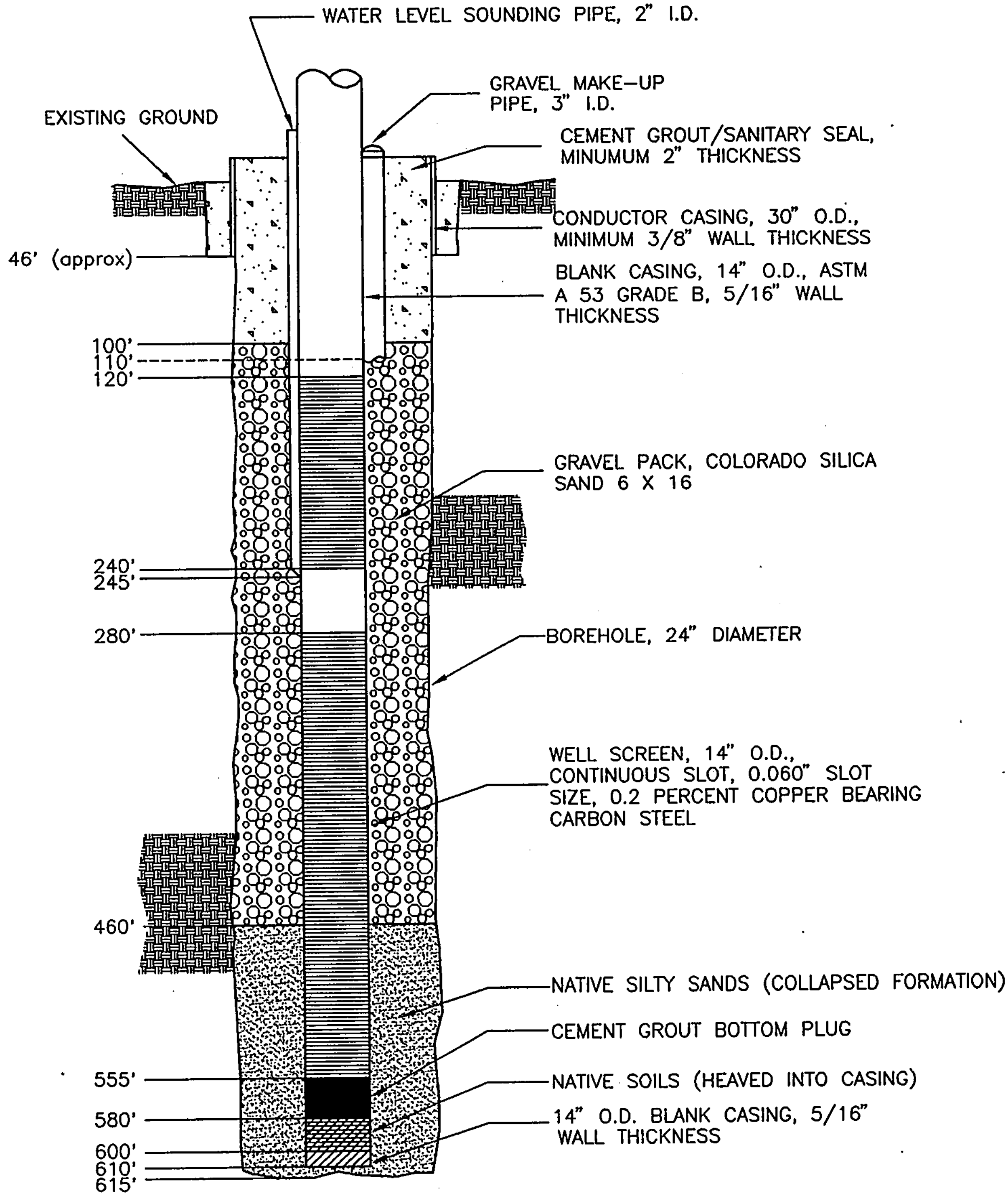



sea CONSULTING ENGINEERS
RENO/SPARKS, NEVADA
LAS VEGAS, NEVADA
PHOENIX, ARIZONA

NDOT
Washoe Lake Wetland Mitigation Area
Water Well and Bore Hole Sites

Project No. 0990-27-1

Plate 1




NTS

**AS BUILT**

| | | |
|---|---|---|
| sea Incorporated CONSULTING ENGINEERS<br>RENO/SPARKS, NEVADA<br>LAS VEGAS, NEVADA<br>PHOENIX, ARIZONA | WELL CONSTRUCTION SCHEMATIC<br>**NDOT**<br>WASHOE LAKE WETLANDS | PROJECT NO.<br>990-27-1<br>Plate No. 2 |

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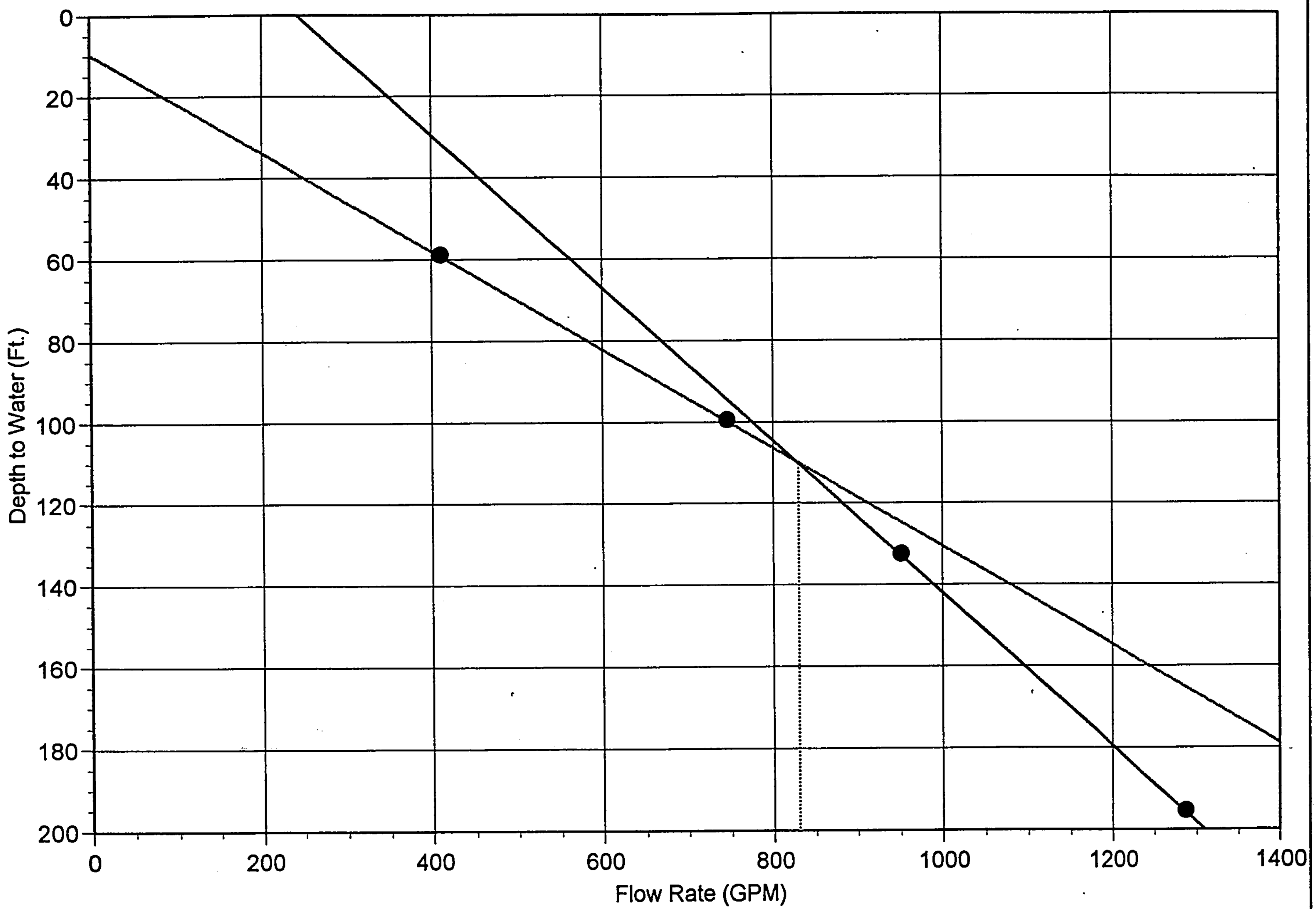


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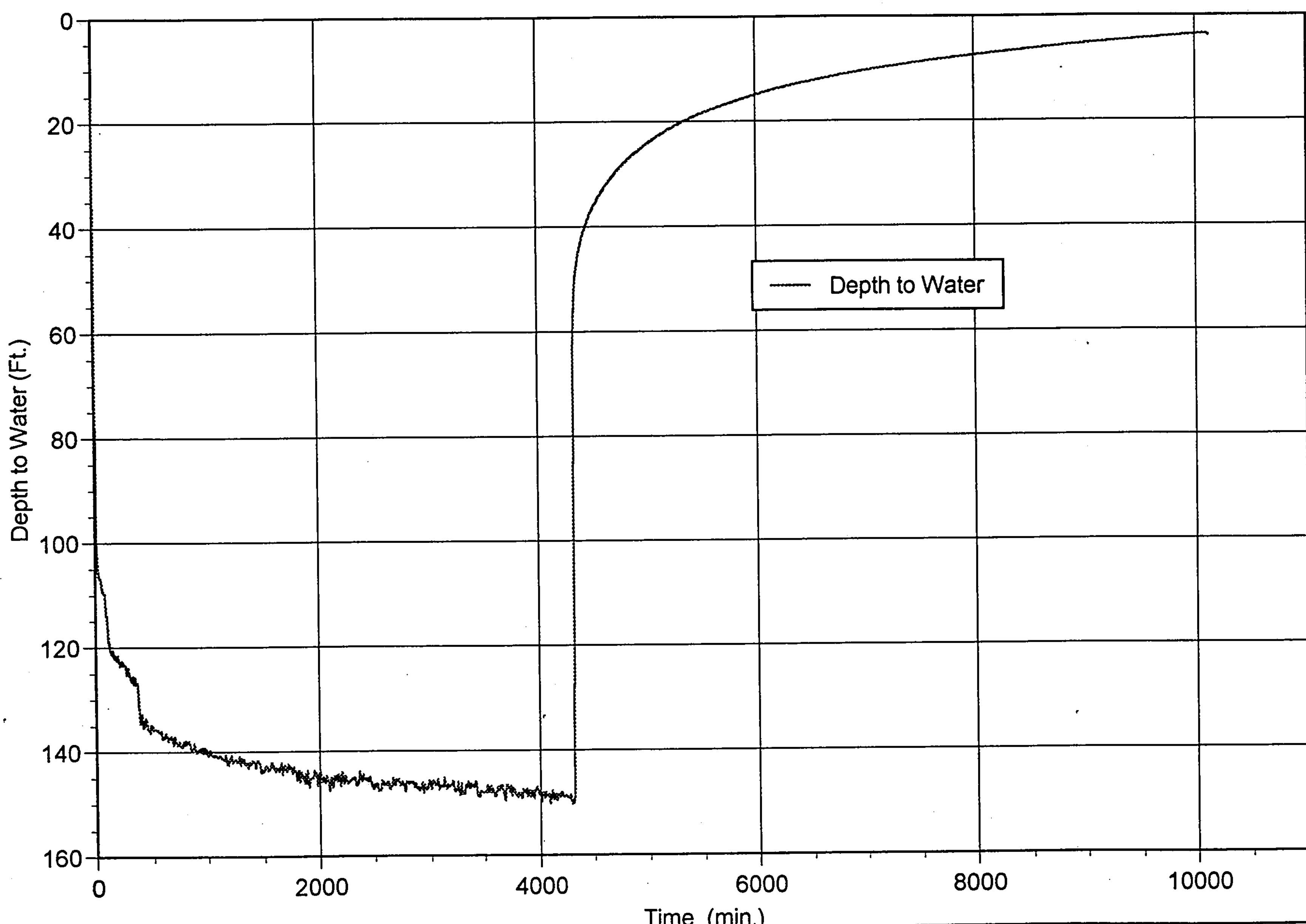
**NDOT Washoe Lake Wetlands Well**
**Step Drawdown Test**

Project No.2944-01-1
Plate No.3

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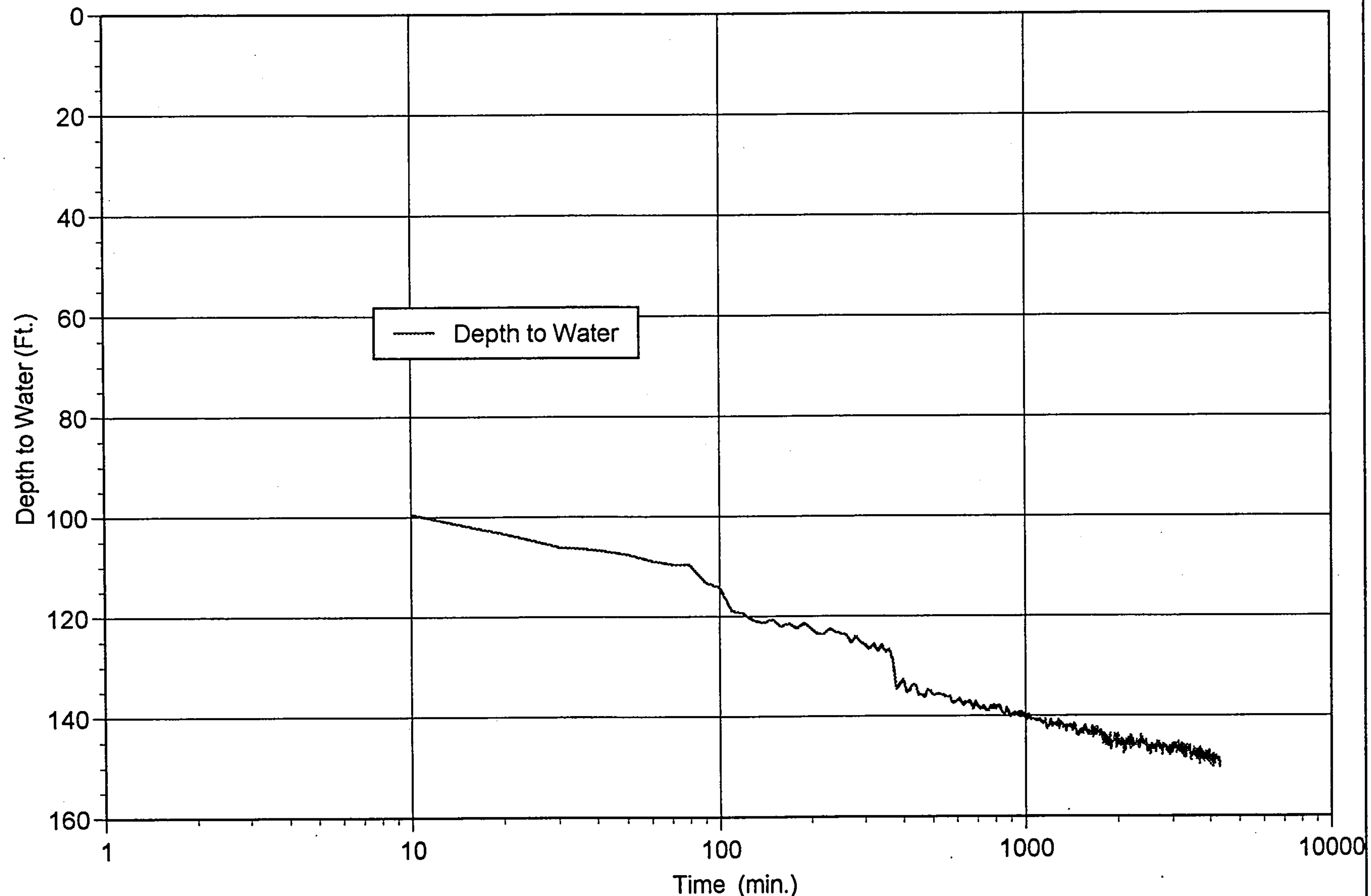
**NDOT Washoe Lake Wetland Well**
**Constant Rate Pumping Test @950 GPM**

Project No.2944-01-1
Plate No. 4




Transmissivity, T = 16720 gpd/ft

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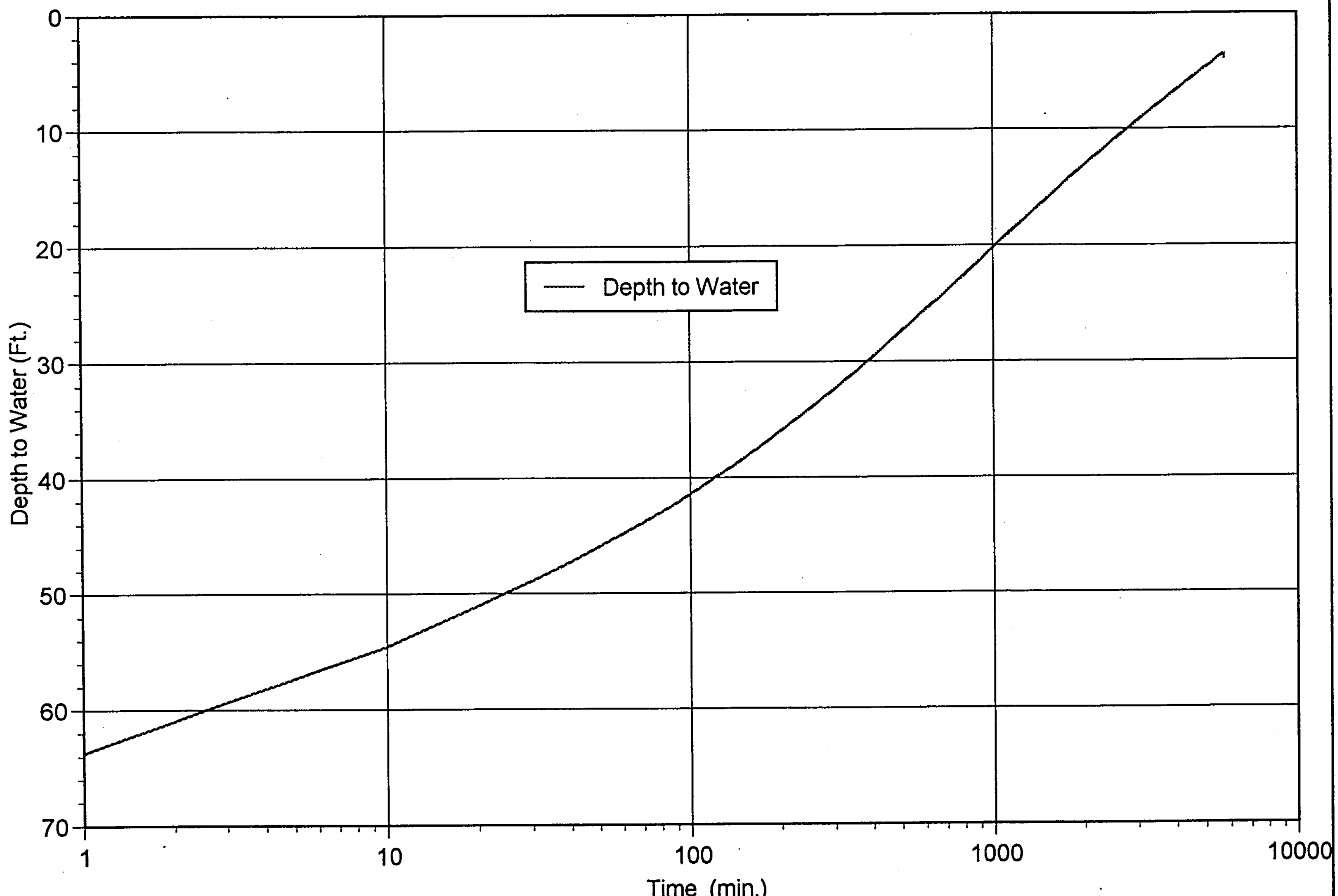
**NDOT Washoe Lake Wetlands Well**
**Constant Rate Pumping Test @950 GPM**

Project No.2944-01-1
Plate No. 5




Transmissivity, T = 10450 gpd/ft

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**NDOT Washoe Lake Wetlands Well**
**Recovery Test**

Project No. 2944-01-1
Plate No. 6

# WELL LOG

WELL NO.: *South Exploration (Production Well Site)*
GROUND ELEVATION.:
LOGGED BY: *D. Smith*
GROUND WATER DEPTH:
DATE: *9-11-96*
DATE MEASURED:
TYPE OF BORING: *Mud Rotary*

| NOTES | Sample Number | Location | PID (ppm) | Number of Blows | Depth in Feet | Soil Class | Well Diagram | Graphic Log | DESCRIPTION |
|---|---|---|---|---|---|---|---|---|---|
| 9-11-96 | | | | | | SM | | | 0.0-15.0: Brown, Silty Sand with estimated 45% medium to low plasticity fines, 55% fine to coarse sand. Subrounded |
| | 1 | | | | 10 | | | | |
| | 2 | | | | 20 | SM | | | 15.0-60.0: Gray, Silty Sand with estimated 35% low plasticity fines, 65% fine to coarse sand. Subrounded. |
| 9-12-96 | 3 | | | | 30 | | | | |
| | 4 | | | | 40 | | | | |
| | 5 | | | | 50 | | | | |
| | 6 | | | | 60 | SM | | | 60.0-120.0: Gray, Silty Sand with estimated 20% low plasticity fines, 80% fine to coarse sand. Subrounded. |
| | 7 | | | | 70 | | | | |
| | 8 | | | | 80 | | | | |
| | 9 | | | | 90 | | | | |
| | 10 | | | | 100 | | | | |
| | 11 | | | | 110 | | | | |
| | 12 | | | | 120 | ML | | | 120.0-130.0: Gray, Sandy Silt with estimated 65% low plasticity fines, 35% fine sand. Subrounded. |
| | 13 | | | | 130 | SM | | | 130.0-140.0: Gray, Silty Sand with estimated 35% low plasticity fines, 65% fine to coarse sand. Subrounded. |
| | 14 | | | | 140 | SM | | | 140.0-160.0: Gray, Sandy Silt with estimated 15% low plasticity fines, 85% fine to coarse sand. Subrounded. |
| | 15 | | | | 150 | | | | |
| | | | | | 160 | SM | | | |

EXPLANATION

Number of Blows: Record number of blows for one foot penetration of sampler using 140 pound hammer falling 30 inches.
Description: Describe soil type by Unified Soil Classification System with emphasis on in-place or natural condition.
PP: Pocket Penetrometer Measurement (tons per square foot)

■ Splitspoon Sample Location

▨ Thin Wall Shelby Location

# WELL LOG

WELL NO.: *South Exploration (Production Well Site)*
GROUND ELEVATION.:
LOGGED BY: *D. Smith*
GROUND WATER DEPTH:
DATE: *9-11-96*
DATE MEASURED:
TYPE OF BORING: *Mud Rotary*

| NOTES | Sample Number | Location | PID (ppm) | Number of Blows | Depth in Feet | Soil Class | Well Diagram | Graphic Log | DESCRIPTION |
|---|---|---|---|---|---|---|---|---|---|
| | 16 | ■ | | | | SM | | | 160.0–200.0: Gray, Silty Sand with estimated 25% low plasticity fines, 75% fine to coarse sand. Subrounded. |
| | 17 | ■ | | | 170 | | | | |
| | 18 | ■ | | | 180 | | | | |
| | 19 | ■ | | | 190 | | | | |
| | 20 | ■ | | | 200 | SM | | | 200.0–220.0: Gray, Silty Sand with estimated 15% low plasticity fines, 85% fine to coarse sand. Subrounded. |
| | 21 | ■ | | | 210 | | | | |
| | 22 | ■ | | | 220 | SM | | | 220.0–310.0: Gray, Silty Sand with estimated 20% low plasticity fines, 80% fine to coarse sand. Subrounded. |
| | 23 | ■ | | | 230 | | | | |
| | 24 | ■ | | | 240 | | | | |
| | 25 | ■ | | | 250 | | | | |
| | 26 | ■ | | | 260 | | | | |
| | 27 | ■ | | | 270 | | | | |
| | 28 | ■ | | | 280 | | | | |
| | 29 | ■ | | | 290 | | | | |
| 9-13-96 | 30 | ■ | | | 300 | | | | |
| | 31 | ■ | | | 310 | SM | | | 310.0–330.0: Gray, Silty Sand with estimated 25% low plasticity fines, 75% fine to coarse sand. Subrounded. |
| | | | | | 320 | | | | |

EXPLANATION
Number of Blows: Record number of blows for one foot penetration of sampler using 140 pound hammer falling 30 inches.
Description: Describe soil type by Unified Soil Classification System with emphasis on in-place or natural condition.
PP: Pocket Penetrometer Measurement (tons per square foot)
■ Splitspoon Sample Location
▨ Thin Wall Shelby Location

# WELL LOG

WELL NO.: *South Exploration (Production Well Site)*
LOGGED BY: *D. Smith*
DATE: *9-11-96*
TYPE OF BORING: *Mud Rotary*
GROUND ELEVATION.:
GROUND WATER DEPTH:
DATE MEASURED:

| NOTES | Sample Number | Location | PID (ppm) | Number of Blows | Depth in Feet | Soil Class | Well Diagram | Graphic Log | DESCRIPTION |
|---|---|---|---|---|---|---|---|---|---|
| | 32 | ■ | | | | SM | | | |
| | 33 | ■ | | | 330 | SP-SM | | | 330.0–360.0: Gray, Poorly Graded Sand with Silt with estimated 10% low plasticity fines, 90% fine to coarse sand. Subrounded. |
| | 34 | ■ | | | 340 | | | | Harder drilling. |
| | 35 | ■ | | | 350 | | | | |
| | 36 | ■ | | | 360 | SM | | | 360.0–450.0: Gray, Silty Sand with estimated 20% low plasticity fines, 80% fine to coarse sand. Subrounded. |
| | 37 | ■ | | | 370 | | | | |
| | 38 | ■ | | | 380 | | | | |
| | 39 | ■ | | | 390 | | | | |
| | 40 | ■ | | | 400 | | | | |
| | 41 | ■ | | | 410 | | | | |
| | 42 | ■ | | | 420 | | | | |
| 9-14-96 | 43 | ■ | | | 430 | | | | |
| | 44 | ■ | | | 440 | | | | |
| | 45 | ■ | | | 450 | SM | | | 450.0–500.0: Gray, Silty Sand with estimated 30% low plasticity fines, 70% fine to coarse sand. Subrounded. |
| | 46 | ■ | | | 460 | | | | |
| | 47 | ■ | | | 470 | | | | |
| | | ■ | | | 480 | | | | |

EXPLANATION
Number of Blows: Record number of blows for one foot penetration of sampler using 140 pound hammer falling 30 inches.
Description: Describe soil type by Unified Soil Classification System with emphasis on in-place or natural condition.
PP: Pocket Penetrometer Measurement (tons per square foot)

■ Splitspoon Sample Location

▨ Thin Wall Shelby Location

# WELL LOG

WELL NO.: South Exploration (Production Well Site) | GROUND ELEVATION.:
LOGGED BY: D. Smith | GROUND WATER DEPTH:
DATE: 9-11-96 | DATE MEASURED:
TYPE OF BORING: Mud Rotary

| NOTES | Sample Number | Location | PID (ppm) | Number of Blows | Depth in Feet | Soil Class | Well Diagram | Graphic Log | DESCRIPTION |
|---|---|---|---|---|---|---|---|---|---|
| | 48 | ■ | | | | SM | | | |
| | 49 | ■ | | | 490 | | | | |
| | 50 | ■ | | | 500 | SM | | | 500.0-590.0: Gray, Silty Sand with estimated 40% low plasticity fines, 60% fine to coarse sand. Subangular. |
| | 51 | ■ | | | 510 | | | | |
| | 52 | ■ | | | 520 | | | | |
| | 53 | ■ | | | 530 | | | | |
| | 54 | ■ | | | 540 | | | | |
| | 55 | ■ | | | 550 | | | | |
| | 56 | ■ | | | 560 | | | | Some clay. |
| | 57 | ■ | | | 570 | | | | |
| | 58 | ■ | | | 580 | | | | Harder drilling. |
| | 59 | ■ | | | 590 | ML | | | 590.0-680.0: Gray, Sandy Silt with estimated 55% low plasticity fines, 45% fine to coarse sand. Subangular. |
| | 60 | | | | 600 | | | | |
| | | | | | 610 | | | | |
| | | | | | 620 | | | | |
| | | | | | 630 | | | | |
| | | | | | 640 | | | | |

EXPLANATION
Number of Blows: Record number of blows for one foot penetration of sampler using 140 pound hammer falling 30 inches.
Description: Describe soil type by Unified Soil Classification System with emphasis on in-place or natural condition.
PP: Pocket Penetrometer Measurement (tons per square foot)

■ Splitspoon Sample Location

▨ Thin Wall Shelby Location

sea Incorporated CONSULTING ENGINEERS
RENO/SPARKS, NEVADA
LAS VEGAS, NEVADA
PHOENIX, ARIZONA

NDOT
Washoe Lake Wetlands
Washoe County, Nevada

Sheet 4 of 5
Project No. 0990-27-1
Plate

# WELL LOG

WELL NO.: *South Exploration (Production Well Site)*
GROUND ELEVATION.:
LOGGED BY: *D. Smith*
GROUND WATER DEPTH:
DATE: *9-11-96*
DATE MEASURED:
TYPE OF BORING: *Mud Rotary*

| NOTES | Sample Number | Location | PID (ppm) | Number of Blows | Depth In Feet | Soil Class | Well Diagram | Graphic Log | DESCRIPTION |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | ML | | | |
| | | | | | 650 | | | | |
| | | | | | 660 | | | | |
| | | | | | 670 | | | | |
| | | | | | 680 | | | | |
| | | | | | 690 | | | | |
| | | | | | 700 | | | | |
| | | | | | 710 | | | | |
| | | | | | 720 | | | | |
| | | | | | 730 | | | | |
| | | | | | 740 | | | | |
| | | | | | 750 | | | | |
| | | | | | 760 | | | | |
| | | | | | 770 | | | | |
| | | | | | 780 | | | | |
| | | | | | 790 | | | | |
| | | | | | 800 | | | | |

EXPLANATION

Number of Blows: Record number of blows for one foot penetration of sampler using 140 pound hammer falling 30 inches.

Description: Describe soil type by Unified Soil Classification System with emphasis on in-place or natural condition.

PP: Pocket Penetrometer Measurement (tons per square foot)

■ Splitspoon Sample Location

▨ Thin Wall Shelby Location

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|---|---|---|---|

# WELL LOG

WELL NO.: *North Exploration*
GROUND ELEVATION.: *5035 (approximate)*
LOGGED BY: *D. Smith*
GROUND WATER DEPTH: *Ground surface (artesian)*
DATE: *9-18-96*
DATE MEASURED: *September 1996*
TYPE OF BORING: *Mud Rotary*

| NOTES | Sample Number | Location | PID (ppm) | Number of Blows | Depth in Feet | Soil Class | Well Diagram | Graphic Log | DESCRIPTION |
|---|---|---|---|---|---|---|---|---|---|
| 9-18-96 | | | | | 0 | SM | | | 0.0–25.0: Brown, Silty Sand with estimated 45% medium to low plasticity fines, 55% fine sand. Subrounded. |
| | 1 | ■ | | | 10 | | | | |
| | 2 | ■ | | | 20 | | | | |
| | | | | | 25 | SM | | | 25.0–35.0: Brown-gray, Silty Sand with estimated 40% low plasticity fines, 60% fine to medium sand. Subrounded. |
| | 3 | ■ | | | 30 | | | | |
| | | | | | 35 | SM | | | 35.0–55.0: Brown-gray, Silty Sand with estimated 20% low plasticity fines, 80% fine to coarse sand. Subrounded. |
| | 4 | ■ | | | 40 | | | | |
| | 5 | ■ | | | 50 | | | | |
| | | | | | 55 | SP-SM | | | 55.0–75.0: Brown-gray, Poorly Graded Sand with Silt with estimated 10% low plasticity fines, 90% fine to coarse sand. Subrounded. |
| | 6 | ■ | | | 60 | | | | |
| | 7 | ■ | | | 70 | | | | |
| | | | | | 75 | SM | | | 75.0–105.0: Brown-gray, Silty Sand with estimated 20% low plasticity fines, 80% fine to medium sand. Subrounded. |
| | 8 | ■ | | | 80 | | | | |
| | 9 | ■ | | | 90 | | | | |
| | 10 | ■ | | | 100 | | | | Harder drilling. |
| | | | | | 105 | ML | | | 105.0–120.0: Brown-gray, Sandy Silt with estimated 55% low to medium plasticity fines, 45% fine sand. Subrounded. |
| | 11 | ■ | | | 110 | | | | |
| | 12 | ■ | | | 120 | SM | | | 120.0–150.0: Brown-gray, Silty Sand with estimated 20% low plasticity fines, 80% fine to medium sand. Subrounded. |
| | 13 | ■ | | | 130 | | | | |
| | 14 | ■ | | | 140 | | | | |
| 9-19-96 | 15 | ■ | | | 150 | SM | | | 150.0–165.0: Brown-gray, Silty Sand with estimated 15% low plasticity fines, 85% fine sand. Subrounded. |
| | | | | | 160 | | | | |

EXPLANATION

Number of Blows: Record number of blows for one foot penetration of sampler using 140 pound hammer falling 30 inches.

Description: Describe soil type by Unified Soil Classification System with emphasis on in-place or natural condition.

PP: Pocket Penetrometer Measurement (tons per square foot)

■ Splitspoon Sample Location

▨ Thin Wall Shelby Location

| sea Incorporated CONSULTING ENGINEERS | RENO/SPARKS, NEVADA<br>LAS VEGAS, NEVADA<br>PHOENIX, ARIZONA | NDOT<br>Washoe Lake Wetlands<br>Washoe County, Nevada | Sheet 1 of 4<br>Project No. 0990-27-1<br>Plate |
|---|---|---|---|

# WELL LOG

WELL NO.: North Exploration
GROUND ELEVATION.: 5035 (approximate)
LOGGED BY: D. Smith
GROUND WATER DEPTH: Ground surface (artesian)
DATE: 9-18-96
DATE MEASURED: September 1996
TYPE OF BORING: Mud Rotary

| NOTES | Sample Number | Location | PID (ppm) | Number of Blows | Depth in Feet | Soil Class | Well Diagram | Graphic Log | DESCRIPTION |
|---|---|---|---|---|---|---|---|---|---|
| | 16 | ■ | | | | SM<br>SM | | | 165.0-180.0: Brown-gray, Silty Sand with estimated 15% low plasticity fines, 85% fine to coarse sand. Subrounded. |
| | 17 | ■ | | | 170 | | | | |
| | 18 | ■ | | | 180 | SM | | | 180.0-240.0: Brown-gray, Silty Sand with estimated 20% low plasticity fines, 80% fine to coarse sand. Subrounded. |
| | 19 | ■ | | | 190 | | | | |
| | 20 | ■ | | | 200 | | | | |
| | 21 | ■ | | | 210 | | | | |
| | 22 | ■ | | | 220 | | | | |
| | 23 | ■ | | | 230 | | | | |
| | 24 | ■ | | | 240 | SM | | | 240.0-250.0: Brown-gray, Silty Sand with estimated 30% low plasticity fines, 70% fine to coarse sand. Subrounded. |
| | 25 | ■ | | | 250 | SM | | | 250.0-270.0: Brown-gray, Silty Sand with estimated 15% low plasticity fines, 85% fine to coarse sand. Subrounded. Harder drilling. |
| | 26 | ■ | | | 260 | | | | |
| | 27 | ■ | | | 270 | SP-SM | | | 270.0-320.0: Brown-gray, Poorly Graded Sand with Silt with estimated 10% low plasticity fines, 90% fine to coarse sand. Subrounded. |
| | 28 | ■ | | | 280 | | | | |
| | 29 | ■ | | | 290 | | | | |
| | 30 | ■ | | | 300 | | | | |
| | 31 | ■ | | | 310 | | | | |
| | | ■ | | | 320 | SM | | | |

EXPLANATION

Number of Blows: Record number of blows for one foot penetration of sampler using 140 pound hammer falling 30 inches.
Description: Describe soil type by Unified Soil Classification System with emphasis on in-place or natural condition.
PP: Pocket Penetrometer Measurement (tons per square foot)

■ Splitspoon Sample Location

▨ Thin Wall Shelby Location

| sea Incorporated CONSULTING ENGINEERS<br>RENO/SPARKS, NEVADA<br>LAS VEGAS, NEVADA<br>PHOENIX, ARIZONA | NDOT<br>Washoe Lake Wetlands<br>Washoe County, Nevada | Sheet 2 of 4<br>Project No. 0990-27-1<br>Plate |
|---|---|---|

# WELL LOG

WELL NO.: *North Exploration*
GROUND ELEVATION.: *5035 (approximate)*
LOGGED BY: *D. Smith*
GROUND WATER DEPTH: *Ground surface (artesian)*
DATE: *9-18-96*
DATE MEASURED: *September 1996*
TYPE OF BORING: *Mud Rotary*

| NOTES | Sample Number | Location | PID (ppm) | Number of Blows | Depth in Feet | Soil Class | Well Diagram | Graphic Log | DESCRIPTION |
|---|---|---|---|---|---|---|---|---|---|
| | 32 | ■ | | | | SM | | | 320.0-335.0: Brown-gray, <u>Silty Sand</u> with estimated 15% low plasticity fines, 85% fine to coarse sand. Subrounded. |
| | 33 | ■ | | | 330 | | | | |
| | 34 | ■ | | | 340 | SM | | | 335.0-390.0: Brown-gray, <u>Silty Sand</u> with estimated 20% low plasticity fines, 80% fine to coarse sand. Subrounded. |
| | 35 | ■ | | | 350 | | | | |
| | 36 | ■ | | | 360 | | | | |
| | 37 | ■ | | | 370 | | | | |
| | 38 | ■ | | | 380 | | | | Harder drilling. |
| | 39 | ■ | | | 390 | SM | | | 390.0-430.0: Brown-gray, <u>Silty Sand</u> with estimated 15% low plasticity fines, 85% fine to coarse sand. Subrounded. |
| | 40 | ■ | | | 400 | | | | |
| | 41 | ■ | | | 410 | | | | |
| | 42 | ■ | | | 420 | | | | |
| | 43 | ■ | | | 430 | SM | | | 430.0-490.0: Brown-gray, <u>Silty Sand</u> with estimated 20% low plasticity fines, 80% fine to coarse sand. Subrounded. |
| | 44 | ■ | | | 440 | | | | |
| | 45 | ■ | | | 450 | | | | |
| | 46 | ■ | | | 460 | | | | |
| 9-20-96 | 47 | ■ | | | 470 | | | | |
| | | ■ | | | 480 | | | | |

EXPLANATION
Number of Blows: Record number of blows for one foot penetration of sampler using 140 pound hammer falling 30 inches.
Description: Describe soil type by Unified Soil Classification System with emphasis on in-place or natural condition.
PP: Pocket Penetrometer Measurement (tons per square foot)
■ Splitspoon Sample Location
▨ Thin Wall Shelby Location

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LAS VEGAS, NEVADA
PHOENIX, ARIZONA

NDOT
Washoe Lake Wetlands
Washoe County, Nevada

Sheet 3 of 4
Project No. 0990-27-1
Plate

# WELL LOG

WELL NO.: *North Exploration* GROUND ELEVATION.: *5035 (approximate)*

LOGGED BY: *D. Smith* GROUND WATER DEPTH: *Ground surface (artesian)*

DATE: *9-18-96* DATE MEASURED: *September 1996*

TYPE OF BORING: *Mud Rotary*

| NOTES | Sample Number | Location | PID (ppm) | Number of Blows | Depth in Feet | Soil Class | Well Diagram | Graphic Log | DESCRIPTION |
|---|---|---|---|---|---|---|---|---|---|
| | 48 | ■ | | | | SM | | | |
| | 49 | ■ | | | 490 | SM | | | 490.0–500.0: Contains some clay. |
| | 50 | ■ | | | 500 | GRANITE | | | 500.0–600.0: Granite and Lithic Fragments with estimated 70% Granite, 30% Lithic Fragments. Little gray clay. Granite: Black-white, quartz, feldspar, and mica. Angular Lithic Fragments: Red-brown-white, assorted composition. Angular. |
| | 51 | ■ | | | 510 | | | | |
| | 52 | ■ | | | 520 | | | | |
| | 53 | ■ | | | 530 | | | | |
| | 54 | ■ | | | 540 | | | | |
| | 55 | ■ | | | 550 | | | | |
| | 56 | ■ | | | 560 | | | | |
| | 57 | ■ | | | 570 | | | | |
| | 58 | ■ | | | 580 | | | | |
| | 59 | ■ | | | 590 | | | | |
| | 60 | | | | 600 | | | | |
| | | | | | 610 | | | | |
| | | | | | 620 | | | | |
| | | | | | 630 | | | | |
| | | | | | 640 | | | | |

EXPLANATION

Number of Blows: Record number of blows for one foot penetration of sampler using 140 pound hammer falling 30 inches.

Description: Describe soil type by Unified Soil Classification System with emphasis on in-place or natural condition.

PP: Pocket Penetrometer Measurement (tons per square foot)

■ Splitspoon Sample Location

▨ Thin Wall Shelby Location

# WELL LOG

WELL NO.: *NDOT East (Abandoned)*
GROUND ELEVATION.: *Approx. 5040*
LOGGED BY: *D. Smith*
GROUND WATER DEPTH: *5 feet*
DATE: *11-10-95*
DATE MEASURED: *11/6/95*
TYPE OF BORING: *Reverse Circulation Rotary*

| NOTES | Sample Number | Location | PID (ppm) | Number of Blows | Depth in Feet | Soil Class | Well Diagram | Graphic Log | DESCRIPTION |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0–21 | SM | | | 0.0-21: Very wet, brown Silty Sand |
| | | | | | 21–23 | CL | | | 21-23: Wet, tan Sandy Clay with estimated 60% medium plastic fines, 40% fine to coarse sand. |
| | | | | | 23–28 | SM | | | 23-28: Wet, mottled orange brown and green tan, interbedded Silty Sand with Poorly Graded Sand and Sandy Silt. |
| 11-7-95 Set conductor to 56' (30 inch O.D.) | 1 | ■ | | | 28–65 | SM | | | 28-65: Wet, brown grey, Silty Sand with estimated 15-20% non to low plastic fines, 80-85% fine to medium sands, minor amounts of gravel. High amounts of micas. |
| 11-11-95 Start drilling with reverse circulation rig. | 2 | ■ | | | 65–75 | SC | | | 65-75: Brown, Clayey Sand, with estimated 25-30% low to medium plastic fines, 70-75% fine to medium sand. |
| | 3 | ■ | | | 75–85 | SM | | | 75-85: Brown, Silty Sand with estimated 15% low plastic fines, 85% fine to coarse sand. |
| | 4, 5, 6, 7 | ■ | | | 85–125 | SP | | | 85-125: Light grey to grey, Poorly Graded Sand with estimated 5% non-plastic fines, 90% fine to coarse sand, 5% gravel. |
| | 8 | ■ | | | 125–135 | GP | | | 125-135: Light reddish grey Sandy Gravel with estimated 0-5% fines, 30-40% sand, 60-70% gravel |
| | 9, 10, 11 | ■ | | | 135–185 | Rhyolite | | | 135-185: Reddish grey, slightly fractured, angular cuttings Rhyolite Bedrock. |

| Sample Number | Depth (feet) |
|---|---|
| 1 | 60 |
| 2 | 70 |
| 3 | 80 |
| 4 | 90 |
| 5 | 100 |
| 6 | 110 |
| 7 | 120 |
| 8 | 130 |
| 9 | 140 |
| 10 | 150 |
| 11 | 160 |

EXPLANATION

Number of Blows: Record number of blows for one foot penetration of sampler using 140 pound hammer falling 30 inches.

Description: Describe soil type by Unified Soil Classification System with emphasis on in-place or natural condition.

PP: Pocket Penetrometer Measurement (tons per square foot)

■ Splitspoon Sample Location

▨ Thin Wall Shelby Location

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NDOT
Washoe Lake Wetlands
Washoe County, Nevada


Project No. 0990-27-1
Plate

# WELL LOG

WELL NO.: NDOT East (Abandoned)
GROUND ELEVATION.: Approx. 5040
LOGGED BY: D. Smith
GROUND WATER DEPTH: 5 feet
DATE: 11-10-95
DATE MEASURED: 11/6/95
TYPE OF BORING: Reverse Circulation Rotary

| NOTES | Sample Number | Location | PID (ppm) | Number of Blows | Depth in Feet | Soil Class | Well Diagram | Graphic Log | DESCRIPTION |
|---|---|---|---|---|---|---|---|---|---|
| | 12 | ■ | | | | Rhyolite | | | |
| | 13 | ■ | | | 180 | | | | |
| | | | | | | Rhyolite | | | 185-200: Rust red to reddish grey, moderately fractured, very fine cuttings <u>Rhyolite Bedrock</u>. |
| | 14 | ■ | | | 190 | | | | |
| | 15 | ■ | | | | | | | |
| | 16 | ■ | | | 200 | Rhyolite | | | 200-215: Dark grey to reddish grey, <u>Rhyolite Bedrock</u>. |
| | 17 | ■ | | | | | | | |
| | 18 | ■ | | | 210 | | | | |
| | 19 | ■ | | | | Rhyolite | | | 215-265: light grey to biege minor red, highly angular medium sized cuttings <u>Rhyolite Bedrock</u>. |
| | 20 | ■ | | | 220 | | | | |
| | 21 | ■ | | | 230 | | | | |
| | 22 | ■ | | | 240 | | | | |
| | 23 | ■ | | | 250 | | | | |
| | 24 | ■ | | | 260 | | | | |
| | | | | | | Rhyolite | | | 265-275: Rust Red, moderately weathered, moderatly fractured <u>Rhyolite Bedrock</u> |
| | 25 | ■ | | | 270 | | | | |
| | 26 | ■ | | | | Rhyolite | | | 275-285: Light grey, <u>Rhyolite Bedrock</u> |
| | 27 | ■ | | | 280 | | | | |
| | 28 | ■ | | | | Rhyolite | | | 285-305: light grey, large angular cuttings <u>Rhyolite Bedrock</u> |
| | 29 | ■ | | | 290 | | | | |
| | 30 | ■ | | | | | | | |
| | 31 | ■ | | | 300 | | | | |
| | 32 | ■ | | | | Rhyolite | | | 305-322: Reddish grey to red, regular angular cuttings <u>Rhyolite Bedrock</u> |
| | 33 | ■ | | | 310 | | | | |
| | 34 | ■ | | | | | | | |
| 11-13-95 3:30 pm | 35 | ■ | | | 320 | | | | |
| | | | | | 330 | | | | |
| | | | | | 340 | | | | |

EXPLANATION

Number of Blows: Record number of blows for one foot penetration of sampler using 140 pound hammer falling 30 inches.

Description: Describe soil type by Unified Soil Classification System with emphasis on in-place or natural condition.

PP: Pocket Penetrometer Measurement (tons per square foot)

■ Splitspoon Sample Location

▨ Thin Wall Shelby Location

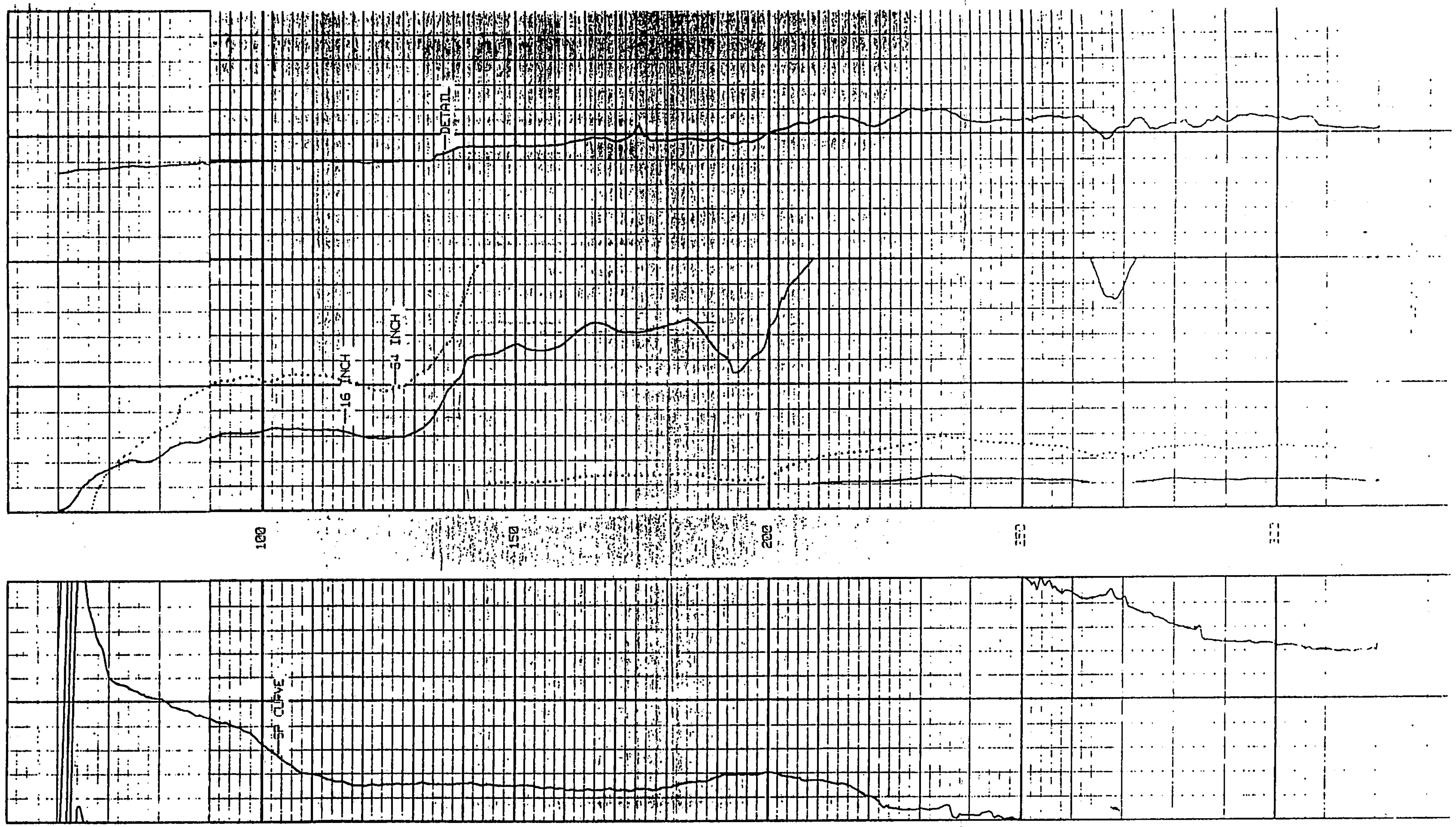
| | | |
|---|---|---|
| sea incorporated CONSULTING ENGINEERS<br>RENO/SPARKS, NEVADA<br>LAS VEGAS, NEVADA<br>PHOENIX, ARIZONA | NDOT<br>Washoe Lake Wetlands<br>Washoe County, Nevada | Sheet 2 of 2<br>Project No. 0990-27-1<br>Plate |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Changes in Mud Type or Additional Samples | | | | | Scale Changes | | | | |
| Date | Sample No. | | | | Type Log | Depth | Scale Up Hole | Scale Down Hole | |
| Depth-Driller | | | | | | | | | |
| Type Fluid in Hole | | | | | | | | | |
| Dens. \| Visc. | | | | | | | | | |
| ph \| Fluid Loss | | ml | | ml | | | | | |
| Source of Sample | | | | | Equipment Data | | | | |
| Rm at Meas. Temp. | at | F | at | F | Run No. | Tool Type | PadType | Tool Pos | Other |
| Rmf at Meas. Temp. | at | F | at | F | ONE | ELECTRIC | | FREE | |
| Rmc at Meas. Temp. | at | F | at | F | | | | | |
| Source: Rmf \| Rmc | | | | | | | | | |
| Rm at BHT | at | F | at | F | | | | | |
| Rmf at BHT | at | F | at | F | | | | | |
| Rmc at BHT | at | F | at | F | | | | | |

REMARKS:

WELL DRILLED BY: ZIM INDUSTRIES, INC.
WELL DRILLER: M.JACKSON

| RESISTANCE ohms | RESISTIVITY ohmmeters2 /meter | DEPTHS | SPONTANEOUS POTENTIAL millivolts |
|---|---|---|---|
| SINGLE POINT Detail Curve | SHORT NORMAL 16 Inch 0 — 200; X10 BACK UP 0 — 2000; LONG NORMAL 64 Inch 0 — 200; X10 BACK UP 0 — 2000 | | 5 mv |




welenco

ELECTRIC LOG

| | |
|---|---|
| FILING NO. | COMPANY NDOT |
| | WELL WASHOE LAKE WETLAND |
| | FIELD WASHOE STATE PARK |
| | COUNTY WASHOE STATE NEVADA |
| JOB NO. 25144 | LOCATION: HWY.395 & E.LAKE BLVD. 1 MILE EAST — SEC TWP RGE |
| OTHER SERV | GAMMA RAY, CALIPER |

Permanent Datum: G.L. Elev: N/A — K.B.
Log Measured From G.L. 0 Ft Above Perm Datum — D.F.
Drilling Measured From G.L. — G.L.

| | | | |
|---|---|---|---|
| Date | 11-13-95 | - - | - - |
| Run No. | ONE | | |
| Depth - Driller | 321' | | |
| Depth - Logger | 322' | | |
| Btm. Log Inter. | 321' | | |
| Top Log Inter. | 50' | | |
| Casing-Driller | 30" at 57' | at | at |
| Casing-Logger | 30" at 57' | at | at |
| Bit Size | 17.5" | | |
| Type Fluid In Hole | BENTONITE | | |
| Dens. \| Visc. | N/A \| N/A | | |
| pH \| Fluid Loss | N/A \| N/A ml | ml | ml |
| Source of Sample | PIT | | |
| Rm at Meas.Temp | 12.0 at 52 F | at F | at F |
| Rmf at Meas.Temp | 12.0 at 52 F | at F | at F |
| Rmc at Meas.Temp | N/A at F | at F | at F |
| Source: Rmf Rmc | MEAS | | |
| Rm at BHT | N/A at F | at F | at F |
| Time Since Circ. | 6 HR. | | |
| Max. Rec. Temp. | N/A F | F | F |
| Equip \| Location | L-11 \| STK. | | |
| Recorded By | M.SHARPLESS | | |
| Witnessed By | D.SMITH | J.MURDOCK | G.ZUNINO |

EQUIPMENT DATA

| LOG TYPE | GAMMA RAY | CALIPER | |
|---|---|---|---|
| RUN NO. | ONE | ONE | |
| TOOL MODEL NO. | MW-1 | MLS-TAC | |
| TOOL SERIAL NO. | #127 | T-132 | |
| DIAMETER | 2.5" | 1.25" | |
| DETECTOR TYPE | SCINT. | PULSE | |
| DETECTOR LENGTH | 4" | 12" | |
| UNITS/DIV. | 18 API | 1 INCH | |
| SENSITIVITY | 100/151 | 500/500 | |
| ZERO DIV L OR R | 0-L | 0-L | |
| SPEED-FPM | 18 | 35 | |
| DATA SAMPLES/FT. | 2 | 2 | |
| FORMATION FACTOR | N/A | N/A | |
| PUMP RATE-GPM | N/A | N/A | |
| PUMP RATE-GPM | | | |
| PUMP RATE-GPM | | | |

| SOURCE TYPE | STRENGTH | SPACING | MODEL NO | SERIAL NO. |
|---|---|---|---|---|
| | | | | |

PERFORATIONS: NONE

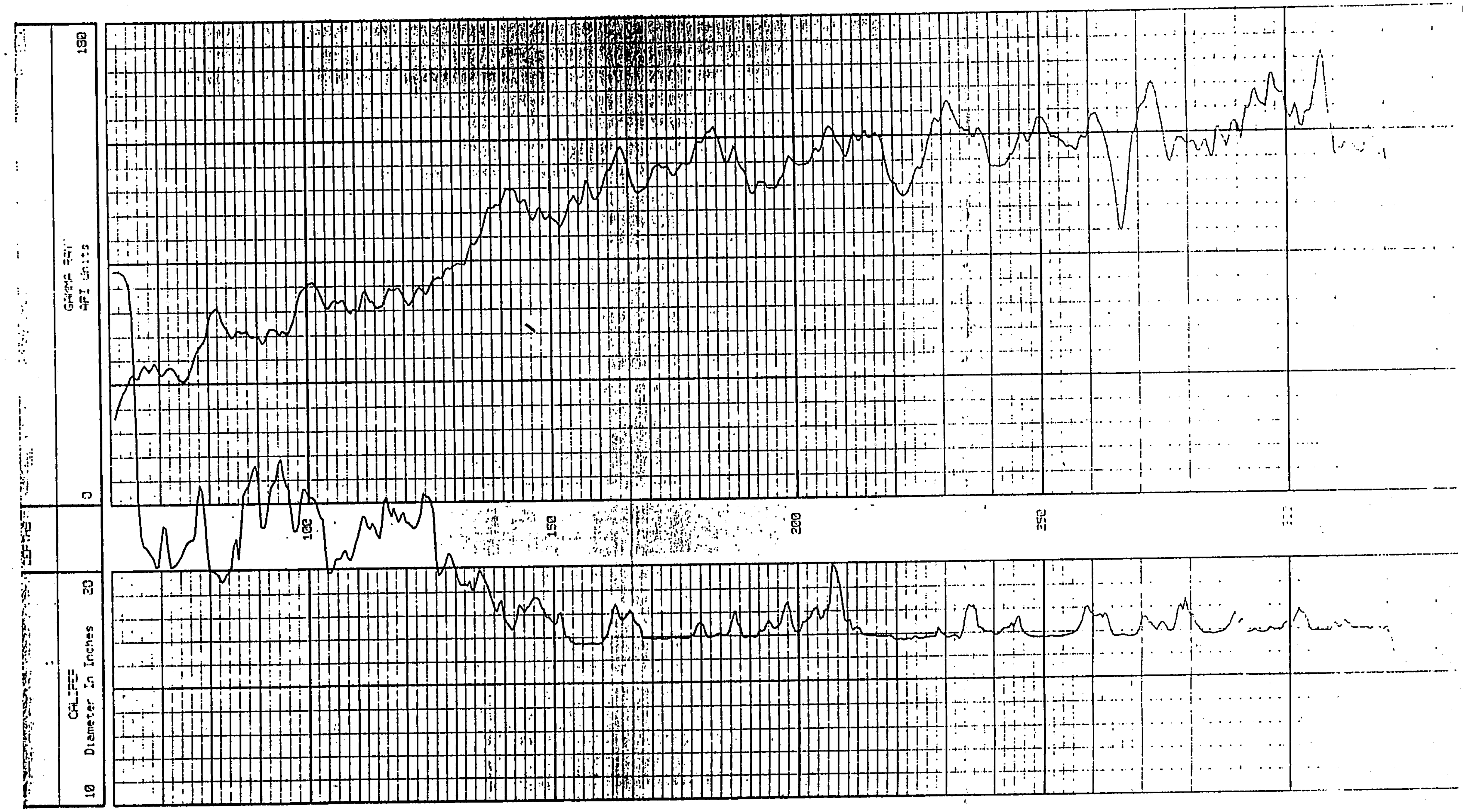
REMARKS: LOG PRESENTATION AT CUSTOMER ORDER.

NOTICE:
All interpretations are opinions based on inferences from electrical or other measurements and we cannot, and do not guarantee the accuracy or correctness of any interpretations, and we shall not, except in the case of gross or willful negligence on our part, be liable or responsible for any loss, costs, damages or expenses incurred or sustained by anyone resulting from any interpretation made by one of our officers, agents or employees. These interpretations are also subject to our General Terms and Conditions as set out in our current Price Schedule.
WELENCO, INC.

welenco

GAMMA RAY-CALIPER LOG

| | | |
|---|---|---|
| FILING NO. | COMPANY NDOT<br>WELL WASHOE LAKE WETLAND<br>FIELD WASHOE LAKE STATE PARK<br>COUNTY WASHOE STATE NEVADA | |
| JOB NO. 95144 | LOCATION: HWY. 395 & E.LAKE BLVD.<br>1 MILE EAST<br>SEC TWP RGE | OTHER SERV:<br>E-LOG |
| PERMANENT DATUM: G.L. ELEV: N/A<br>LOG MEASURED FROM G.L. 0 FT ABOVE PERM DATUM<br>DRILLING MEASURED FROM G.L. | | ELEVATION:<br>KB.<br>DF.<br>GL. |




| DATE | 11-13-95 | 11-13-95 | |
|---|---|---|---|
| TYPE OF LOG | GAMMA RAY | CALIPER | |
| RUN NO. | ONE | ONE | |
| DEPTH - DRILLER | 321' | 321' | |
| DEPTH - LOGGER | 322' | 322' | |
| BOTTOM LOGGED INT | 321' | 321' | |
| TOP LOGGED INT | 60' | 60' | |
| TYPE FLUID IN HOLE | BENTONITE | BENTONITE | |
| FLUID LEVEL | FULL | FULL | |
| MAX TEMP DEG F | N/A | N/A | |
| OPERATING RIG TIME | .75 HR. | .5 HR. | |
| EQUIP. LOCATION | L-11 STK. | L-11 STK. | |
| OPERATOR | M.SHARPLESS | M.SHARPLESS | |
| WITNESSED BY | D.SMITH | J.MURDOCK | G.ZUNINO |

| RUN | BORE HOLE RECORD | | | CASING RECORD | | | |
|---|---|---|---|---|---|---|---|
| NO. | BIT | FROM | TO | SIZE | TYPE | FROM | TO |
| 1 | 17.5" | 57' | TD | 30" | STEEL | SURF | 57' |
| | | | | | | | |
| | | | | | | | |

**HIGH DESERT LABORATORIES**
**INCORPORATED**

Client: SEA, Incorporated
Address: 950 Industrial Way
Sparks, Nevada 89431
Phone Number: 358-6931
Date Sampled: 11/18/96 Date Submitted: 11/18/96
Client Reference: sample labeled NDOT Well.
Laboratory Reference Numbers: 96-2405 through 96-2407.
Analysis Performed: Hydrogen Activity, Total Alkalinity, Total Dissolved Solids, Chloride, Fluoride, Nitrogen as Nitrate, Sulfate and Total Metals as below.

| Analysis | Result |
|---|---|
| pH, SU | 7.70 |
| Total Alkalinity, as mg $CaCO_3$/L | 81 |
| Bicarbonate, mg/L | 99 |
| Carbonate, mg/L | N/P |
| Total Dissolved Solids, mg/L | 116 |
| Chloride, mg/L | <5.0 |
| Nitrate (as N), mg/L | <0.5 |
| Sulfate, mg/L | <10 |
| Arsenic, mg/L | 0.005 |
| Calcium, mg/L | 15 |
| Iron, mg/L | 0.78 |
| Magnesium, mg/L | 2.1 |
| Manganese, mg/L | 0.17 |
| Potassium, mg/L | 2.2 |
| Sodium, mg/L | 16 |

Note:
N/P is equivalent to "not present" by the acid neutralizing definition of alkalinity.

Analysis By: Hlubucek/Sharp

Approved By: C. W. Sharp

Date: 12/5/96
Laboratory Report Number 4650

**CHEMAX Laboratories, Inc.**

Analytical and Environmental Chemists
EPA Lab ID #NV004

(702) 355-0202
Fax (702) 355-0817

# LABORATORY REPORT

Report To: High Desert Laboratories, Inc.
321 Freeport Boulevard
Sparks, NV 89431

Lab Report No.: 16398
Account No.: HDLAB

Telephone: 359-0330

Fax: 359-4106

Work Authorized By: Bill Sharp
Date Sampled: 11/18/96
Number of Samples: 1
Source: SEA, NDOT Well
Chemax Control No. 96-8325
Notes:

Date Submitted: 12/10/96
Sampled By: Client
Your Reference:

| Parameter | Results |
|---|---|
| Boron, mg/L | <0.05 |
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |

Remarks:

Analysis By: Faulstich

Date: 12/17/96

Approved By: [signature]

Date: 12/17/96



992 Spice Islands Drive, Sparks, Nevada 89431 • P.O. Box 21122, Reno, Nevada 89515

# CHAIN OF CUSTODY RECORD

| | |
|---|---|
| Client Name: SEA Inc | Phone Number: |
| Client Address: 950 Industrial Way | PO Number: |
| City, State, Zip: Sparks 89431 | |
| Project Name: | Project Number: |
| Report Attention: Dwight Smith | Sampled By: Mike Griswold |

| Sample number | Date sampled | Time sampled | Type Composite or Grab | Sample description | Number of Containers | General Panel / Mineral | | | | | | | | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| N/A | 11/18/96 | 1000 | G | NDOT Well | (3) | | | | | | | | | Ø/$HNO_3$/$H_2SO_4$ |

| | Signature | Company | Date | Time |
|---|---|---|---|---|
| Relinquished by | Mike Griswold | [illegible] | 11/18/96 | 0420 |
| Received by | Bill Sharp | HDL | 11/18/96 | 0420 |
| Relinquished by | | | | |
| Received by | | | | |
| Relinquished by | | | | |
| Received by | | | | |

HIGH DESERT LABORATORIES INCORPORATED
321 Freeport Blvd. Sparks, Nevada 89431
P.O. Box 6535 Reno, Nevada 89513
FAX (702) 359-4106
(702) 359-0330

A Report Prepared For

State of Nevada
Department of Transportation
1263 South Stewart Street
Carson City, Nevada 89712

# HYDROGEOLOGIC EVALUATION WASHOE LAKE MITIGATION AREA WASHOE COUNTY, NEVADA

Project No. 24586.1

By

Hayden Bridwell
Staff Geologist

W. Cliff Yeckes, P.G.
Managing Principal Hydrogeologist
Nevada Environmental Manager #EM-1014

Harding Lawson Associates
4170 South Decatur Boulevard, Suite A-1
Las Vegas, Nevada 89103
(702) 251-5449

September 21, 1993

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# 1.0 INTRODUCTION

Harding Lawson Associates (HLA) is pleased to provide this hydrogeologic evaluation of the Washoe Lake Mitigation Area conducted for the Nevada Department of Transportation (NDOT). This scope of work was described in HLA's Task Order 1 dated May 6, 1993. The Task Order was approved May 11, 1993, by Daryl N. James of the NDOT.

## 1.1 Purpose

The NDOT plans to create 269 acres of wetlands along the southern fringe of Washoe Lake in Washoe County, Nevada. The purpose of this project was to conduct a hydrogeologic evaluation of the Washoe Lake Mitigation Area to evaluate the possibility and cost-effectiveness of using groundwater wells as a means to inundate the required acreage during periods of inadequate surface water availability.

## 1.2 Scope

HLA accomplished the above purpose by performing the following:

- A water well usage survey utilizing Well Driller's Reports for domestic and agricultural wells located in the Washoe Valley within a 2 mile radius of the mitigation area.
- A review of maps and analytical reports summarizing geologic, hydrologic, hydrogeologic, and soils characteristics of the Washoe Valley area.
- A review of Water Chemistry Analysis records compiled by the Nevada Division of Health for groundwater samples recovered from wells within a 2 mile radius of the mitigation area.
- The performance and data analysis of a geophysical resistivity survey conducted in the mitigation area.
- The preparation of this report summarizing the findings.

## 1.3 Background

The Washoe Lake mitigation area encompasses approximately 269 acres along the southern fringe of Washoe Lake in Washoe County, Nevada. A location map is shown on Plate 1. The mitigation area is bounded by levees to the north and south, Highway 395 to the west, and East Lake Boulevard to the east. A site plan is shown on Plate 2. The NDOT plans to construct four additional levees parallel to the existing ones. Once completed, 140 acres will be inundated with water. The area must remain flooded to retain its wetlands status, and as surface water recharge is not dependable, NDOT desires to establish groundwater as an alternate water source, if possible.

The NDOT has calculated that approximately 700 acre feet of water per year will be required to inundate the area, excluding all other sources. The 700 acre feet may need to be supplied in a period of less than 1 year as significant fluctuations in surface water availability within the mitigation area occurs as a result of seasonal fluctuations. Based on discussions with NDOT, a production rate of 700 acre feet in a six month period (summer) was assumed. This would require construction of a groundwater production well or wells capable of continuously producing approximately 1,000 gallons per minute. Little or no information regarding groundwater quality, availability, production, etc., has been developed for the NDOT Washoe Lake Mitigation Area. As a result, HLA has conducted a preliminary hydrogeologic evaluation in an attempt to avoid the high costs of well installation, should the subsurface conditions prove unfavorable to groundwater development, or the groundwater quality prove unacceptable to the area wildlife.

# 2.0 GENERAL SITE CHARACTERIZATION

## 2.1 Location

The NDOT Washoe Lake Mitigation Area encompasses approximately 269 acres along the southern fringe of Washoe Lake in Washoe County, approximately 3 miles north of Carson City, Nevada. Specifically, the site is located in portions of the southeast 1/4 of Section 23, southern portion of Section 24, 1/4 of the southwest 1/4 Section 19, northwest 1/4 of the northwest of Section 30, northern portion of Section 25, and the northeast 1/4 of the northeast 1/4 of Section 26, Township 16 north, Range 20 east, Mount Diablo Base and Meridian (Plate 1). The mitigation area is bounded by levies to the north and south, Highway 395 to the west, and East Lake Boulevard to the east (Plate 2).

## 2.2 Topography

The topography in the mitigation area consists of the relatively level alluvial floor of the Washoe Valley which is bounded on the west by the Carson Range, a frontal range of the Sierra Nevada, and on the east by the Virginia Range (maximum altitudes of approximately 9,900 and 7,500 feet above sea level, respectively). The altitude of the valley floor is approximately 5,050 feet above sea level (Arteaga & Nicols, 1984). The valley floor slopes gently to the north, with a maximum slope of approximately 1.3%.

The most prominent physiographic feature of the Washoe Valley is Washoe Lake, which comprises approximately 7.5 square miles when full. Washoe Lake overflows northward into smaller Little Washoe Lake which empties into Steamboat Creek, a tributary of the Truckee River located approximately 13 miles north of the valley (Arteaga & Nicols, 1984).

## 2.3 Site Description

The site is presently composed of grass pasture-lands and inundated areas. The mitigation area is bordered by Highway 395 to the west, East Lake Boulevard to the east, and levees (approximately six feet above the valley floor) to the north and south. McEwen Creek, flowing east from the Carson Range, flows through the site from the south, emptying into Washoe Lake (Plate 2). The levy on the northern border of the site retains a portion of McEwen Creek, inundating the area adjacent to the southern edge of the levee.

Privately-owned ranches maintain cattle on the fenced pasture-lands. The pastures are irrigated via water pumped from Washoe Lake. Nesting and migratory waterfowl inhabit the area.

## 2.4 Wetlands Status

In 1989, the NDOT established the Washoe Lake Mitigation Area to replace wetlands lost or impacted as a result of highway construction activities in west-central Nevada (James, 1991).

# 3.0 ENVIRONMENTAL SETTING

## 3.1 Climate

Precipitation generally moves eastward across the Washoe Valley. As moisture-bearing air masses move eastward across the Sierra Nevada Mountains, they rise and cool, causing precipitation. Unless the air mass is very moist, it will contain little moisture by the time it reaches the Washoe Valley. This "rain shadow" effect results in a mean annual precipitation rate of approximately 10 inches per year in the Washoe Valley, while this rate is as high as 60 inches per year in the highest regions of the adjacent Carson Range to the west (Arteaga & Nicols, 1984).

Winters in the Washoe Valley are long, with moderate amounts of snow on the valley floor. Snowfall in the surrounding Carson and Virginia Ranges can be quite heavy. Temperatures in the short summer season range from 70-85 degrees (F) warm during the day to 50-40 degrees (F) at night. With the exception of occasional thunderstorms, summer precipitation is rare (Rush, 1967).

Precipitation in recent years has been below normal. In late spring of 1991, Washoe Lake dried up as a result of drought conditions (James, 1991). Subsequent precipitation, however, has re-established much of the lake and surrounding wetlands.

## 3.2 Geology

Washoe Valley is a basin filled with Quaternary alluvial deposits shed from the surrounding Carson and Virginia Ranges, and lake bed deposits near the margin of Washoe Lake. Alluvial deposits consist of poorly-bedded gravel with sand. Lake bed deposits consist of well-bedded silt and sand (Trexler, 1977). According to the "Washoe City Folio Geologic Cross Sections Map" (Tabor & Ellen, 1976), alluvium is up to 1,500 feet thick approximately 1.5 miles north of the mitigation area.

In the vicinity of the mitigation area, the Carson and Virginia Ranges consist of Cretaceous granodiorite overlain by Tertiary volcanics (Trexler, 1977).

Well logs reveal that the bedrock under Washoe Valley is not significantly fractured and/or water-bearing.

## 3.3 Faulting

In the assessment of aquifer production an important factor relates to recently documented surficial displacement. Faulting and displacement can result in significant variations in groundwater production by causing groundwater level fluctuations, "no flow" boundaries, vertical impermeable zones, etc. The more recent the latest displacement along a fault, the more likely movement will occur during the life of the project effecting groundwater production or the water distribution system. Holocene-age faults (from approximately 0 - 12,000 years before present) are considered to be more probable sites for near-future earthquake events than are Pleistocene-age faults (from approximately 12,000 - 2,000,000 years before present).

The most current and applicable published information is the "Earthquake Hazards Map, Carson City Quadrangle" (Trexler & Bell, 1979). The map indicates a Pleistocene-age fault directly south of the mitigation area. Although this fault trends toward the site, no surface expression is visible on the map, aerial photographs, or on the ground surface.

Therefore, based on published information, aerial photograph review and field evidence, it is HLA's opinion that minimal hydrogeological impacts from faulting are anticipated. Additional information may be developed following future pump testing.

## 3.4 Hydrogeology

The following information and data were derived from Rush (1967).

The coefficient of transmissivity is the measure of the resistance to groundwater flow in an aquifer. The coefficient of storage in a heterogeneous valley-fill reservoir is a measure of the amount of downward drainage of water as water levels are lowered by pumping. When utilized together, these two coefficients can be used to describe the distribution and amount of water-level decline that would result under specific pumping conditions.

The coefficients of transmissivity and storage were determined for two wells located in the Washoe Valley, approximately 2.5 miles northeast and 3 miles northwest, respectively, of the mitigation area. These values were 50,000 gallons per day (gpd) per foot, and 150,000 gpd per foot. It is not uncommon for these values to fluctuate widely in alluvial deposits such as seen in the Washoe Lake area. The following are possibilities for the fluctuations in values:

- A wide range in the water-yielding properties of the valley fill from one place to another, which could be attributed to varying subsurface soil types, in particular decomposed granitic detritus.

- Most water production seems to be associated with and derived from sand lenses, which require special techniques in well construction and development to obtain an acceptable well.

- Many of the low-yielding wells in the valley are less than 200 feet deep, suggesting that a considerable thickness of valley fill must be penetrated to obtain large well yields.

Recoverable groundwater in storage is that part of the water moving through the valley fill reservoir that will drain by gravity in response to pumping. Recoverable groundwater in storage is the product of the specific yield, the area of the groundwater reservoir, and the selected saturated thickness of the alluvium. Specific yield of a soil is the ratio of the volume of water which the groundwater reservoir will yield by gravity to the reservoir volume. This ratio is stated as a percentage. In the Washoe Valley, the average specific yield of the valley fill reservoir is approximately 15%. The selected thickness of the aquifer used in this estimation was the uppermost 100 feet.

Based on Rush's data, a rough estimate of recoverable groundwater for the Washoe Lake Mitigation Area can be made. Using a surface area of 269 acres multiplied by the selected depth of 100 feet and multiplied by the drainable volume of 15%, the estimated recoverable groundwater in storage for the mitigation area is 4,035 acre feet.

Wells that penetrate more than the upper 100 feet of the aquifer, however, will have the potential of yielding greater volumes of water than the above calculation suggests. The apparent variable characteristics of subsurface soils must also be considered when making these estimations.

### 3.5 Surface Hydrology

Depth to groundwater in the mitigation area generally varies from 0 to 5 feet below ground surface (Rush, 1967). Water stored in Washoe Lake and Little Washoe Lake, and in inundated areas, can be considered rejected groundwater recharge. If the valley fill reservoir is not fully or nearly saturated, much of this surficial water would infiltrate.

McEwen Creek, flowing east from the Carson Range, flows through the mitigation area from the south, emptying into Washoe Lake (Plate 2). Stream flow for McEwen Creek was measured for the months of May through November, 1966 (Rush, 1967). For this period of time, the flow for McEwen Creek averaged 0.25 cubic feet per second.

Several other streams located to the north of the mitigation area flowing from the Carson and Virginia Ranges also drain into Washoe Lake. Water in Washoe Lake flows to the north into Little Washoe Lake, which empties into Steamboat Creek, a tributary of the Truckee River located approximately 13 miles to the north of the valley (Arteaga & Nicols, 1984).

Precipitation for the Washoe Valley averages approximately 10 inches per year (Arteaga & Nicols, 1984). In years of normal precipitation and stream runoff, Washoe Lake remains full, and the surrounding wetlands remain inundated and/or moist. During drought years, however, Washoe Lake and the surrounding inundated areas may dry up. Over the last several years, Washoe Lake has been dry due to low precipitation. The lake is filling now due to the abundant snow pack from the 1992-1993 winter.

Since the mitigation area remains saturated in the winter and spring months during years of normal precipitation and stream runoff, the operation of groundwater wells for surficial water supply may be minimal during these naturally wet periods. Groundwater demand for the maintenance of wetlands, however, will be much higher during dry months and drought periods.

### 3.6 Soils

Soil types and characteristics are important aspects when considering the amount of available groundwater, and the ease at which it may be accessed. Soils consisting mainly of clays and silts may be reservoirs for large quantities of groundwater, but will not easily yield the water. Conversely, aquifers consisting of large amounts of uncemented sand and/or gravel may contain and yield large volumes of groundwater.

According to Baumer (1978), the soils in the mitigation area were formed from detritus derived dominantly from the surrounding granitic rocks, and consist mainly of slightly to strongly saline loamy sands. A loam is defined as a soil material that is 7% - 27% clay, 28% - 50% silt, and less than 52% sand.

Permeability is the quality of the soil that enables water to move downward through the profile. A high permeability would enable surficial water to recharge subsurface aquifers at a high rate, resulting in a potential for large quantities of groundwater. The permeability of soils in the mitigation area is moderately rapid (6.0 - 20 inches per hour) (Baumer, 1978).

Baumer's research suggests that soils in the mitigation area may provide favorable reservoirs for large quantities of groundwater.

# 4.0 DATA GATHERING AND ANALYSES

The following sections describe the field, research, and analytical techniques used to obtain the objectives of this project.

## 4.1 Literature Search

During the week of May 17, 1993, an HLA geologist visited the following facilities to review and/or obtain information pertaining to this project:

- Nevada Division of Water Resources, Carson City, Nevada: Obtained copies of Well Driller's Reports for 82 groundwater wells located within a 2 mile radius of the mitigation area, and copies of reports discussing the hydrologic, geologic, and hydrogeologic characteristics of the Washoe Valley area.

- U.S Geological Survey, Carson City, Nevada: Obtained reports discussing the hydrologic, geologic, and hydrogeologic characteristics of the Washoe Valley area.

- Nevada Bureau of Mines and Geology, Reno, Nevada: Obtained various geologic and hydrogeologic maps pertaining to the mitigation area.

A soil survey report of Washoe County was obtained from the United States Department of Agriculture, Soil Conservation Service, in Reno, Nevada.

All of the above-referenced literature was reviewed before preparation of this report.

## 4.2 Water Well Usage Survey

Well Driller Reports for groundwater wells located within a 2 mile radius of the mitigation area were reviewed. Data obtained from these reports are summarized in Appendix A.

In most cases, depth to water varies from surface to approximately 50 feet below ground surface. Well depths vary from 64 to 468 feet below ground surface. In all cases, well screen occurs toward the bottom of the interval, suggesting that water quality in Washoe Valley improves with depth.

Most well production rates were determined to be less than 50 gallons per minute (GPM). There were, however, 6 wells with reported production rates of 100 GPM or more. All of these higher-producing wells were deep (260 - 468 feet below ground surface), with some reaching bedrock.

These data suggest that a large diameter well installed and screened deep into the valley fill reservoir may have the potential to produce large quantities of high quality groundwater.

### 4.3 Water Chemistry Analyses

Water Chemistry Analysis reports were reviewed for analyses performed on groundwater samples recovered from wells located within a 2 mile radius of the site. Of the 21 samples recovered for analyses, 9 met the chemical quality of the State of Nevada Drinking Water Standards. The most frequent constituents exceeding the State Drinking Water Standards were iron and manganese. Fluoride, arsenic and zinc also exceeded State limits in some instances. Copies of the Water Chemistry Analysis reports are shown in Appendix B.

### 4.4 Geophysical Analysis

To delineate subsurface stratigraphy and potential groundwater-bearing horizons, HLA conducted a geophysical survey in the mitigation area on June 8 and 9, 1993. Details, results, data, figures, and recommendations from the survey are included in Appendix C.

Geophysical activities consisted of six direct-current resistivity soundings. The locations of the soundings, designated VES-1 through VES-6, are shown on Plate 1 in Appendix C. Each sounding measured vertical variations of electrical resistivity in the subsurface soils. Variations in resistivity can be associated with soil and pore water conditions to help predict favorable locations for future groundwater production wells.

On the basis of the electrical resistivity survey conducted for the mitigation area, the study area appears to consist of four major resistivity layers. It is assumed that the controlling factors effecting resistivity include a combination of subsurface soil types (i.e. clay, silt, sand, gravel), water quality [i.e. total dissolved solids (TDS), conductivity], and the presence of bedrock. Typically resistivity values decrease with an increase in water quality such as TDS. Clayey and silty soils will also contribute to low resistivity values. Coarse grained sediments such as sands and gravels that have low TDS porewater will generally exhibit higher resistivity values and offer a good potential for a future high-capacity groundwater well. Generally, little-weathered and unfractured bedrock has very high resistivity properties.

The four resistivity layers shown in the cross-sections on Plates 2 and 3 of Appendix C have the following characteristics:

TABLE 1 - APPARENT SUBSURFACE LAYERS

| Approximate Resistivity Range | Possible Hydrogeologic Properties |
|---|---|
| Less than 40 ohm-meters | Clayey or silty soils, possibly high TDS groundwater, |
| 40 to 90 ohm-meters | Clayey to sandy soils, intermediate TDS groundwater |
| 90 to 190 ohm-meters | Silty to sandy soils, low TDS groundwater, possible fractured/weathered bedrock |
| Greater than 190 ohm-meters | Rock or partially saturated sediments |

Layer 1 extends from the surface to depths ranging from less than 10 feet to approximately 150 feet below ground surface (bgs). Since resistivity values for Layer 1 are generally less than 40 ohm-meters, these subsurface soils are interpreted to be poor areas for water production due to the presence of fine grained materials and/or poor groundwater quality.

Layer 2 apparently consists of a number of different materials and is variable in thickness. Along the northern levy, Layer 2 has resistivity values ranging from 77 to 96 ohm-meters, and is thickest toward the center of the valley. Along the southern levy, Layer 2 has generally higher resistivity values ranging from 98 to 190 ohm-meters, and a thickness of up to 550 feet near the eastern margin of the levee (VES-4). The combination of the high resistivity and thickness of this layer make it attractive for high producing groundwater wells.

Layer 3 displays resistivity values ranging from 35 to 88 ohm-meters and a thickness of 500 to over 1,000 feet. The estimated depth to the top of Layer 3 is generally greater than 750 feet bgs. The combination of low resistivity and depth make this layer unattractive as an exploitable groundwater source.

Layer 4 is interpreted to be the approximate minimum depth to bedrock.

Layer 2 displays the most favorable characteristics for groundwater exploitation. The area near VES-4 and VES-5, adjacent to the southern levee, exhibit particularly favorable conditions for future wells. Groundwater wells of the appropriate depth and screened

Along the southern cross-section (Plate 3), Layer 2 has generally higher resistivity values of from 98 to 190 ohm—meters and a thickness of up to 550 feet near VES—4. The area near VES—5 and VES—4 exhibit particularly favorable conditions for a future well. The combination of high resistivity and a relatively thick layer suggests that a high producing, good-quality well may be located in this area. Another possible location for a favorable well site would be near VES—3, where a very thick layer of moderate resistivity (96 ohm—meters) indicates a thick permeable layer with the potential for high-production capacity. However, the water quality at VES—3 may not be as good as Layer 2 in the vicinity of VES—4. Other regions of Layer 2 have lower resistivity values and are interpreted to have less favorable conditions for a well.

Layer 3 has resistivity values ranging from 35 to 88 ohm—meters and a thickness of 500 to over 1,000 feet. The depth to the top of Layer 3 is generally greater than 750 feet below ground level. The combination of low resistivity and depth to this resistivity layer make it unattractive as an exploitable water source.

Layer 4 is interpreted to be the approximate minimum depth to electrically resistive bedrock. These data are based on including a resistive basement layer of greater than 1,000 ohm—meters during the computer modeling. This layer represents the interpreted minimum depth to unweathered, unfractured bedrock beneath the site. The accuracy of the modeled depth to Layer 4 cannot be reliably estimated but is assumed to be poor compared to the upper layers.

interval should be able to access large quantities of high quality groundwater in this area. With the gentle gradient down to the north, water may be pumped to the surface, and gravity fed to the rest of the mitigation area.

Another possible location for a favorable groundwater well would be adjacent to the northern levee near VES-3. Subsurface soils in this area include a very thick layer of moderate resistivity (96 ohm-meters), indicating a permeable layer that has the potential for high production capacity. The water quality at VES-3, however, may not be as good as Layer 2 in the vicinity of VES-4 and VES-5. Groundwater recovered from wells located adjacent to the northern levee would have to be pumped once it reached the surface to inundate areas up-gradient to the south.

## 5.0 DISCUSSION

Based on the results of the research and field activities described in preceding sections, it appears that hydrogeologic conditions in the mitigation area are favorable for production wells capable of providing groundwater of the quality and quantity necessary to fulfill the NDOT's requirements. Further, location of the wells in the southern most portion of the mitigation area to facilitate installation of a gravity fed distribution system also appears feasible.

At this time, HLA recommends that a single 10-14 inch diameter recovery well be installed at the location shown on Plate 2. This well should be drilled to a depth of approximately 600 feet below the ground surface and screened form approximately 150 feet to 550 feet (layer 2, as described by the geophysical survey). The specific screen interval and depth can be modified as necessary during drilling. As the hydrogeologic conditions appear favorable for the production well, the expense of placing a monitoring well or pilot hole does not appear justifiable. The costs for installation of a monitoring well (to 600 feet are simply to high to justify installing the target diameter production well. Design and generation of specifications for the production well is beyond the scope of this project and can be performed at a later date based on the requirements of NDOT.

A number of well drilling methods can be applied on this site to include reverse circulation rotary; air rotary with foam, etc. Selection of the method should be based on drillers experience, cost and impacts of drilling methods to the local wetlands environment.

All well installation activities should be overseen and soils classified by an experienced hydrogeologist.

It is unlikely that an individual well will produce the necessary quantity of water (+/- 1000 gpm). Based on the water well usage survey and hydrogeologic characteristics of the mitigation area, it appears reasonable to estimate that a 10-12 inch diameter well installed as summarized above will produce 350 to 500 gpm. Obviously, this estimate must be refined by pump testing the well following installation. Due to this estimated production rate and to provide a reasonable amount of redundancy, should a pump fail during a dry period, three wells should be planned. The exact locations (in the southern portion of the mitigation area), depths, etc. of the two additional wells can be formalized following installation and pump testing of the initial well.

As previously mentioned, pump testing of the initial well will be required to predict groundwater production rates, additional well locations, etc. It is recommended that following well development, a continuous 72 hour pump test be conducted, data reduced and hydrogeologic conditions evaluated. This test will provide quantitative data regarding:

- aquifer types,
- hydraulic conductivities,
- storage coefficient,
- well yields,
- long term production potentials,
- transmissivities,
- drawdowns,
- radius of influence, and
- potential difficulties due to hydrogeologic factors not identified during literature review, geophysical activities and well drilling.

It is also important to note that pumping may result in a more rapid lowering of existing surface water in the Washoe Lake (beyond the mitigation area). Further information regarding these impacts can be provided following pump testing.

HLA was informed by Mr. Al Porta of the Water Pollution Control Department of the Nevada Division of Environmental Protection (NDEP) that a National Pollutant Discharge Elimination System (NPDES) permit will not be required since the pumped groundwater will be used for wildlife maintenance, and not consumption. Upon NDOT's request, HLA will apply for a waiver of NPDES permit requirements from NDEP.

Design of the purging and distribution system can be provided by HLA upon request of NDOT.

# REFERENCES

Arteaga, F.E., & Nicols, W.D., 1984, Hydrology of Washoe Valley, Washoe County, Nevada: U.S.Geological Survey Open-File Report 84-465, 29 pp.

Baumer, O.W., 1978, Soil Survey of Washoe County, Nevada, South Part: United States Department of Agriculture, Soil Conservation Service, 608 pp.

James, D., 1991, Washoe Lake Mitigation Area, 1991 Annual Report: Unpublished report by the Nevada Department of Transportation to the U.S. Army Corps of Engineers, 5 pp.

Rush, F.E., Water-Resources Appraisal of Washoe Valley, Nevada: Nevada Department of Conservation and Natural Resources, Water Resources - Reconnaissance Series, Report 41, 39 pp.

Tabor, R.W., & Ellen, S., 1976, Washoe City Folio Geologic Cross Sections Map, Environmental Series: Nevada Bureau of Mines and Geology.

Trexler, D.T., 1977, Carson City Folio Geologic Map: Nevada Bureau of Mines and Geology, Environmental Series, Map No. 1ag.

Trexler, D.T., & Bell, J.W., 1979, Earthquake Hazards Map, Carson City Quadrangle: Nevada Bureau of Mines and Geology, Map No. 1Ai

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Carson City, Nevada 89712

Attn: Mr. Gary Zunino

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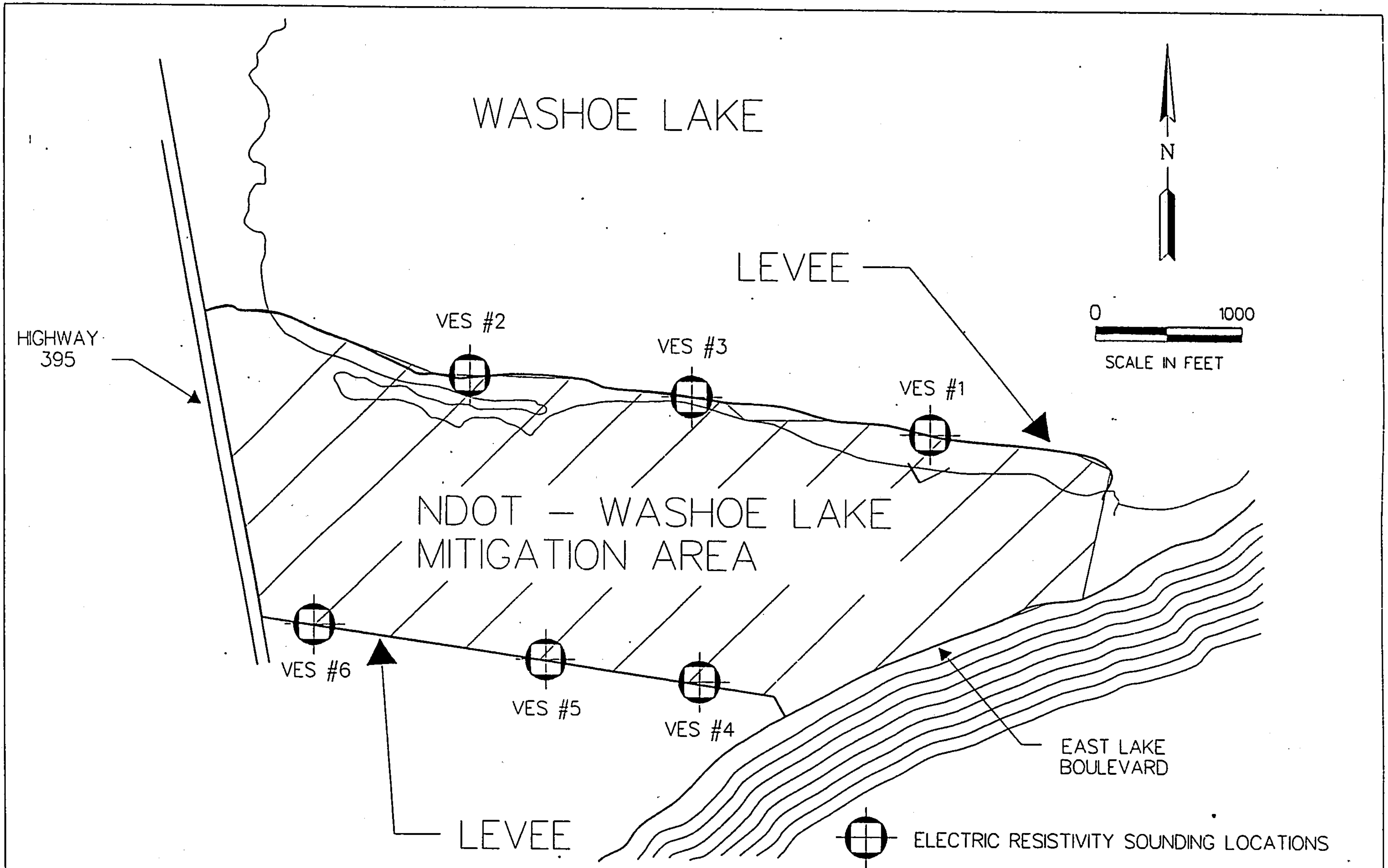
Quality Control Reviewer

Robert J. Gegenheimer
Project Geologist
Nevada Environmental Manager #EM-1228

HB/WCY/ccl



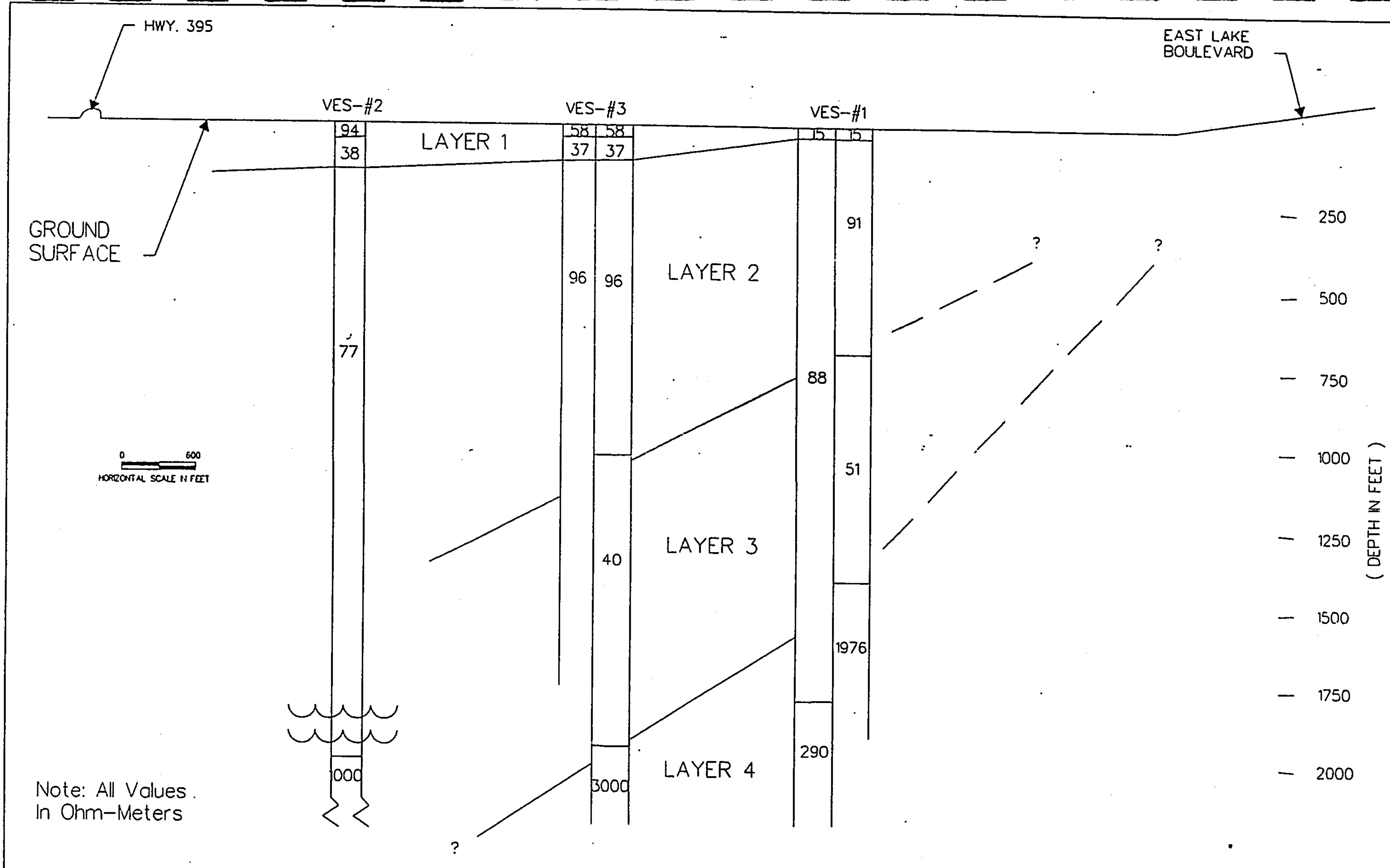

Harding Lawson Associates
Engineering and Environmental Services

# ELECTRIC RESISTIVITY SOUNDING LOCATIONS

NDOT – WASHOE LAKE MITIGATION AREA
WASHOE COUNTY, NEVADA

PLATE 1

| DRAWN | PROJECT NUMBER | APPROVED | DATE | REVISED DATE |
|---|---|---|---|---|
| KBH | 24586.1 | HS73 | 6/93 | |

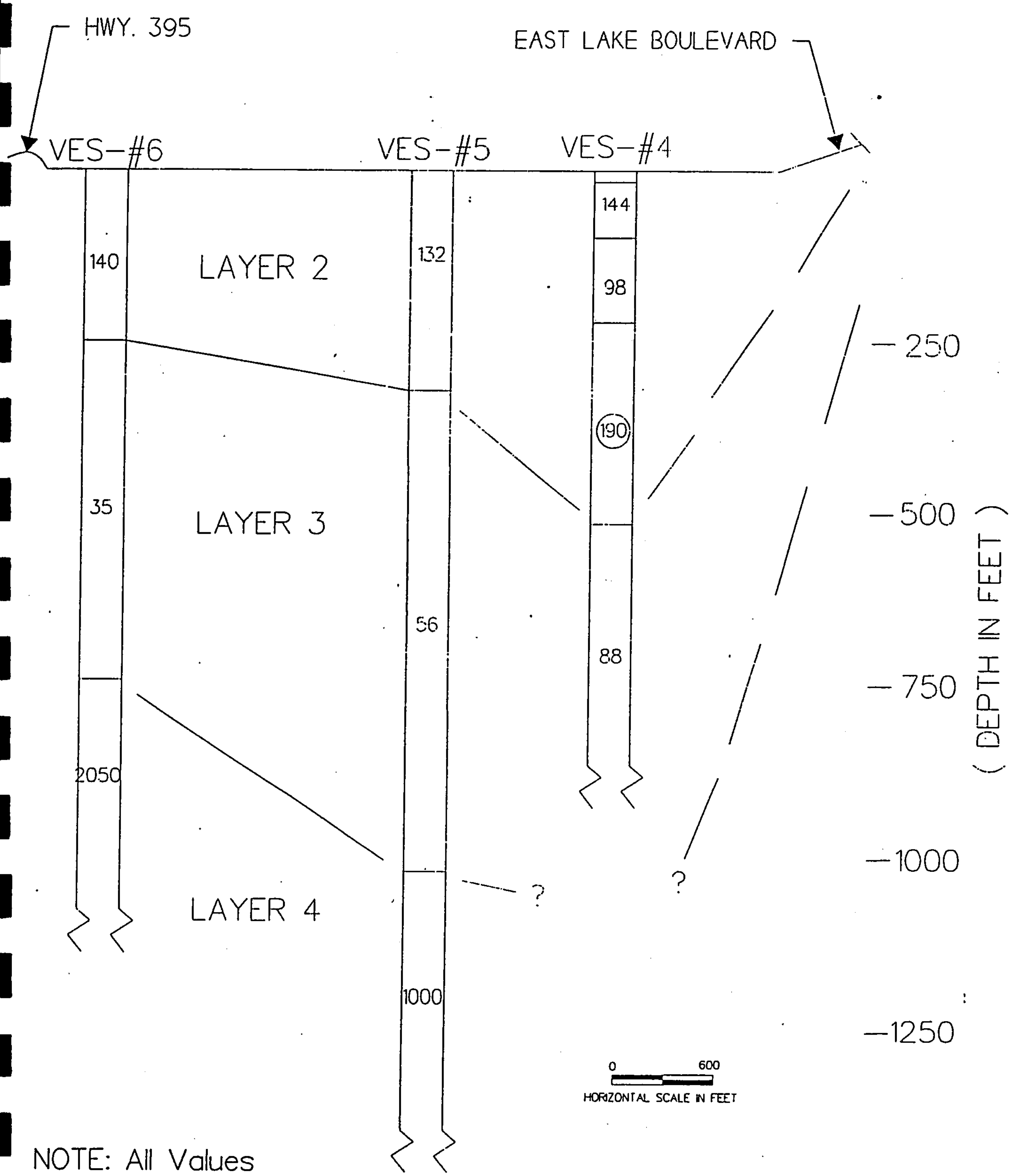



Harding Lawson Associates
Engineering and
Environmental Services

ELECTRICAL RESISTIVITY SURVEY/CROSS SECTION
PARALLEL TO NORTHERN LEVEE
NDOT WASHOE LAKE MITIGATION AREA
WASHOE COUNTY, NEVADA

PLATE 2

| DRAWN | PROJECT NUMBER | APPROVED | DATE | REVISED DATE |
|---|---|---|---|---|
| KBH | 24586.1 | [signature] | 7/93 | |



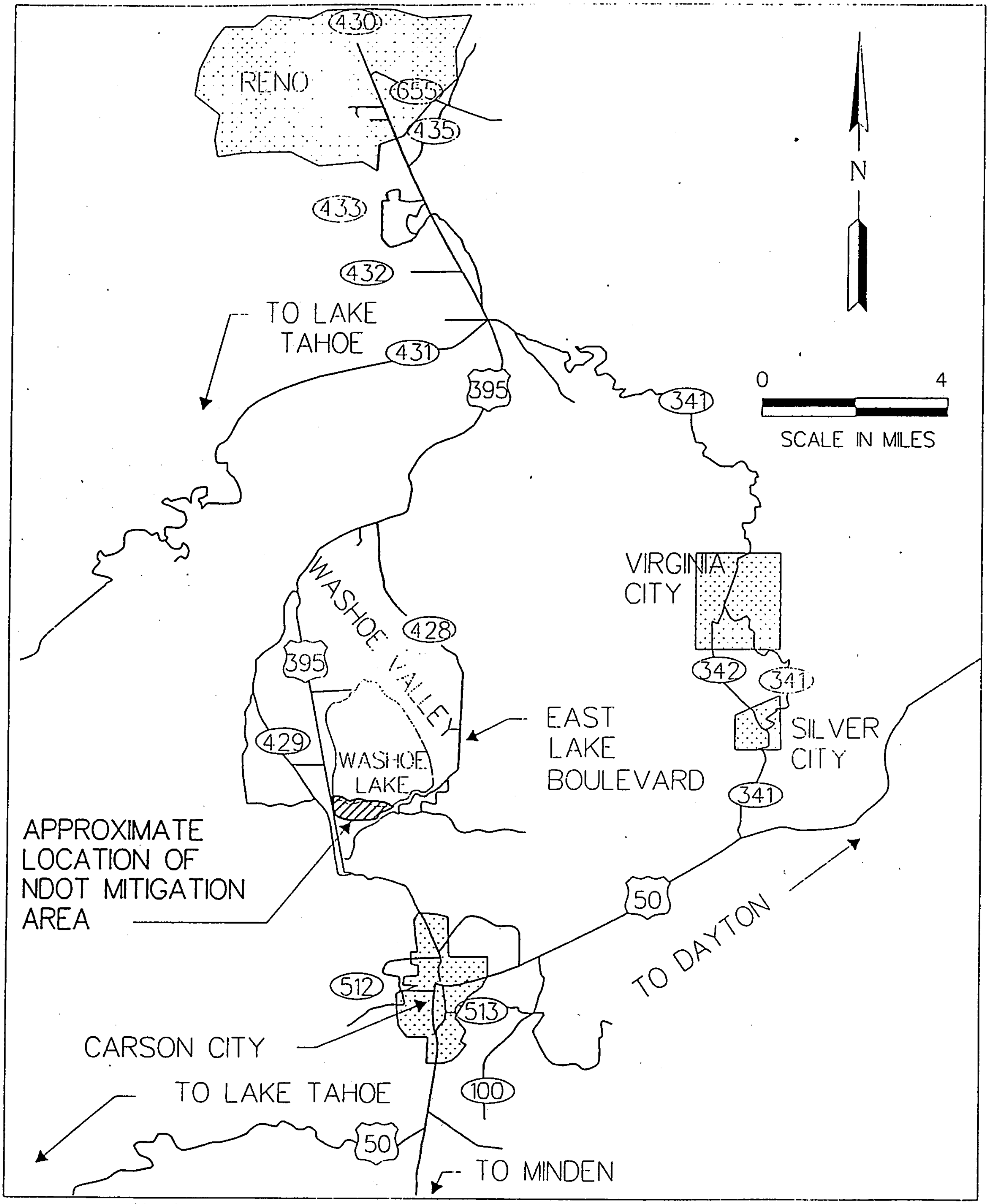

NOTE: All Values
In Ohm-Meters

Harding Lawson Associates
Engineering and
Environmental Services

ELECTRIC RESISTIVITY SURVEY/CROSS SECTION
PARALLEL TO SOUTHERN LEVEE
NDOT WASHOE LAKE MITIGATION AREA
WASHOE COUNTY, NEVADA

PLATE 3

| DRAWN | JOB NUMBER | APPROVED | DATE | REVISED DATE |
|---|---|---|---|---|
| KBH | 24586.1 | HB | 7/93 | |

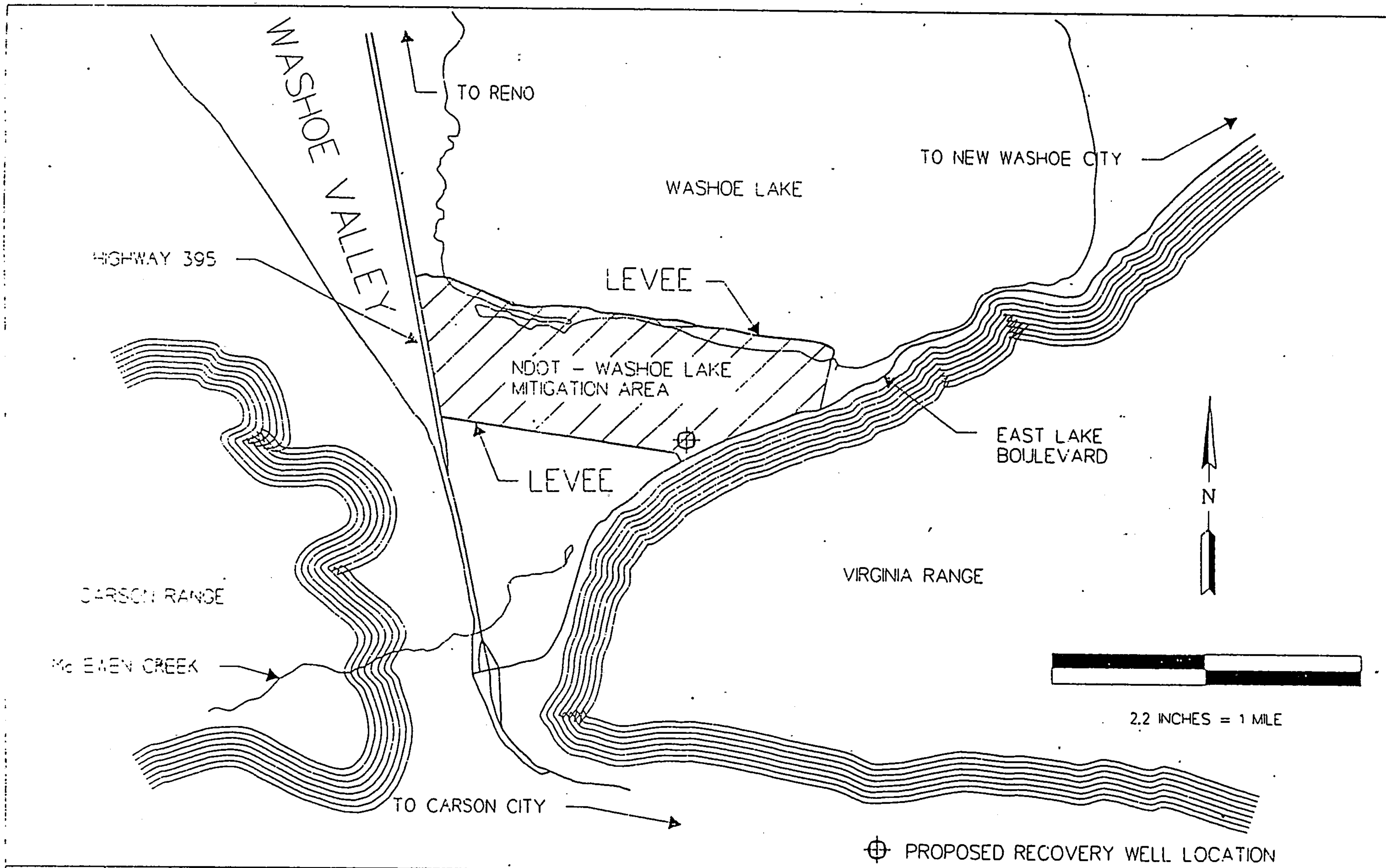



Harding Lawson Associates
Engineering and
Environmental Services

LOCATION MAP
NDOT – WASHOE LAKE MITIGATION AREA
WASHOE COUNTY, NEVADA

PLATE
1

| DRAWN | JOB NUMBER | APPROVED | DATE | REVISED DATE |
|---|---|---|---|---|
| KBH | 24586.1 | | 6/93 | |




Harding Lawson Associates
Engineering and
Environmental Services

SITE PLAN
NDOT -- WASHOE LAKE MITIGATION AREA
WASHOE COUNTY, NEVADA

PLATE
2

| DRAWN | PROJECT NUMBER | APPROVED | DATE | REVISED DATE |
|---|---|---|---|---|
| KBH | 24586.1 | [signature] | 6/93 | |

# APPENDIX C
# GEOPHYSICAL SURVEY

# Geophysical Survey

This appendix reports the results of Harding Lawson Associates' (HLA) geophysical survey at Washoe Lake State Park near Carson City, Nevada.

## INTRODUCTION

A direct current electrical resistivity survey was conducted to obtain information that will assist in delineating subsurface stratigraphy. The objective of this investigation was to provide information on the configuration of a possible permeable layer that may be suitable for the construction of a high—volume groundwater production well.

The geophysical field work was conducted on June 8 and 9, 1993, by HLA geophysicist Thomas Casebier with assistance from HLA engineer Kevin Dansie and HLA geologist Hayden Bridwell.

## SCOPE

Vertical electrical soundings (VES) were performed at six locations within the approximately 269—acre site. The soundings are designated VES—1 through VES—6. The approximate locations of each VES are shown on Plate 1. Location information was based on odometer readings made in the field from prominent surface features. Spatial restrictions due to flooded areas required that VES—1, VES—2, and VES—3 be oriented parallel to the east-west Lakeside Levee. VES—4 was oriented from southwest to northeast and VES—5 and VES—6 were oriented in the north—south direction.

## METHODS

### Direct Current (Dc) Resistivity

VES was used to measure vertical variations of electrical resistivity (the inverse of conductivity) of the soil. Variations in resistivity can be associated with soil and pore water conditions.

VES data were collected using the Schlumberger four—electrode array. This array consists of four earth-contacting electrodes arranged in a collinear array. Electrical current (I) is introduced into the earth through the two outer electrodes (A and B) while the resulting potential developed (delta V) is measured between the two inner electrodes (M and N). By separating the electrodes (A and B) by increasingly greater distances, the electrical current is forced to flow deeper into the subsurface, thus increasing the depth of investigation. Current electrode spacings (AB/2) were expanded from 4.64 meters (15.2 feet) to 681 or 1,000 meters (2,235 or 3,280 feet) to obtain resistivity layer information to a depth greater than approximately 500 feet. VES data were measured at AB/2 electrode spacing intervals corresponding to six measurements per decade.

The potential electrodes are maintained at a fairly close spacing relative to the current electrodes (AB/MN> = 5). MN is increased only when the potential becomes too small to measure accurately. Therefore, it is our procedure to repeat at least two readings using both the initial and the expanded MN. Any variation in the measurements can then be compensated for by shifting the data taken at the larger MN spacing to overlap those taken at the smaller MN. Each sounding required at least one MN shift.

## Field Procedures

The VES locations were determined in the field to avoid influences from cultural features and to provide maximum coverage of the survey area. The locations were also chosen in an attempt to avoid lateral resistivity variations that could adversely affect the validity of the one—dimensional VES modeling.

All VES data were measured using an HLA-built modular DC resistivity system. The transmitter system is powered by a motor-generator and a variable direct-current power supply capable of supplying approximately 1,000 watts. The current across the AB electrodes is controlled by a high-capacity manual switch and is measured on a digital multimeter with a maximum range of 20 amps. The AB electrodes were copper—clad steel stakes. The resistivity system was calibrated daily using a resistor test box with four resistance ranges.

# DATA ANALYSIS

Upon completion of the field work, the data were returned to our Novato, California, office for final interpretation.

## Resistivity Models

The program "VES32" distributed by ABEM AB was used to reduce the resistivity data. The program refines models (layered resistivity cases) for which the theoretical curve of measured resistivity versus the AB/2 spacing approximately matches the field data.

The program determines a combination of layer thicknesses and resistivities that gives the best possible fit to the measured data. These interpretations assume that the geology consists of generally flat lying, laterally uniform layers. Deviations from these conditions will produce errors in the interpreted layer parameters. In most cases, two models were considered for each VES dataset. Generally, the preferred model is the one having the fewest number of layers that gives an acceptable fit to the data.

Plates 2 and 3 present the interpreted model values for the VES data in the form of bar graphs superimposed on cross—sections. The preferred model(s) is presented showing the layer resistivity, thickness, and depth.

### Accuracy Estimate

The accuracy of electrical resistivity data depends on a number of factors including instrument precision, geologic inhomogeneities, and influences from cultural features. Typically, the accuracy of a VES depth model is 5 to 10 percent of the depth. The VES models can be refined by correlation with future boring(s) intercepting the aquifer near an existing VES.

## RESULTS AND DISCUSSION

On the basis of the electrical resistivity survey conducted for the study, the survey area appears to consist of four major resistivity layers. It is assumed that the factors affecting resistivity include a combination of the following: soil type (i.e., clay, silt, sand, gravel) water quality (i.e., total dissolved solids, conductivity) and the presence if bedrock. Typically resistivity values decrease with an increase in TDS. Clayey and, to a lesser extent silty soils, will also contribute to low resistivity values. Coarse-grained sediments such as sands and gravels that have low TDS pore water will generally exhibit higher resistivity values and are the target for a future high-capacity well. Generally, basement rock that is little-weathered and unfractured has very high resistivity properties. Bedrock weathering and fracturing will tend to lower these values and, therefore, some bedrock may have similar electrical properties to permeable sediments with low to moderate TDS.

The four resistivity layers shown in the cross-sections on Plates 2 and 3 can be summarized as follows:

| Approximate Resistivity Range | Possible Hydrogeologic Properties |
|---|---|
| Less than 40 ohm-meters | Clayey or silty soils, possibly high TDS groundwater |
| 40 to 90 ohm-meters | Clayey to sandy soils, intermediate TDS groundwater |
| 90 to 190 ohm-meters | Silty to sandy soils, low TDS groundwater, possible fractured/weathered bedrock |
| greater than 190 ohm-meters | Rock or partially saturated sediments |

Layer 1 extends from the surface to depths ranging from less than 10 feet to approximately 150 feet and covers much of the survey area. Resistivity values for Layer 1 are generally less than 40 ohm-meters. These materials are interpreted to be poor areas for water production due to the presence of fine-grained soil and/or poor quality groundwater.

Layer 2 probably consists of a number of different materials and is variable in thickness. Along the lakeside cross-section on Plate 2, Layer 2 has resistivity values of from 77 to 96 ohm-meters and is thickest toward the center of the valley. The thickness of Layer 2 along the lake ranges from approximately 700 feet at VES—1 to nearly 1,000 feet at VES—3.

SEA, Incorporated • 950 Industrial Way • Sparks, Nevada 89431 • (702) 358-6931 • Fax 358-6954

# MEMO

**TO:** Jim Murdock, Gary Zunino

**FROM:** Dwight Smith, Frank Alverson

**DATE:** November 14, 1995

**PROJECT:** NDOT

**PROJECT NO:** 990-009-882

**REGARDING:** Washoe Lake Wetlands Mitigation Area Well

Volcanic "bedrock" has been encountered during drilling at the wetlands well site. As discussed in our previous correspondence and communication, potential for encountering volcanic rock at the southeast corner of the wetlands mitigation area was anticipated by SEA, based on aerial geophysical data recently collected by Washoe County Public Utilities (potential not identified by previous hydrogeologic consultant). However, if volcanic rock is highly fractured and permeable, significant quantities of water can be produced. When encountered at 135 feet below ground surface, drilling was therefore recommended to be continued into the volcanic rock. Drilling was advanced approximately 187 feet into the rock for a total drilled depth of 322 feet below ground surface. Volcanic materials encountered were geologically logged as competent volcanic andesite with occasional thin fractured intervals. The consistency of drilled cuttings and drilling rates indicate a relatively uniform rock mass.

On November 13, 1995, electrical bore hole logging was performed to further evaluate the potential water yield properties of the volcanic rock. Electrical logging was interpreted in the field by the electric logging contractor, the driller, and SEA hydrogeologic staff. The logged volcanic rock does not appear to contain a high degree of fracturing or permeability which is critical to water yield and long-term water production. The consensus during site review of the electric logging data was that significant water production from the penetrated volcanic rock would not be expected. No data indicated that more favorable production conditions exist at greater depth, and while the conditions at greater depth are unknown, data to support continued drilling was not present. It was therefore the recommendation of SEA to NDOT to review and pursue more hydrogeologically favorable alternatives.

Several options were discussed:

1. Termination of drilling and completion of a small domestic-type well for water supply to future State Parks facilities,

2. Termination of drilling, abandonment of the open bore hole in accordance with State regulations, and termination of drilling contract with a future well to be drilled at another on-site location under a new contract,

3 Termination of drilling, abandonment of the open bore hole, and remobilization of the existing drilling contractor to a new drilling location, with provision of drilling service under a change order to the existing contract.

Items for consideration should include water rights concerns, project requirements and scheduling, contractual requirements, specific location for a second attempt at well drilling, etc. Water rights concerns are being addressed by Mr. Mike Buschelman at Summit Engineering. SEA hydrogeologic staff can assist in selection of a new drilling location upon request by NDOT.

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# MEMO

| | | | |
|---|---|---|---|
| **TO:** | Mr. Jim Murdock, Mr. Gary Zunino | **PROJECT:** | NDOT |
| **FROM:** | Dwight Smith | **PROJECT NO:** | 990-009-882 |
| **DATE:** | November 17, 1995 | | |
| **REGARDING:** | Washoe Lake Wetlands Mitigation Area Well | | |

As discussed in the meeting held at the office of SEA on November 16, 1995, we have conducted a review of hydrogeologic data in the vicinity of the wetlands mitigation projection. Data reviewed has included:

Washoe County Public Utility Division aerial geophysical survey data (see attached sketch),

Well logs in the vicinity of the site filed at the State Engineers office (see attached sketch),

Site resistivity survey data collected by Harding Lawson Associates,

Geologic mapping prepared by the Nevada Bureau of Mines and Geology (see attached copy),

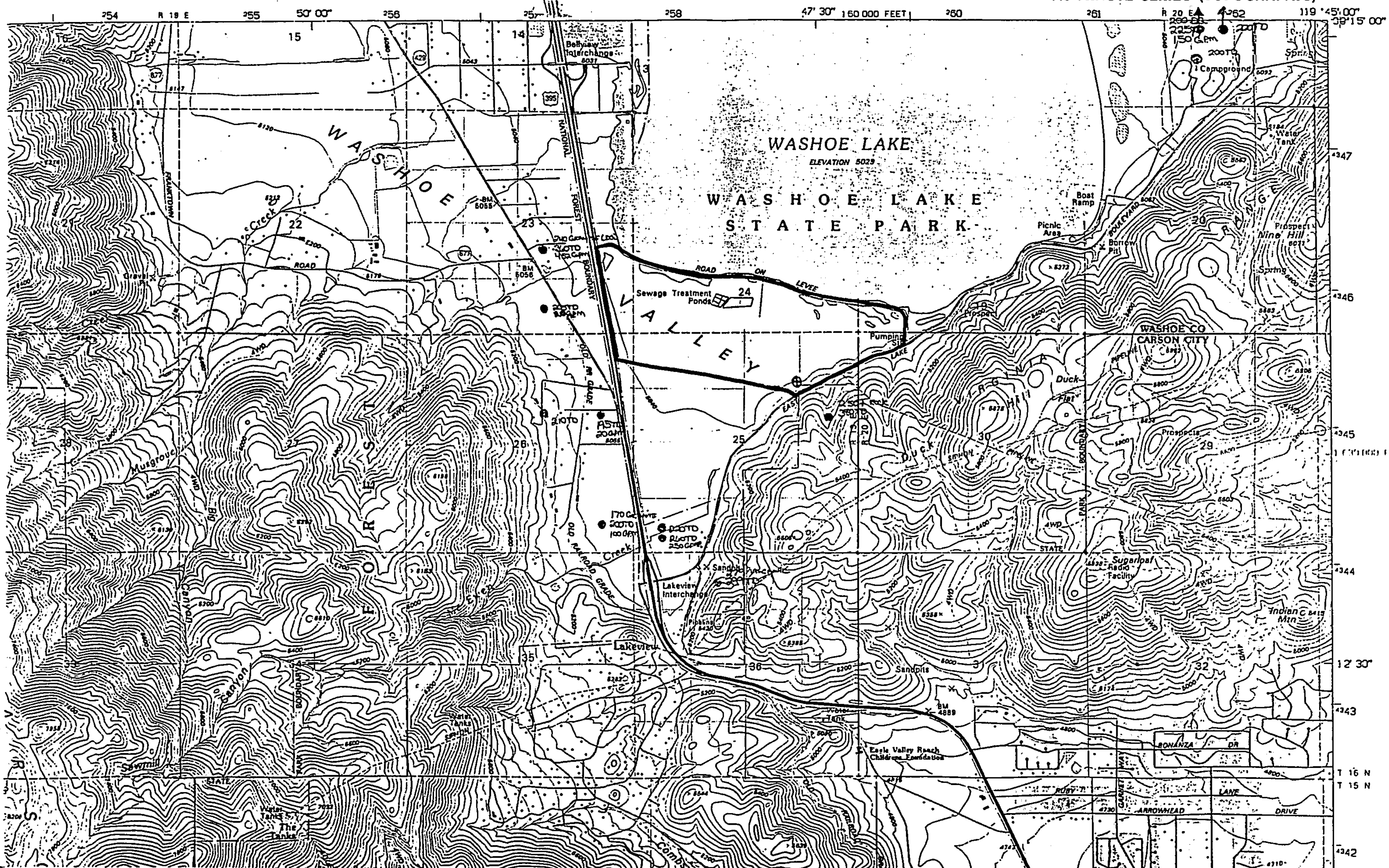
Field observations made during our recent hydrogeologic work at the site.

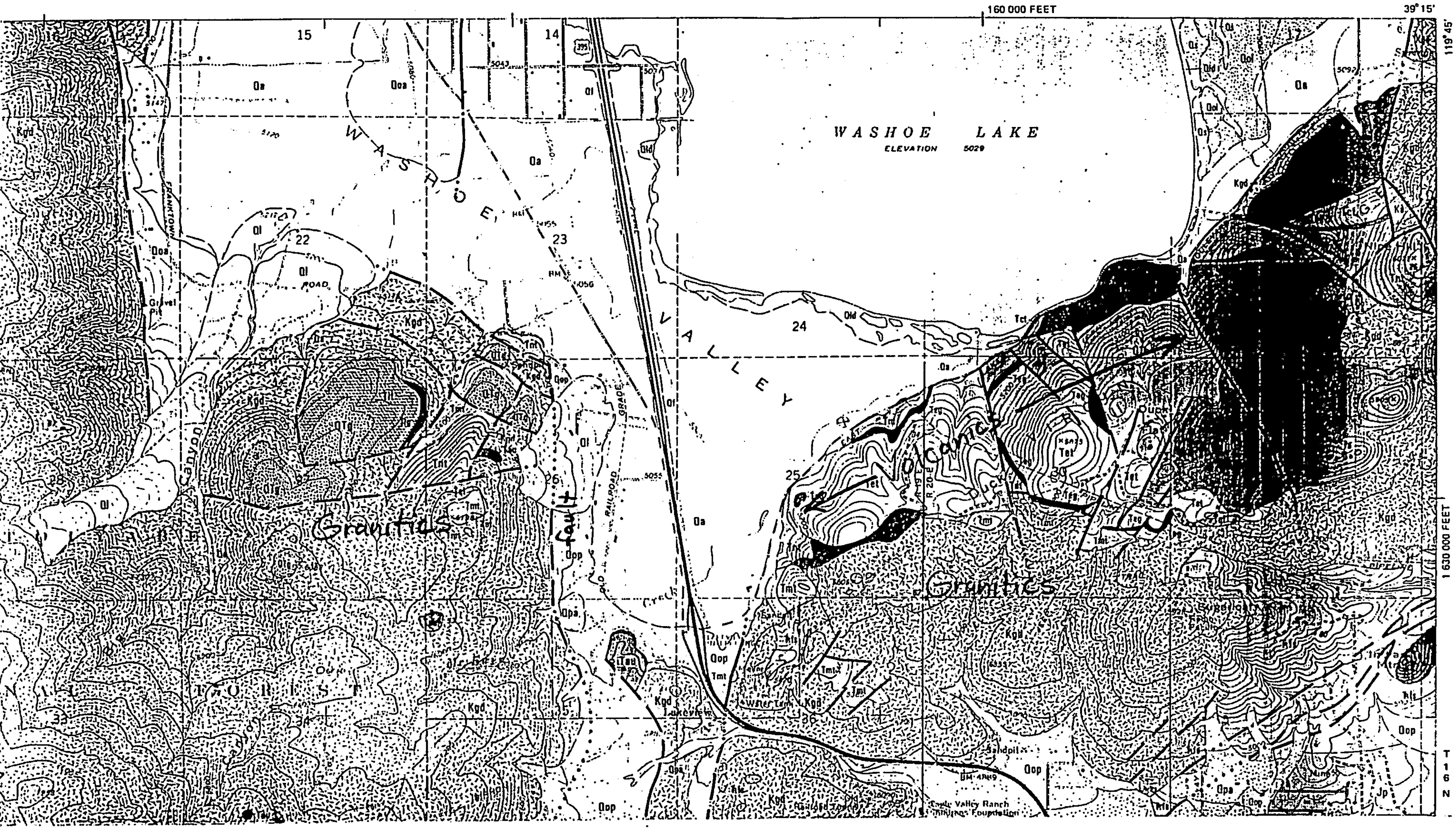
As reviewed in our meeting, this hydrogeologic data along with engineering considerations for the wetlands project have led to the recommended locations for drilling exploration shown on the attached drawing. At these more centrally located valley floor sites, the potential for encountering a substantial thickness of alluvial material exists. Geophysical data from both the Washoe County and HLA surveys indicate potential for encountering moderate permeability materials. While the ground water storage and transmission properties can not be determined until actual well construction is completed, these locations are felt to represent higher potential for on-site water production, based on the data available. It was noted that although more favorable exploration locations have been selected, none of the data reviewed indicated strong possibilities for a single well of production capacity of 1,000 gpm. Exploration bore holes will provide data to assist in selection of the most favorable location(s) at the site, and may allow for final production well design prior to bid solicitation.

F:\wp-geo\wpdocs\990\990882B.MMO)

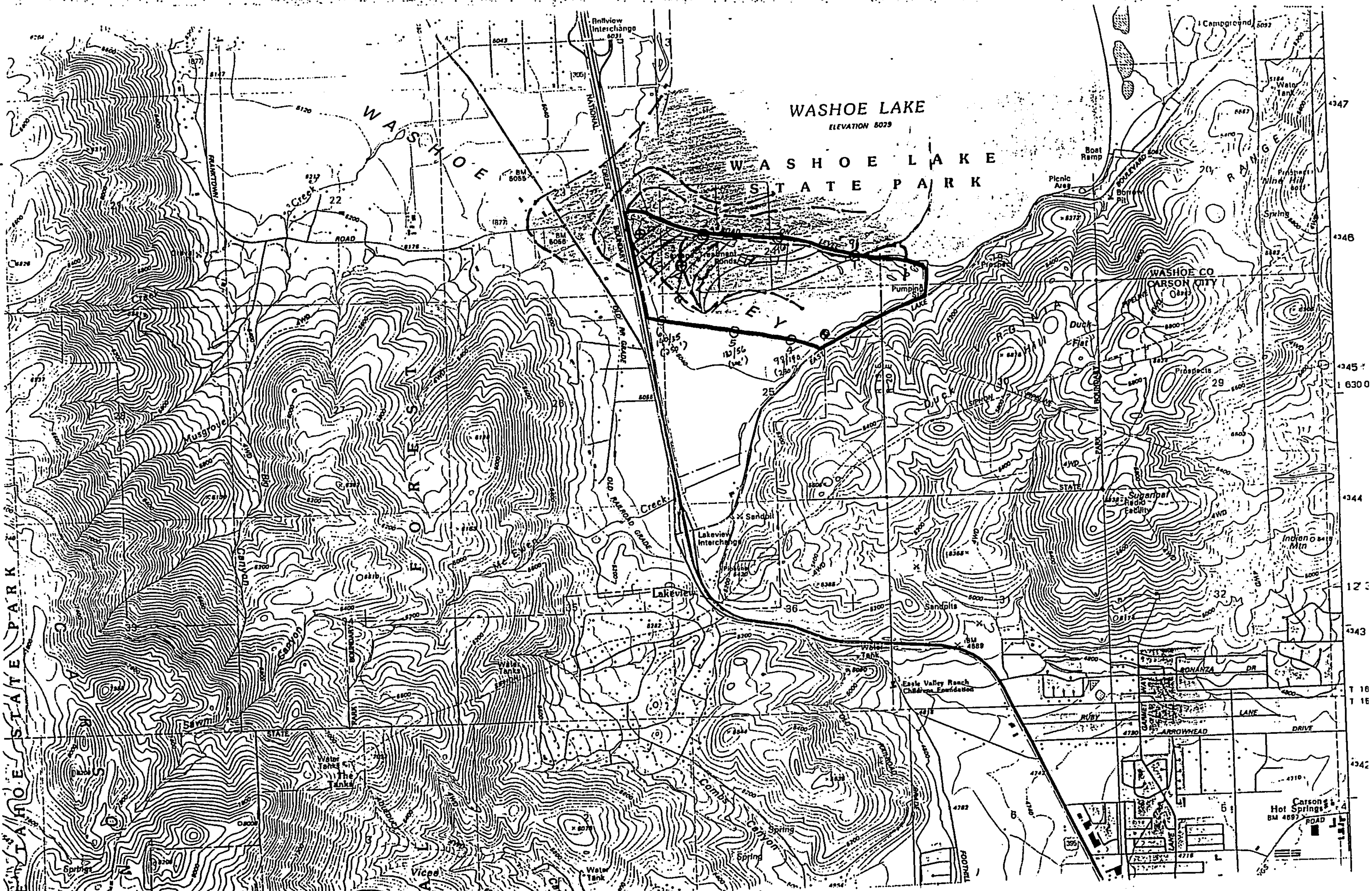
'ERIOR

CARSON CITY QUADRANGLE
NEVADA
7.5 MINUTE SERIES (TOPOGRAPHIC)




160 000 FEET
39°15'
119°45'
1 630 000 FEET
WASHOE LAKE
ELEVATION 5029
WASHOE
VALLEY
FRANKTOWN
ROAD
RAILROAD
GRADE
Canyon
FOREST
Gravel Pit
Lakeview
Sandpit
Eagle Valley Ranch
Granitics
Volcanics
fault
T 16 N

CARS


WASHOE LAKE
ELEVATION 5029
WASHOE LAKE STATE PARK
Bellview Interchange
Boat Ramp
Picnic Area
Borrow Pit
Campground
Water Tank
WASHOE CO
CARSON CITY
Duck Flat
Pumping Sta
Sewage Treatment Ponds
Lakeview Interchange
Lakeview
Sandpit
Sandpits
Sugarloaf Radio Facility
Indian Mtn
Prospects
Eagle Valley Ranch Childrens Foundation
BONANZA DR
RUBY LANE
ARROWHEAD DRIVE
FOOTHILL
Carson Hot Springs
FRANKTOWN ROAD
OLD RAILROAD GRADE
NATIONAL FOREST BOUNDARY
STATE PARK BOUNDARY
Musgrove
Big Canyon
Sawmill
Combs Canyon
Spring
The Tanks
Water Tanks
Vicee Can
WASHOE
FOREST
CARSON
TAHOE STATE PARK
RANGE

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# MEMO

| | | | |
|---|---|---|---|
| **TO:** | Jim Murdock, Daryl James | **PROJECT:** | NDOT |
| **FROM:** | Dwight Smith, Frank Alverson | **PROJECT NO:** | 990-009-882 |
| **DATE:** | November 16, 1995 | | |
| **REGARDING:** | Washoe Lake Wetlands Mitigation Area Well - Exploration Drilling | | |

Based on SEA's hydrogeologic review of the site, two areas for possible ground water production have been determined and are shown on the attached site map. As discussed in our meeting on November 16, 1995, exploration of geologic materials at these locations is recommended. Exploration can be conducted by drilling a small diameter (6" - 10") bore hole using mud rotary drilling techniques. The depth of drilling should be anticipated to be 600 feet, however, actual depth will be dictated by the geology encountered. During drilling, samples of the drilled cuttings should be collected at minimum 10-foot depth intervals, for preparation of a geologic log. Electric logging should be performed when the bore hole has been advanced to the final drilled depth. Electric logging will be used to assess water bearing properties of the materials encountered and should include: standard resistivities, spontaneous potential and natural gamma. Following electric logging, the bore hole should be abandoned with a cement grout or neat cement product, in accordance with State regulations.

Access to both drilling sites will require constructing a temporary gravel access road and drilling pad. The northwest site will require approximately 100 feet of access improvement, and the southwest site will require approximately 600 feet of access road.

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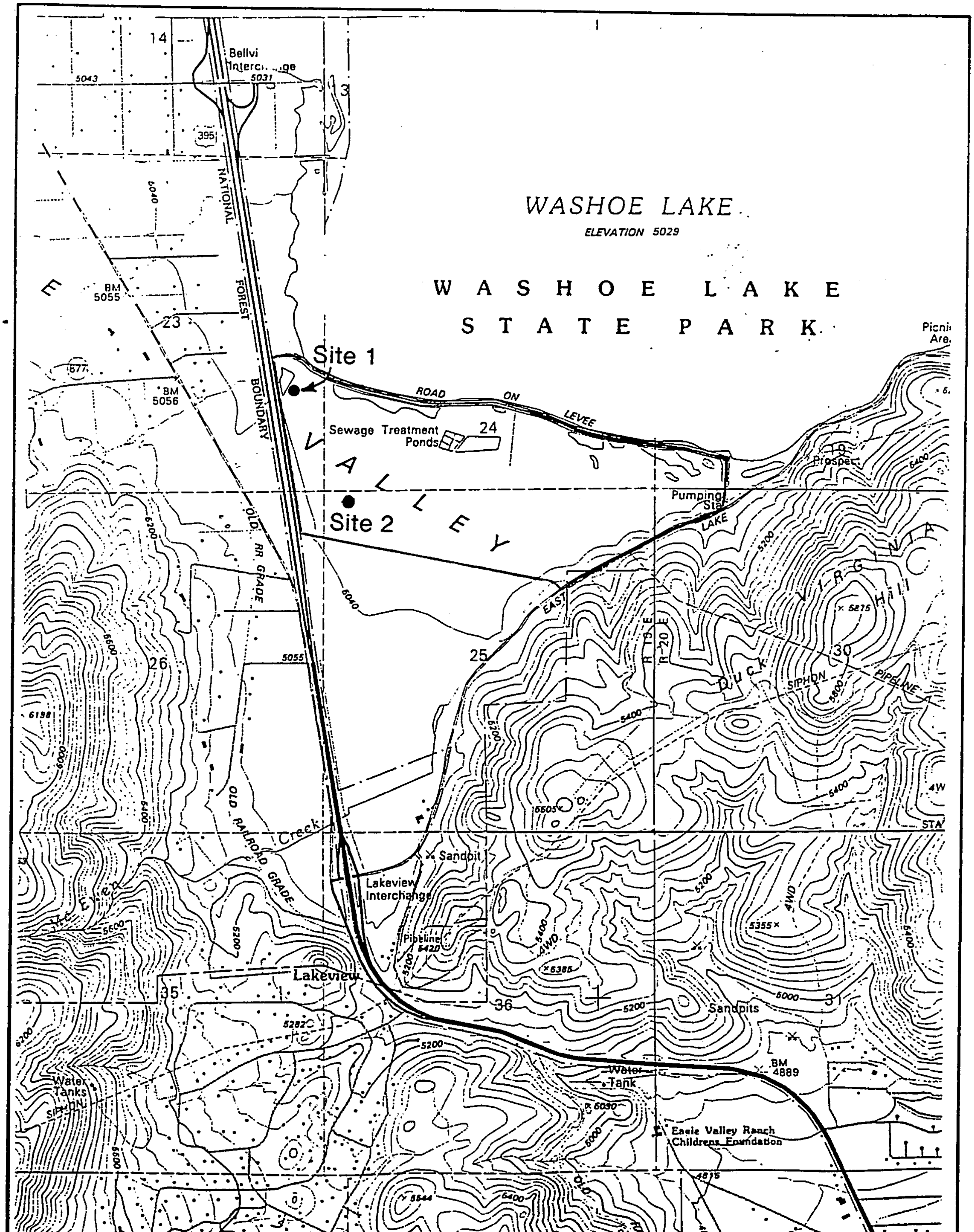



RENO/SPARKS, NEVADA
LAS VEGAS, NEVADA
PHOENIX, ARIZONA

**NDOT**

**Washoe Lake Wetland Mitigation Area**

**Water Exploration Sites**

**Project No.**

**welenco**

## GAMMA RAY LOG

| | | |
|---|---|---|
| FILING NO. | COMPANY | ZIM INDUSTRIES, INC. |
| | WELL | NDOT-SOUTH EXPLORATION HOLE |
| | FIELD | WASHOE LAKE |
| | COUNTY | WASHOE  STATE NEVADA |
| JOB NO. 26707 | LOCATION: SEC TWP RGE | OTHER SERV: E-LOG |

PERMANENT DATUM: G.L.  ELEV: N/A
LOG MEASURED FROM G.L. FT ABOVE PERM DATUM
DRILLING MEASURED FROM G.L.
ELEVATION: KB. DF. GL.

| | | | |
|---|---|---|---|
| DATE | 09-15-96 | | |
| TYPE OF LOG | GAMMA RAY | | |
| RUN NO. | ONE | | |
| DEPTH - DRILLER | 680' | | |
| DEPTH - LOGGER | 677' | | |
| BOTTOM LOGGED INT | 676' | | |
| TOP LOGGED INT | 0' | | |
| TYPE FLUID IN HOLE | BENTONITE | | |
| FLUID LEVEL | FULL | | |
| MAX TEMP DEG F | N/A | | |
| OPERATING RIG TIME | 1 HR. | | |
| EQUIP. LOCATION | L-17 STK. | | |
| OPERATOR | M.SHARPLESS | | |
| WITNESSED BY | D.SMITH | J.MURDOCK | M.JACKSON |

| RUN | BORE HOLE RECORD | | | CASING RECORD | | | |
|---|---|---|---|---|---|---|---|
| NO. | BIT | FROM | TO | SIZE | TYPE | FROM | TO |
| 1 | 12.25" | 9' | TD | 14" | STEEL | SURF | 9' |

### EQUIPMENT DATA

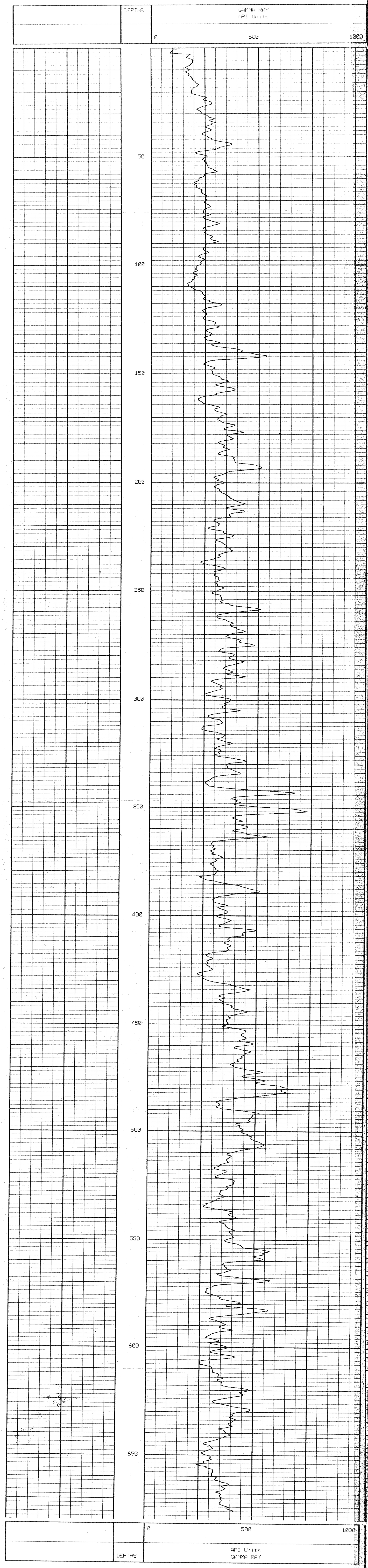
| | | | |
|---|---|---|---|
| LOG TYPE | GAMMA RAY | | |
| RUN NO. | ONE | | |
| TOOL MODEL NO. | MLS-OLT | | |
| TOOL SERIAL NO. | T-156 | | |
| DIAMETER | 1.75" | | |
| DETECTOR TYPE | SCINT. | | |
| DETECTOR LENGTH | 4" | | |
| UNITS/DIV. | 50 API | | |
| SENSITIVITY | 100/750 | | |
| ZERO DIV L OR R | 0-L | | |
| SPEED-FPM | 20 | | |
| DATA SAMPLES/FT. | 2 | | |
| FORMATION FACTOR | N/A | | |
| PUMP RATE-GPM | N/A | | |
| PUMP RATE-GPM | | | |
| PUMP RATE-GPM | | | |

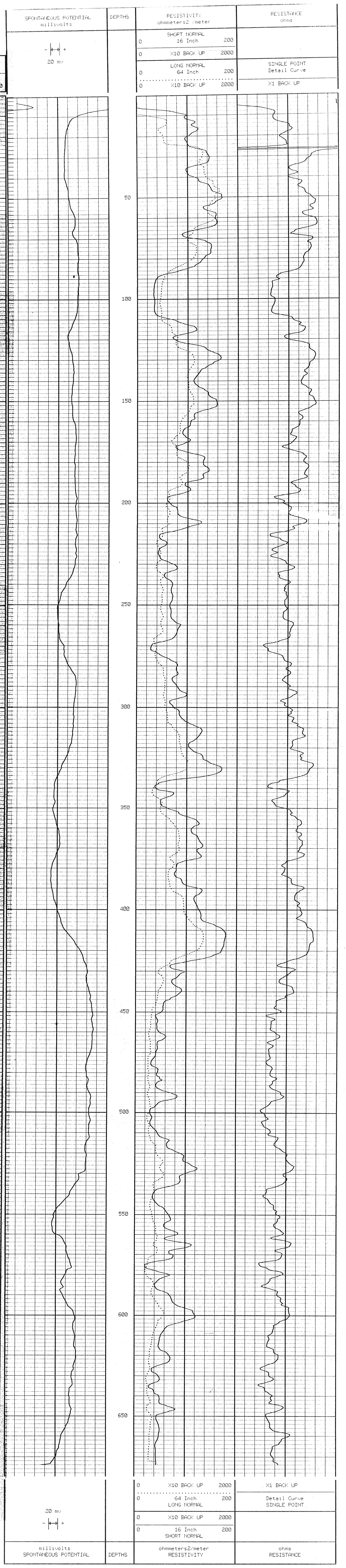
| SOURCE TYPE | STRENGTH | SPACING | MODEL NO | SERIAL NO. |
|---|---|---|---|---|
| | | | | |

PERFORATIONS: NONE

REMARKS:

NOTICE:
All interpretations are opinions based on inferences from electrical or other measurements and we cannot, and do not guarantee the accuracy or correctness of any interpretations, and we shall not, except in the case of gross or willful negligence on our part, be liable or responsible for any loss, costs, damages or expenses incurred or sustained by anyone resulting from any interpretation made by one of our officers, agents or employees. These interpretations are also subject to our General Terms and Conditions as set out in our current Price Schedule.
WELENCO, INC.




**welenco**

## ELECTRIC LOG

| | | |
|---|---|---|
| FILING NO. | COMPANY | ZIM INDUSTRIES, INC. |
| | WELL | NDOT-SOUTH EXPLORATION HOLE |
| | FIELD | WASHOE LAKE |
| | COUNTY | WASHOE  STATE NEVADA |
| JOB NO. 26707 | LOCATION: SEC TWP RGE | OTHER SERV: GAMMA RAY |

Permanent Datum: G.L.  Elev: N/A  K.B.
Log Measured From G.L. Ft Above Perm Datum  D.F.
Drilling Measured From G.L.  G.L.

| | | | |
|---|---|---|---|
| Date | 09-15-96 | - - | - - |
| Run No. | ONE | | |
| Depth - Driller | 680' | | |
| Depth - Logger | 675' | | |
| Btm. Log Inter. | 674' | | |
| Top Log Inter. | 9' | | |
| Casing-Driller | 14" at 9' | at | at |
| Casing-Logger | 14" at 9' | at | at |
| Bit Size | 12.25" | | |
| Type Fluid In Hole | BENTONITE | | |
| Dens. \| Visc. | N/A \| N/A | \| | \| |
| pH \| Fluid Loss | N/A \| N/A ml | \| ml | \| ml |
| Source of Sample | PIT | | |
| Rm at Meas.Temp | 13.0 at 60 F | at F | at F |
| Rmf at Meas.Temp | N/A at F | at F | at F |
| Rmc at Meas.Temp | N/A at F | at F | at F |
| Source:Rmf Rmc | MEAS \| | \| | \| |
| Rm at BHT | N/A at F | at F | at F |
| Time Since Circ. | N/A | | |
| Max. Rec. Temp. | N/A F | F | F |
| Equip \| Location | L-17 \| STK. | \| | \| |
| Recorded By | M.SHARPLESS | | |
| Witnessed By | J.MURDOCK | D.SMITH | M.JACKSON |

Fold Here

This Heading and Log Conform To API RP 31

| Changes in Mud Type or Additional Samples | | |
|---|---|---|
| Date \| Sample No. | | |
| Depth-Driller | | |
| Type Fluid in Hole | | |
| Dens. \| Visc. | | |
| ph \| Fluid Loss | ml | ml |
| Source of Sample | | |
| Rm at Meas. Temp. | at F | at F |
| Rmf at Meas. Temp. | at F | at F |
| Rmc at Meas. Temp. | at F | at F |
| Source:Rmf \| Rmc | | |
| Rm at BHT | at F | at F |
| Rmf at BHT | at F | at F |
| Rmc at BHT | at F | at F |

| Scale Changes | | | |
|---|---|---|---|
| Type Log | Depth | Scale Up Hole | Scale Down Hole |
| | | | |

| Equipment Data | | | | |
|---|---|---|---|---|
| Run No. | Tool Type | PadType | Tool Pos | Other |
| ONE | ELECTRIC | | FREE | |

REMARKS:

WELL DRILLED BY: ZIM INDUSTRIES, INC.
WELL DRILLER: M.JACKSON

**welenco**

## GAMMA RAY LOG

| | |
|---|---|
| FILING NO. | COMPANY ZIM INDUSTRIES, INC. |
| | WELL NDOT-NORTH EXPLORATION WELL |
| | FIELD WASHOE LAKE |
| | COUNTY WASHOE STATE NEVADA |
| JOB NO. 26711 | LOCATION: SEC TWP RGE |
| OTHER SERV: | E-LOG |

PERMANENT DATUM: G.L. ELEV:
LOG MEASURED FROM G.L. FT ABOVE PERM DATUM
DRILLING MEASURED FROM G.L.
ELEVATION: KB. DF. GL.

| | | | |
|---|---|---|---|
| DATE | 09-21-96 | | |
| TYPE OF LOG | GAMMA RAY | | |
| RUN NO. | ONE | | |
| DEPTH - DRILLER | 600' | | |
| DEPTH - LOGGER | 600' | | |
| BOTTOM LOGGED INT | 599' | | |
| TOP LOGGED INT | 0' | | |
| TYPE FLUID IN HOLE | BENTONITE | | |
| FLUID LEVEL | FULL | | |
| MAX TEMP DEG F | N/A | | |
| OPERATING RIG TIME | 1 HR. | | |
| EQUIP. LOCATION | L-17 STK. | | |
| OPERATOR | M.SHARPLESS | | |
| WITNESSED BY | D.SMITH | G.GEIGER | M.JACKSON |

| RUN NO. | BORE HOLE RECORD BIT | FROM | TO | CASING RECORD SIZE | TYPE | FROM | TO |
|---|---|---|---|---|---|---|---|
| 1 | 8.5" | 15' | TD | | | | |

### EQUIPMENT DATA

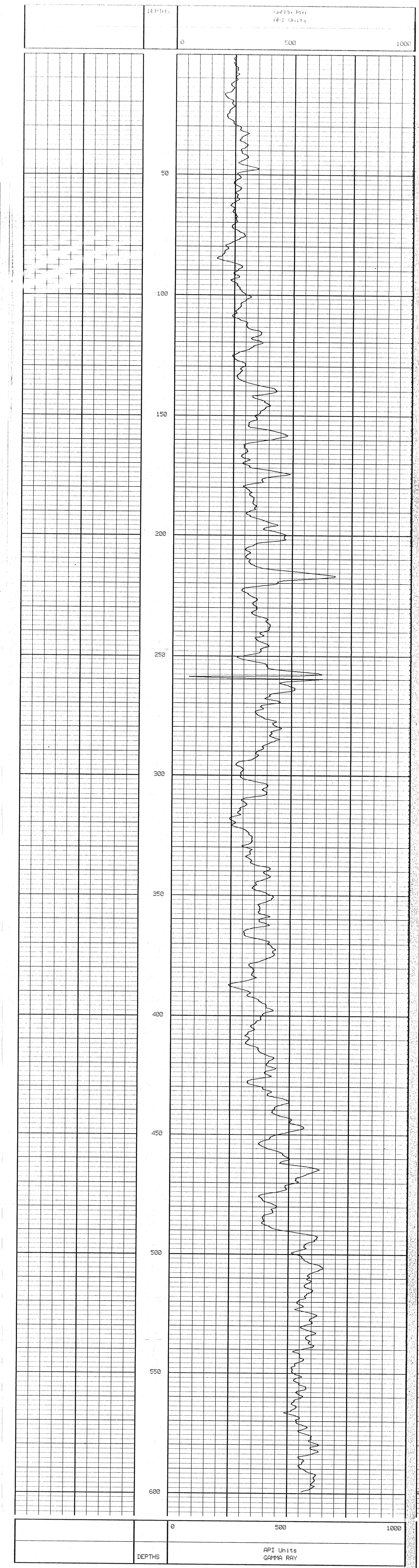
| | | | |
|---|---|---|---|
| LOG TYPE | GAMMA RAY | | |
| RUN NO. | ONE | | |
| TOOL MODEL NO. | MLS-OLT | | |
| TOOL SERIAL NO. | T-152 | | |
| DIAMETER | 1.75" | | |
| DETECTOR TYPE | SCINT. | | |
| DETECTOR LENGTH | 4" | | |
| UNITS/DIV. | 50 API | | |
| SENSITIVITY | 50/750 | | |
| ZERO DIV L OR R | 0-L | | |
| SPEED-FPM | 25 | | |
| DATA SAMPLES/FT. | 2 | | |
| FORMATION FACTOR | N/A | | |
| PUMP RATE-GPM | N/A | | |
| PUMP RATE-GPM | | | |
| PUMP RATE-GPM | | | |

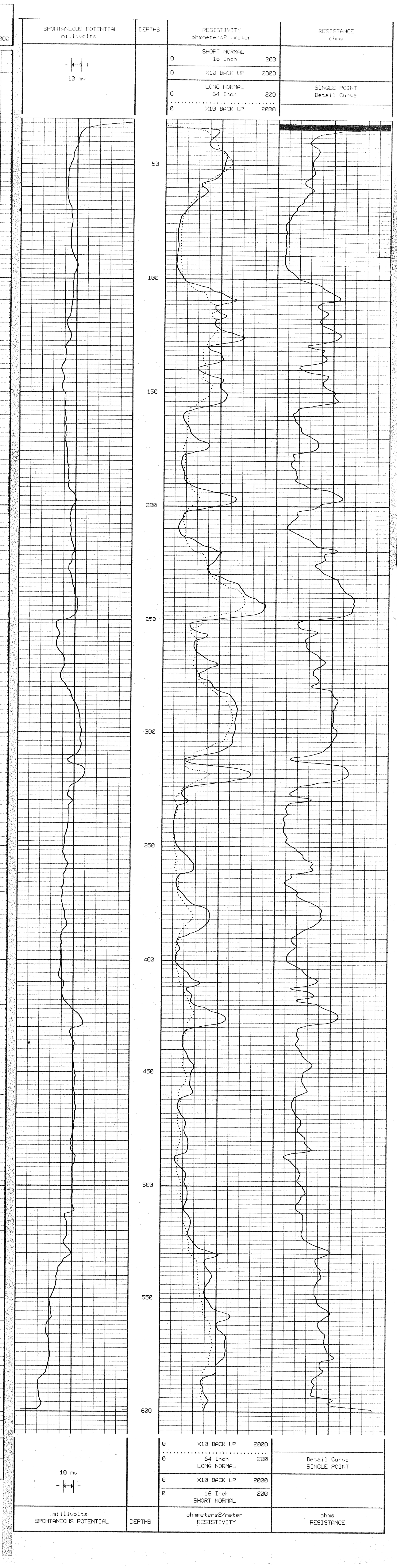
| SOURCE TYPE | STRENGTH | SPACING | MODEL NO | SERIAL NO. |
|---|---|---|---|---|
| | | | | |

PERFORATIONS: NONE

REMARKS:






**welenco**

## ELECTRIC LOG

| | |
|---|---|
| FILING NO. | COMPANY ZIM INDUSTRIES, INC. |
| | WELL NDOT-NORTH EXPLORATION WELL |
| | FIELD WASHOE LAKE |
| | COUNTY WASHOE STATE NEVADA |
| JOB NO. 26711 | LOCATION: SEC TWP RGE |
| OTHER SERV: | GAMMA RAY |

Permanent Datum: G.L. Elev: N/A
Log Measured From G.L. Ft Above Perm Datum
Drilling Measured From G.L.
K.B. D.F. G.L.

| | | | |
|---|---|---|---|
| Date | 09-21-96 | - - | - - |
| Run No. | ONE | | |
| Depth - Driller | 600' | | |
| Depth - Logger | 600' | | |
| Btm. Log Inter. | 599' | | |
| Top Log Inter. | 40' | | |
| Casing-Driller | N/A at | at | at |
| Casing-Logger | N/A at | at | at |
| Bit Size | 8.5" | | |
| Type Fluid In Hole | BENTONITE | | |
| Dens. Visc. | N/A N/A | | |
| pH Fluid Loss | N/A N/A ml | ml | ml |
| Source of Sample | PIT | | |
| Rm at Meas.Temp | 11.5 at 85 F | at F | at F |
| Rmf at Meas.Temp | N/A at F | at F | at F |
| Rmc at Meas.Temp | M/A at F | at F | at F |
| Source:Rmf Rmc | MEAS | | |
| Rm at BHT | N/A at F | at F | at F |
| Time Since Circ. | 3 HR. | | |
| Max. Rec. Temp. | N/A F | F | F |
| Equip Location | L-17 STK | | |
| Recorded By | M.SHARPLESS | | |
| Witnessed By | D.SMITH | G.GEIGER | M.JACKSON |

Fold Here

This Heading and Log Conform To API RP 31

| Changes in Mud Type or Additional Samples | | |
|---|---|---|
| Date / Sample No. | | |
| Depth-Driller | | |
| Type Fluid in Hole | | |
| Dens. / Visc. | | |
| ph / Fluid Loss | ml | ml |
| Source of Sample | | |
| Rm at Meas. Temp. | at F | at F |
| Rmf at Meas. Temp. | at F | at F |
| Rmc at Meas. Temp. | at F | at F |
| Source:Rmf / Rmc | | |
| Rm at BHT | at F | at F |
| Rmf at BHT | at F | at F |
| Rmc at BHT | at F | at F |

| Scale Changes | | | |
|---|---|---|---|
| Type Log | Depth | Scale Up Hole | Scale Down Hole |

| Equipment Data | | | | |
|---|---|---|---|---|
| Run No. | Tool Type | PadType | Tool Pos | Other |
| ONE | ELECTRIC | | FREE | |

REMARKS:
WELL DRILLED BY:ZIM INDUSTRIES, INC.
WELL DRILLER:MARVIN "THE DRILL" JACKSON