

City of Big Bear Lake
Department of Water and Power

**Geohydrologic Characteristics
and Artificial Recharge Potential
of the Sand Canyon Area**

DRAFT

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1

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* Map Pocket in back of report.

Geohydrologic Characteristics and Artificial Recharge

Potential of the Sand Canyon Area

City of Big Bear Lake - Department of Water and Power

1 EXECUTIVE SUMMARY

A geohydrologic investigation was undertaken of the Sand Canyon area southeast of Big Bear Lake in San Bernardino County, California. Specifically, the area investigated covered portions of Sand Canyon, Bow Canyon, and Rathbone Canyon, a total area of approximately 1.3 square miles.

The purpose of the investigation was to determine geohydrologic characteristics of the Sand Canyon area and the feasibility of developing a program to artificially recharge and recover reclaimed wastewater. Specifically, it was necessary to determine whether 758 acre-ft could be stored underground using aquifers in the upper Sand Canyon area and recover the stored water through an extraction well system located downstream. To comply with the California Department of Health Services (DOHS) guidelines for ground water recharge with reclaimed municipal wastewater, specific requirements also needed to be met. These requirements included determination of native ground water quality, movement, retention time underground, and distance between recharge basins and extraction wells.

Eight exploratory/test wells were drilled in conjunction with this study. A total of 2,305 ft were drilled during the month of October 1990 with individual well depths ranging from 200 to 500 ft. During drilling, formation and water samples were collected and analyzed for aquifer parameters and water quality properties.

Ground water flow is southeast to northwest with an average seepage velocity ranging from 3 to 13 ft/day. Storage potential in the channel and surrounding area is estimated at approximately 1,500 acre-ft.

Data from the geohydrologic investigation and test drilling were incorporated into a ground water model of the area. Through use of the model, the feasibility of recharging and recovering water stored during MWD's 7-month Seasonal Storage Period was investigated. The area for recharge would be located in the Sand Canyon channel above Teton Road. Extraction well sites would be downstream near Moonridge Road.

Results of the investigation show that 758 acre-ft of reclaimed wastewater can be recharged into aquifers in the upper Sand Canyon area. Recovery of stored water is feasible through a system of three extraction wells located near the intersection of Sand

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Canyon drainage and Moonridge road. Here, test drilling results showed excellent aquifer potential with well yields expected to average 200 gpm.

This report also addresses the required items in the October 1, 1990 letter from Black and Veatch regarding compliance with DOHS proposed guidelines for recharge of reclaimed municipal wastewater. In discussion of these items, appropriate sections of the report are referred to.

2 INTRODUCTION

2.1 Purpose And Scope

The purpose of the investigation was to determine geohydrologic characteristics of the Sand Canyon area and the potential for artificial recharge and recovery of ground water.

The scope of the work included a review of background reports, analyses of related geologic and hydrologic data, field investigations, areal photo interpretation, drilling of eight small diameter exploratory/test wells, and construction of a ground water model of the Sand Canyon area.

2.2 Project Location

Sand Canyon is a relatively small canyon draining a portion of the San Bernardino Mountains southeast of Big Bear Lake. The total drainage area is 711 acres with an average precipitation of 22.5 inches (Black and Veatch, 1990). The Canyon drains in a southeast to northwest direction and is characterized by steep slopes on both sides. The area is accessible from Moonridge road which intersects Highway 18, the main thoroughfare through the communities of Big Bear Lake and Big Bear City (see Figure 1).

The total area investigated covers approximately 1.3 square miles (827 acres) which includes portions of Sand Canyon, Bow Canyon, and Rathbone Canyon. Although the current investigation focuses on Sand Canyon, it was necessary to include a much wider area to understand regional geologic and hydrologic characteristics. The area of interest encompasses approximately 50-200 acres of Sand Canyon and vicinity drainage from the Cady well (upper end) to Moonridge Road on the lower end (see Figure 2). The total length

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between these two points is approximately one mile. Elevations in the Sand Canyon area range from 7,040 ft at the bottom of the study area (near Moonridge Road), to approximately 7,200 ft in the upper Sand Canyon area (near the Cady well). The ridges on either side attain elevations of 7,300 to 7,400 ft amsl.

In the upper portion of Sand Canyon (between the Cady well and Teton Road), the stream channel is relatively unimproved ranging in width from 20 to 50 ft. The widest portion is in the vicinity of Teton Road. At a distance of approximately 1,000 ft below Teton Road, the channel appears to have been improved with a fairly constant width of 20 to 30 ft. Near Moonridge Road, Sand Canyon merges with Bow Canyon drainage and together join the Rathbone drainage flowing northerly towards Big Bear Lake.

3 GEOHYDROLOGY OF THE SAND CANYON AREA

3.1 General Geology

The project area is located in the San Bernardino Mountains of Southern California which is an uplifted and faulted region of Pliocene to recent sedimentary strata. These strata unconformably overlie Plutonic and metamorphic basement rocks (Dibblee 1964). The sedimentary strata in the Sand Canyon area contain Pleistocene Fanglomerates and Pleistocene to Recent surficial alluvial deposits which unconformably overlie the Fanglomerates. Hydrologically, Sand Canyon is a sub-basin of the Rathbone drainage basin.

3.2 Aquifer Systems

The following section describes aquifer systems in the area with consideration to geologic and *potential* hydrologic properties. When describing a potential aquifer system, consideration is given to the artificial recharge program proposed for the area. Geologic formations presently unsaturated are technically not considered aquifers. However, when the artificial recharge program is implemented, these formations will become saturated and store and transmit ground water (i.e. become aquifers). With this in mind, the following descriptions and discussions are made. The geologic formation designations are after Dibblee (1964) and shown on the geologic map and appropriate cross sections (see Plate 1 and Figures 2 and 4).

Geohydrologic Characteristics of the Sand Canyon Area

This report however sub-divides zones within Dibblee's Fanglomerate. This was necessary due to the special interest of this report on upper permeable formations suitable for ground water recharge.

3.2.1 Recent Alluvium (Qal) -

The most recent materials found in the area consist of alluvial material, slopewash and landslide debris. The alluvium is unconsolidated and composed of interlayered sand, gravel, silt and clay. The maximum thickness of the alluvium in Sand Canyon is approximately 40 ft and is presently unsaturated. The Recent alluvium overlies older Fanglomerates.

3.2.2 Fanglomerate (Qof) -

The Fanglomerate in the Sand Canyon area was deposited as alluvial fans and fluvial plains composed of unsorted boulders, cobbles, pebbles, and sand derived mostly from gneiss, quartzite and quartz monzonite. These deposits reach depths of approximately 700 feet and constitute the perched, unconfined and semi-confined aquifers. The Fanglomerate overlies the crystalline basement complex.

3.2.2.1 Subdivision Of Aquifers Within The Fanglomerate -

During the exploratory drilling, a detailed understanding was gained as to the nature of the upper unconsolidated materials in the Sand Canyon area. Recharge and recovery of stored water will take place in the upper 200-500 ft of unconsolidated alluvial material. Since the primary purpose of the investigation was to determine artificial recharge and recovery potential, an investigation of deeper strata or low permeability zones at depth was not done.

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3.2.2.1.1 A-Zone -

For purposes of this report, the upper approximately 150 ft to 500 ft of the Fanglomerate is defined as the A-Zone (Qof-A). This zone contains medium to high permeability material including silty sand and gravel.

3.2.2.1.2 B-Zone -

Interbedded within the A-Zone is a deposit of very high permeability material comprised mostly of medium to coarse sand and gravel. This is defined as the B-Zone (Qof-B). The thickness of the B-Zone ranges from approximately 50 ft in the upper Sand Canyon area (near TH-1) to over 300 ft in the lower portion near the proposed extraction well locations (i.e. near TH-5).

3.2.2.1.3 C-Zone - Low Permeability Zone -

Beneath the A and B Zones at depths of approximately 200 to 550 ft, a thick low permeability zone is found composed predominantly of clay, silty clay and sandy silt. This low permeability zone is referred to as the C-Zone (Qof-C) and provides a lower limit on downward percolating recharge water. Underlying the C-Zone is the basement complex (i.e. bedrock--primarily diorite). The only control for depth to basement complex was from the Cady well log. Other bedrock depths seen on the cross sections were inferred.

Plate 1 (map pocket) and Figure 4 show geologic cross sections through the area. Figure 3 shows the location of the cross sections.

3.3 Ground Water Movement And Storage

Ground water-level elevations and flow directions were determined from depth to water measurements made in the eight exploratory/test wells. Also for control, depths to water were obtained for the two existing wells (Cady and Sand Canyon). The following table summarizes current depth to water and ground water elevations.

Geohydrologic Characteristics of the Sand Canyon Area

Table 1 - Summary of Ground Water Elevations in the Sand Canyon Area

Well	Land Surface Elev. [ft]	Depth to Water [ft]	Ground Water Level Elev. [ft]
TH - 1	7,215	55	7,160
TH - 2	7,190	50	7,140
TH - 3	7,155	138	7,017
TH - 4	7,075	164	6,911
TH - 5	7,070	106	6,964
TH - 6	7,210	58	7,152
TH - 7	7,210	65	7,145
TH - 8	7,145	200	6,945
Sand Canyon	7,050	110	6,940
Cady Well	7,275	106	7,169

Surface elevations were estimated using a standard USGS 7 1/2 minute topographic quadrangle map (1:24,000 scale).

The depth to ground water was somewhat dependent on whether or not the coarse gravel layer of the B-Zone was present. When the B-Zone gravels were encountered, the depth to water seemed to be near the top of these gravels. When no B-Zone was found, depth to water was deeper ranging from approximately 138 to 200 ft below ground surface. This suggests that the B-Zone gravels (when present) act as a permeable drain within the A-zone. However, the B-Zone gravels do not seem to be distributed uniformly throughout the area and are probably associated with an ancestral drainage channel within Sand Canyon.

The direction of ground water flow is from the southeast to the northwest. The direction parallels the Sand Canyon surface drainage for the most part. However, halfway between Teton and Moonridge roads, the surface drainage turns westerly while ground water flow continues in the northwest direction. Figure 5 is a contour map of ground water elevations showing flow directions.

Geohydrologic Characteristics of the Sand Canyon Area

NOTE

Depth to water obtained from field measurements during drilling were made within the inner tube of the drill pipe. This method represents a point sample of water level depth which may differ from the average depth measured in a fully screened piezometer.

3.3.1 Hydraulic Conductivity And Seepage Velocity Estimate -

The hydraulic conductivity was estimated from correlating grain size distribution (from samples collected during drilling) with Masch-Denny prediction curves relating grain size and hydraulic conductivity (Masch-Denny, 1986). The resulting hydraulic conductivities ranged from approximately 90 to 350 gpd/ft² (see Table 3). Mechanical grading analyses of material sampled during drilling is shown in Appendix B.

Ground water seepage velocities were calculated using hydraulic gradients measured from the ground water contour map of Figure 5 and the hydraulic conductivities as estimated in Table 3. The effective porosity was estimated using relationships between grain size and effective porosity (Morris and Johnson, 1967) and ranged between 0.15 and 0.20.

Hydraulic gradients in the reach between TH-1 (upper end of recharge ponds) and TH-5 (extraction well area) averaged 0.05. The ground water seepage velocity was calculated from:

$$V = \frac{K}{\Theta \times 7.48} \frac{dh}{dx}$$

where:

- V = Ground Water Seepage Velocity [ft/day]
- K = Hydraulic Conductivity [gpd/ft²]
- Θ = Effective Porosity [fraction]
- dh/dx = Hydraulic Gradient [ft/ft]

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The negative sign in the above equation is for convention only and indicates that ground water is flowing in the direction of decreasing head.

With effective porosities ranging between 0.15 to 0.20 and hydraulic conductivities from 100 to 300 gpd/ft², the resulting seepage velocities ranged from a low of 3.3 ft/day to a high of 13.4 ft/day (see Table 3).

3.3.2 Ground Water Storage Potential -

Ground water storage potential can be calculated by multiplying the saturated thickness by the effective porosity. Effective porosities were estimated from grain size relationships measured from aquifer samples collected during the test drilling (see Appendix B).

Assuming an average area of 200 acres within the Sand Canyon channel and vicinity, an average saturated thickness of 50 ft and an effective porosity of 0.15, the available storage potential is calculated as:

$$S = A \times b \times \Theta$$

where:

S = ground water storage potential [1,500 acre-ft]

A = area [200 acres]

b = available thickness [50 ft]

Θ = average effective porosity [0.15]

4 EXPLORATORY DRILLING AND TESTING

4.1 Dual-Tube Drilling Method

During the course of the investigation, eight exploratory/test wells were drilled within and near the channel of Sand Canyon. The location of the wells were chosen to gain an understanding of the nature of the subsurface geologic materials; the depth to water; and artificial recharge and recovery potential. The depths of the wells ranged from a minimum of 200 ft to a maximum of 500 ft with a total of 2,305 ft drilled. Drilling began on

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October 10, 1990 and was completed on October 20, 1990.

The wells were drilled by Layne Environmental of Fontana, California using a *Dual-Tube* rotary drilling rig. The dual-tube method of drilling consists of using reverse circulation and a five-inch diameter drill pipe. The drill pipe contains a smaller inner pipe of approximately two inches in diameter.

In this method of drilling, high pressure air is forced down through the annular space between the inner and outer drill pipe and returns (with formation cuttings) through the inner pipe. The drill cuttings are diverted from the main circulating air stream into a *Cyclone*, (a funnel-shaped trap designed to reduce air velocity and control the discharge material).

Dual-tube drilling is especially suited for exploratory drilling as it uses air as the drilling fluid eliminating the need for drilling mud. One advantage is that material dropping out of the Cyclone is a *point sample* of the formation being drilled. An observation can also be made of the material's moisture content (dry, moist, or saturated). If saturated, the amount of water can be measured and discharge rate estimated from a particular aquifer zone.

The following table summarizes basic information on the exploratory/test wells. The following section discusses each well in detail.

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Table 2 - Summary of Sand Canyon Exploratory and Production Wells

Exploratory/Test Wells

Well	Land Surface [ft amsl]	Total Depth [ft]	Depth to Clay (C-Zone) [ft]	Depth to Water [ft]	Water Level Elev. [ft amsl]
TH - 1	7,215	200	200	55	7,160
TH - 2	7,190	200	180	50	7,140
TH - 3	7,155	260	200	138	7,017
TH - 4	7,075	220	190	164	6,911
TH - 5	7,070	500	>500	106	6,964
TH - 6	7,210	280	240	58	7,152
TH - 7	7,210	300	>300	65	7,145
TH - 8	7,145	345	310	200	6,945
Total		2,305 ft			

Existing Production Wells

Well	Land Surface [ft amsl]	Total Depth [ft]	Depth to Clay (C-Zone) [ft]	Depth to Water [ft]	Water Level Elev. [ft amsl]
Sand Canyon Well	7,050	350	325	110	6,940
* Cady Well	7,275	735	200	106	7,169

* Not in service at the present time as development is not complete.

Geohydrologic Characteristics of the Sand Canyon Area

4.2 Exploratory Well Logging And Testing Procedure

Samples of drilling material were collected every five feet. As the material came out of the Cyclone, it was collected in a five-gallon bucket and bagged in one-gallon plastic Ziplock bags. The cuttings were analyzed both in the field (at the time of collection by the project geohydrologist) as well as under a microscope in GEOSCIENCE's laboratory.

Mechanical grading analyses were performed on selected formation samples collected during drilling and are shown in Appendix B. Appendix A contains a detailed description of the lithologic log of each of the exploratory wells.

Water samples were also collected from selected zones during drilling when saturated material was encountered. The water sample collection procedure consisted of air-lift pumping a particular zone and collecting a water sample in a five-gallon bucket. The five gallon sample was then sub-sampled and sent to a certified laboratory for general mineral analysis (i.e. Clinical Laboratory of San Bernardino). The five water samples analyzed are considered representative of ground water conditions in the Sand Canyon area. Results are summarized in Table 5 and laboratory results in Appendix C.

Production tests (i.e. drill-stem tests) were also conducted when possible and yield estimated from a particular zone. Two wells in particular showed excellent yield potential: (1) TH-1 approximately 20 gpm; and (2) TH-5 approximately 50 gpm. It should be noted that the yields obtained from the drill-stem tests are only estimates of the total yield potential. A large capacity production well drilled at these locations would be expected to yield at least five times more than the point sample obtained from the drill-stem test.

4.3 Test Hole 1 (TH-1)

Test hole 1 was started on October 11, 1990 and completed to a depth of 200 ft on October 11, 1990. TH-1 encountered surficial alluvial sediments mainly the A-Zone and B-Zone of the Qof Fanglomerate. From ground surface to a depth of 20 ft, material consisted of recent stream channel deposits. Drilling continued from 20 to 80 ft through silty sands of the A-Zone. At a depth of 80 to 155 ft, material changed to the coarser B-Zone reflecting a stream channel within the older alluvial fans. The lower section of this zone (145-155 ft) contained small clay layers ranging from 1-2 ft in thickness.

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Water was first found at 80 ft and finally stabilized at 55 ft. A discharge test from the end of the drill stem yielded approximately 20 gpm. A water sample was collected during this test and sent to the laboratory for analysis.

Drilling continued to a total depth of 200 ft. From 155 to 200 ft the material consisted of mostly silts and clay with a few thin sand and gravel layers.

4.4 Test Hole 2 (TH-2)

Test Hole 2 commenced drilling on October 10, 1990 and was completed to a depth of 200 ft on October 11, 1990.

NOTE

TH-2 was drilled before TH-1 as access to TH-1 was not immediately available.

As with TH-1, TH-2 encountered surficial alluvial sediments. The surficial alluvium was found at the surface to a depth of 15 ft and consisted of unconsolidated, unsaturated sands and gravel. This zone is typical of recent stream channel deposits in the area. Drilling continued to a depth of 60 ft through moist silty sands characteristic of the upper A-Zone. At 60 ft drilling stopped for the night. Drilling continued on October 11, to 70 ft through similar silty sands of the A-Zone. At 70 ft, the material became coarser typical of B-Zone sands and gravels. Drilling continued to a depth of about 125 ft. At 102 ft a considerable amount of water was encountered which continued to a depth of 125 ft. From 125 ft to 180 ft, the material changed back to the finer A-Zone consisting predominately of silty sand with some gravel and sandy clay.

At 180 ft the low permeability C-Zone was encountered composed of brown and grey clay with some sand and silt. This zone represents the lower limit available for artificially recharged water. Depth to water was measured at 50 ft below land surface.

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4.5 Test Hole No. 3 (TH-3)

Test Hole No. 3 began on October 13, 1990 and was completed to a depth of 260 ft on October 13, 1990. The upper formations consisted of a 40 ft bed of recent surficial stream channel deposits overlying a 200 ft sequence of sediments characteristic of the A-Zone. Unlike TH-1 and TH-2, surficial sediments in TH-3 directly overlie sediments typical of the C-Zone. The B-Zone was not encountered in TH-3.

During drilling, water was first encountered at about 140 ft in thin gravel beds. The depth to water stabilized at 138 ft.

4.6 Test Hole No.4 (TH-4)

Drilling of Test Hole 4 began on October 14, 1990 and was completed to a total depth of 220 ft on October 14, 1990.

The lithologic sequences encountered in TH-4 were similar to the sequences encountered in TH-3. From ground surface to a depth of 20 ft, formations were predominantly recent surficial stream channel deposits. At 20 ft, the material changed (as in TH-3) to sedimentary sequences characteristic of the A-Zone (silty sand with some clay and gravel). These sediments were encountered up to a depth of about 180 ft. At 180 ft sediments typical of the low permeability C-Zone were encountered and continued to the total well depth of 220 ft. The material was similar to TH-3, predominately brownish clay with some silt and sand. Drilling rates in the C-Zone were relatively slow due to clay plugging.

The first saturated zone was encountered at 178 ft in a sandy clay layer; however this zone yielded very little water. The hole was left overnight with the bit suspended at 200 ft to allow the piezometric surface to equilibrate. A static water level (SWL) of 164 ft was measured the next morning.

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4.7 Test Hole No.5 (TH-5)

Test Hole 5 began on October 15, 1990 and was completed to a depth of 500 ft on October 16, 1990. Lithologic sequences encountered in TH-5 were similar to test holes TH-1 and TH-2. Drilling proceeded through a surficial bed, about 25 ft thick composed of recent stream channel deposits. The underlying lithologic sequences of the A-Zone were encountered to a depth of 175 ft. Coarse sand and gravel, characteristic of the B-Zone was first found at 175 ft and continued to the final depth of 500 ft.

For economical reasons, drilling was terminated at 500 ft. Saturated zones were first encountered at approximately 150 ft with water stabilizing at 106 ft. Formations were fairly consistent to the total depth of 500 ft. A drill-stem production test resulted in a discharge rate of 50 gpm indicating excellent yield potential at this site.

NOTE

A production well completed near TH-5 would be expected to yield over 200 gpm.

4.8 Test Hole No. 6 (TH-6)

Test Hole 6 began on October 16, 1990 and was completed to a depth of 280 ft on October 17, 1990. The upper 10 ft of material encountered was composed of recent surficial stream channel deposits, primarily sands and gravel. At 10 ft, the material changed to sediments characteristic of the A-Zone continuing to a depth of 95 ft. From 95 ft to 120 ft, the material changed to B-Zone coarse sands and gravels. At 120 ft the material changed back to A-Zone. Drilling continued in the A-Zone to a depth of 240 ft where material changed to low permeability clays of the C-Zone. The C-Zone continued to the total well depth of 280 ft.

Saturated zones were first encountered at 87 ft in the upper gravels. Drilling stopped on October 16, at a depth of 100 ft. The bit was pulled up to 80 ft and the well left to equilibrate overnight. A static water level of 58 ft was measured the next morning.

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Formations underlying the lower A-Zone yielded relatively small quantities of water and represent the lower boundary of the permeable deposits suitable for recharge.

4.9 Test Hole No.7 (TH-7)

Test hole 7 began on October 18, 1990 and was completed to a total depth of 300 ft on October 19, 1990. Formations encountered were similar to TH-6. Drilling proceeded through the surface alluvial sediment, A-Zone, B-Zone and back into the A-Zone. However, TH-7 did not penetrate the underlying the C-Zone. Recent alluvial sediments in TH-6 consisted of a 10 ft surficial layer. The upper A-Zone consisted of silty sand and gravel encountered from 10 ft to 120 ft. At 120 ft, the lithology changed to a coarse sand and gravel characteristic of the B-Zone. Drilling in the B-Zone continued to a depth of 185 ft where the lower A-Zone was encountered again continuing to the total well depth of 300 ft.

Saturated zones were encountered at 115 ft. Samples in these zones were moist and yielded small to moderate quantities to water. However, as in TH-6, materials below 185 ft yielded little to no water. Depth to water in TH-7 was measured at 65 ft.

4.10 Test Hole No.8 (TH-8)

Test Hole 8 began on October 20, 1990 and was completed to a total depth of 345 ft on October 20, 1990. Lithologic sequences in TH-8 were similar to those found in TH-3. Drilling proceeded through thin (20 ft) surficial alluvial sediments consisting of sand and gravel. A thick sequence (220 ft) of the A-Zone composed predominantly of silty sand and clay directly underlies the alluvium. Lithologies comprising the C-Zone were encountered from 240 ft to the total depth of 345 ft.

A static water level measurement was made several hours after reaching total depth. The bit was suspended at a depth of 240 ft and the depth of water measured at 200 ft below land surface.

Geohydrologic Characteristics of the Sand Canyon Area

5 GROUND WATER QUALITY IN THE SAND CANYON AREA

Ground water was sampled from five of the eight test wells and sent to the Clinical Laboratory of San Bernardino, Inc for analysis. A general mineral analysis was run on all five samples with results summarized in Table 5 and Appendix C.

In general, water quality was very good in all samples with total dissolved solids (TDS) ranging from 226 to 288 mg/l. However Manganese exceeded the maximum contaminant level (MCL) in wells TH-2 and TH-3 and iron exceeded the MCL in TH-2.

6 POTENTIAL CHANNEL INFILTRATION RATES

Theoretical infiltration rates were determined using a combination of the Green-Ampt equation (Green and Ampt, 1911), Philip equation (Philip, 1969), Todd's equation (Todd, 1980) and experience with artificial recharge rates in Southern California.

The resulting values estimated for long-term vertical infiltration rates in the Sand Canyon area ranged between 1.5 and 4.5 ft/day. These values were calculated using the Philip equation and dividing the results by 3. This approach was felt to be conservative as the values obtained are similar to long-term percolation rates observed in other similar Southern California areas (Roscoe Moss Co., 1990).

Actual field infiltration rates should be measured using field infiltration tests and would be a part of the final design phase of the project. However, for purposes of this investigation, the values calculated above are considered realistic (see Table 4).

7 ARTIFICIAL RECHARGE AND RECOVERY POTENTIAL IN SAND CANYON

To properly evaluate the artificial recharge and recovery potential in the Sand Canyon area, it was necessary to construct a ground water simulation model of the area. Using the model, recharge of reclaimed wastewater was simulated during the 7-month *Seasonal Storage Period*.

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NOTE

Metropolitan Water District's *Seasonal Storage Program* allows purchase of water at a discounted rate during the months of October through April.

Recovery of water stored during the 7-month seasonal storage period was extracted through a system of three wells. The following section discusses the Sand Canyon ground water model.

7.1 Ground Water Model Of The Sand Canyon Recharge/Extraction System

7.1.1 General -

The model used to simulate ground water flow in the Sand Canyon area utilizes an algorithm solution technique based on a finite difference approximation of the differential equation of ground water flow. The model programs interact with various hydrogeologic and operational data files which provide a *data base* for the model. Additional support programs allow for missing data interpolation and model data array generation. The model and associated data bases graphically display output in a *layered* form whereby geohydrologic data are superimposed on a standard base map.

7.1.2 Model Size And Grid Geometry -

The ground water model covers approximately 1.3 square miles of surface area with a variable-grid network consisting of 53 nodes in the east-west direction (j-direction) and 54 nodes in the north-south direction (i-direction) totalling 2,862 nodes (see Figure 6).

NOTE

A model node is the center of a model grid block and is denoted by an "i,j" value. In the Sand Canyon Model, the j-direction increases in a west to east direction and the model i-direction increases in a north to south direction.

Geohydrologic Characteristics of the Sand Canyon Area

The smallest grid in the model measures approximately 66 ft x 92 ft and is compatible with the detail necessary to evaluate pumping and recharge in the area. The following table lists model nodes:

Model j-direction node widths, ft

1:	554.794	369.863	184.932	184.932	92.4658
6:	92.4658	92.4658	92.4658	92.4658	92.4658
11:	92.4658	92.4658	92.4658	92.4658	92.4658
16:	92.4658	92.4658	92.4658	92.4658	92.4658
21:	92.4658	92.4658	92.4658	92.4658	92.4658
26:	92.4658	92.4658	92.4658	92.4658	92.4658
31:	92.4658	92.4658	92.4658	92.4658	92.4658
36:	92.4658	92.4658	92.4658	92.4658	92.4658
41:	92.4658	92.4658	92.4658	92.4658	92.4658
46:	92.4658	92.4658	92.4658	92.4658	92.4658
51:	184.932	369.863	554.794		184.932

Total j-direction = 6750.0 ft

Model i-direction node widths, ft

1:	393.750	262.500	131.250	131.250	131.250
6:	131.250	131.250	65.6250	65.6250	65.6250
11:	65.6250	65.6250	65.6250	65.6250	65.6250
16:	65.6250	65.6250	65.6250	65.6250	65.6250
21:	65.6250	65.6250	65.6250	65.6250	65.6250
26:	65.6250	65.6250	65.6250	65.6250	65.6250
31:	65.6250	65.6250	65.6250	65.6250	65.6250
36:	65.6250	65.6250	65.6250	65.6250	65.6250
41:	65.6250	65.6250	65.6250	65.6250	65.6250
46:	65.6250	65.6250	131.250	131.250	131.250
51:	131.250	131.250	262.500	393.750	

Total i-direction = 5250.0 ft

Geohydrologic Characteristics of the Sand Canyon Area

Vertically, the model is single-layered with all interbedded aquifers (A and B-Zones) combined together as a single unit.

7.1.3 Boundary Conditions. -

Within the modeled area, no geologic or hydrologic boundaries exist as the Fanglomerate underlies the entire Sand Canyon area. The boundaries are considered *open* and interference is prevented from reaching these boundaries by the *pad effect* of increasingly larger nodes near model edges.

7.1.4 Model Data Parameters -

Various hydrogeologic and operational parameters were necessary to simulate ground water flow. These parameters include initial water-levels, transmissivity, storativity, pumping and recharge. Water-level elevations were constructed from data obtained from measurements in the exploratory/test wells and are shown on the contour map of Figure 5.

Ground water-level data were entered into the model using a digitizer and a series of control-point gridding programs. Contour refinement by hand contouring was necessary to adequately reflect hydrodynamic conditions in areas where control point data (i.e. wells) were lacking.

A uniform transmissivity of 30,000 gpd/ft was used throughout the model. This value was estimated based on average hydraulic conductivities and saturated thickness of the A and B Zones. A Storativity value of 0.15 was assumed throughout the model representing the average value for the upper aquifer system.

Geohydrologic Characteristics of the Sand Canyon Area

For the average vertical infiltration rate in the recharge area, the minimum value of 1.5 ft/day was used (see Table 4). To accomplish the recharge of 758 acre-ft during the 7-month period, 18 model nodes totaling approximately 2.5 acres were necessary. The area of recharge was determined considering the infiltration rate and required volume of water to be recharged during the Seasonal Storage Period. The area proposed for artificial recharge is within the Sand Canyon stream channel extending from Teton Road to the vicinity of TH-1 (see Figure 6).

The three proposed extraction wells are located in the vicinity of TH-5. Test drilling results in this area showed excellent aquifer yield potential with over 300 ft of saturated sands and gravels. Table 6 summarizes pumping and recharge nodes used in the model.

The model predictive run consisted of turning on the artificial recharge nodes for the period October through April (MWD's Seasonal Storage Period) and the three extraction well nodes for the entire 12-month period. The effect of the recharge and recovery program was evaluated by analyzing changes in water levels at the end of the 7-month recharge cycle and again at the end of 12 months. These changes are plotted as *regional drawdown* contours on figures 6 and 7. The 7-month regional drawdown (Figure 6), is the difference between the initial water-level elevation (i.e. October) and the water level elevation at the end of April. The 12-month regional drawdown (Figure 7), is the difference between the initial water level and the end of December water level.

As can be seen on Figure 6, the impact of the recharge on the extraction wells is clearly shown. Ground water mounds develop in the vicinity of the recharge basins attaining a maximum height of approximately 10 ft. This height is well below ground surface as initial depths to water in this area are 50-55 ft. By comparing Figures 6 and 7, it can be seen that drawdowns are less than at the end of 7 months than at 12 months verifying that the artificial recharge was contributing to a portion of the extraction well discharge.

Stabilization of the pumping wells was rapid attaining equilibrium within approximately one month. Prior to the start of the recharge cycle, drawdowns still exist in the vicinity of the extraction well field. These drawdowns are the result of continuously pumping the three extraction wells at an average rate of 200 gpm each. During the recharge period, the drawdowns in the vicinity of the well field would be less as a portion of the recharge supplying flow to the wells would be supplied from artificial recharge in upper Sand Canyon.

Geohydrologic Characteristics of the Sand Canyon Area

Appendix D contains selected hydrographs of various model nodes from the upper recharge area to the extraction well sites. These hydrographs show ground water level changes during the 12-month model simulation period.

8 TRAVEL TIME AND DISTANCE BETWEEN RECHARGE AND EXTRACTION

The travel time from the lowermost recharge pond (near Teton Road) to the site of the extraction wells (near TH-5) was calculated using the following equation:

$$dt = dx / V$$

where:

dt = travel time [days]

dx = distance between recharge and extraction areas, [ft]

V = Horizontal Ground Water Seepage Velocity, [ft/day]

According to the DOHS guidelines (see Table II Black and Veatch, 1990), the proposed Sand Canyon recharge project is a *Category I* project. As the depth to ground water exceeds 20 ft, the required retention time underground is six months. In addition, the minimum distance between recharge and recovery must be greater than 500 ft.

To calculate the minimum recharge/extraction distance considering a retention time of six months, the minimum and maximum horizontal seepage velocities as summarized in Table 3 were used. In considering underground retention time, the worst case (greatest distance) scenario was used. Also, no time was allowed for vertical percolation from the pond to the water table even though calculations range from 11 to 33 days (-see Table 7).

The following equation was used to calculate the minimum distance between the recharge and extraction areas.

Geohydrologic Characteristics of the Sand Canyon Area

$$dx = V \times dt$$

where:

dx = minimum distance between recharge and extraction [ft]

V = ground water seepage velocity [ft/day]

dt = underground retention time (DOHS requirement) [180 days]

Results are plotted as *Residence Time Isopleths* on Figure 8. Assuming no retention time for vertical percolation, the minimum distance between the extraction wells and the lowermost recharge pond (near Teton Road) ranges from 594 to 2,412 ft (see shaded line on Table 7). The dashed isopleths on Figure 8 denote the slower velocity (3.3 ft/day) while the solid lines represent a seepage velocity of 13.4 ft/day. Tables

9 COMPLIANCE WITH DOHS REQUIREMENTS FOR GROUND WATER RECHARGE

The following section discusses compliance with the proposed DOHS requirements for ground water recharge using reclaimed municipal wastewater. The format for this section is in accordance with the October 1, 1990 letter from Black and Veatch to DWP City of Big Bear Lake. The items discussed are those items preceded by an asterisk in the section *Information Needed to Complete Documents*.

9.1 Discussion Of Items

Item (3) *Characterize ground water quality in basin*

Five samples of ground water were taken during the exploratory test drilling program and analyzed by a certified laboratory. Laboratory results may be seen in Appendix C, Table 5 and Section 5.

Geohydrologic Characteristics of the Sand Canyon Area

Item (4) *Determine travel time from recharge site by plotting residence time isopleths.*

This is discussed in detail in section 8 and shown on Figure 8.

Item (8) *Soil types.*

See section 3 and Appendix A.

Item (9) *Percolation rates.*

See section 6 and Table 4.

Item (10) *Rates and direction of ground water movement.*

See section 3.3 and Table 3.

Item (12) *Thickness of recharge aquifer.*

See section 3, Plate 1, Figures 2, 4 and Appendix A.

Item (13) *Location and properties of low permeability layers.*

See section 3, Plate 1, Figures 2, 4 and Appendix A.

Item (16) *Number of aquifers in area, depth, extent and thickness.*

See section 3, Plate 1, Figures 2, 4, and Appendix A.

Item (17) *Head difference between aquifers.*

See section 3, Figure 5 and Table 1.

Geohydrologic Characteristics of the Sand Canyon Area

Item (18) *Leakage between aquifers.*

See Section 3.

Item (19) *Water level contour maps for each aquifer.*

See Figure 5.

Item (20) *Hydrological nature of site, including recharge and discharge areas*

See Section 3.3 and Figure 5

Item (21) *Impact of recharge waters on basin including: description of recharge water types recharge water quantities and qualities recharges water points of application and movements*

See Sections 5, 7 and 8.

Item (35) *Well logs and site borings showing subsurface materials and properties.*

See Appendix A

Item (36) *Percolation data; number and location of tests.*

See section 5.

Item (37) *Infiltration rates (K) of vadose zone.*

See section 5.

Geohydrologic Characteristics of the Sand Canyon Area

References

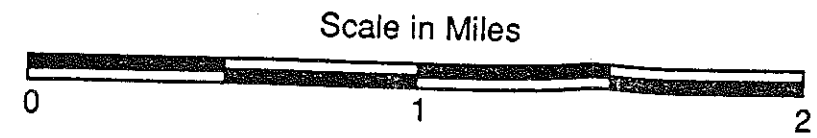
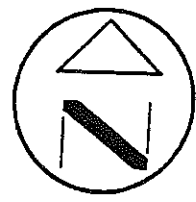
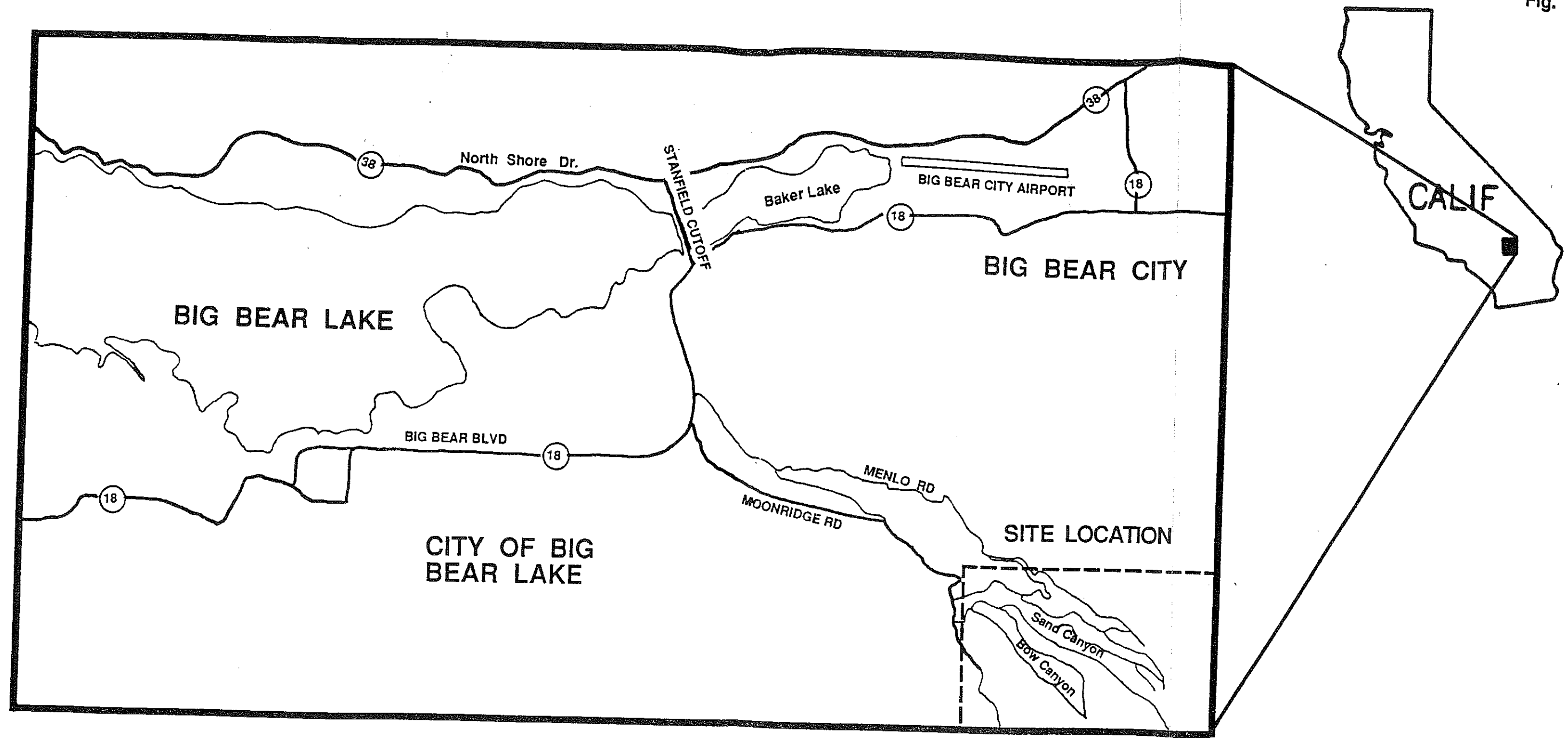
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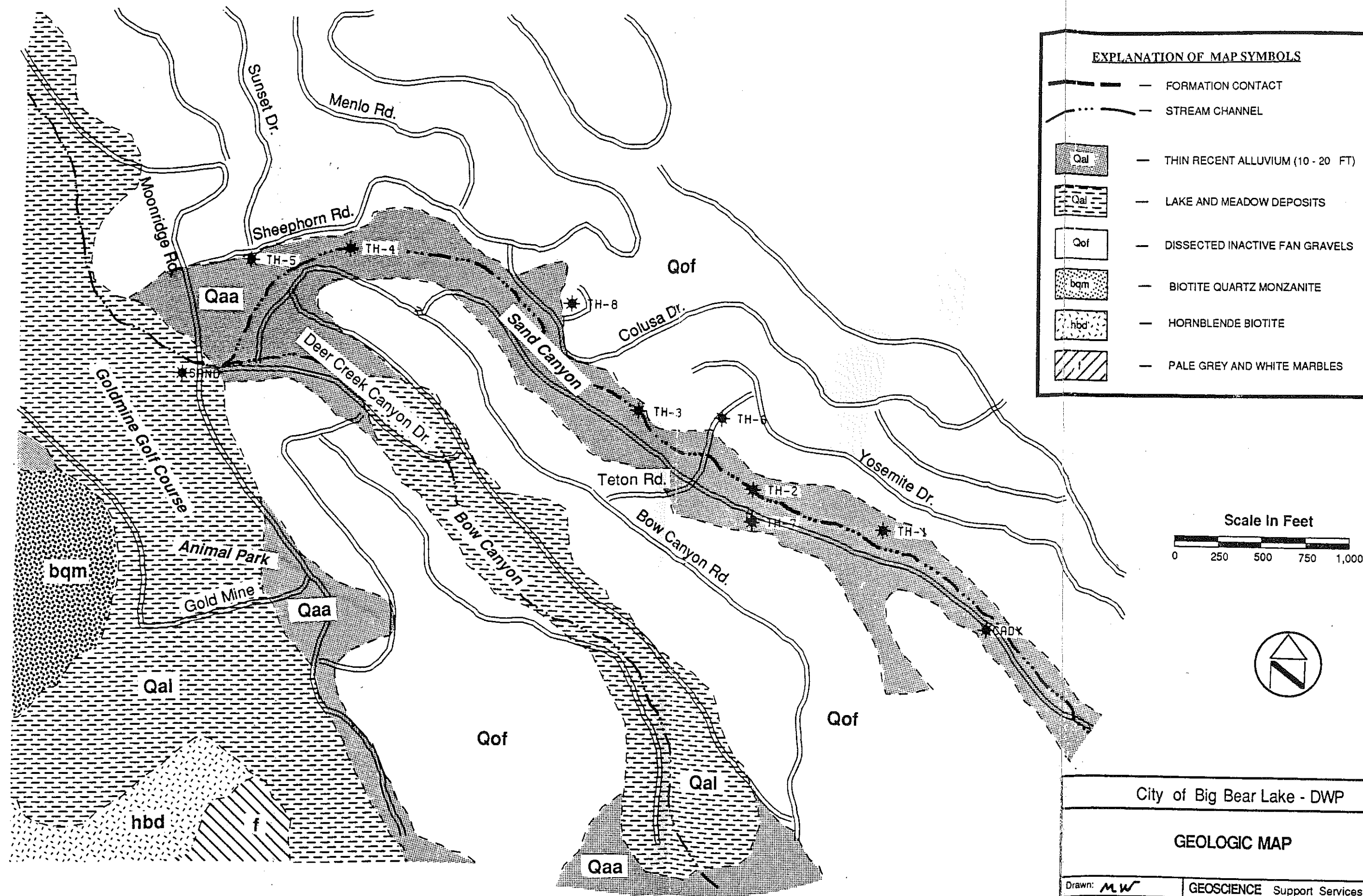
FIGURES

Fig. 1

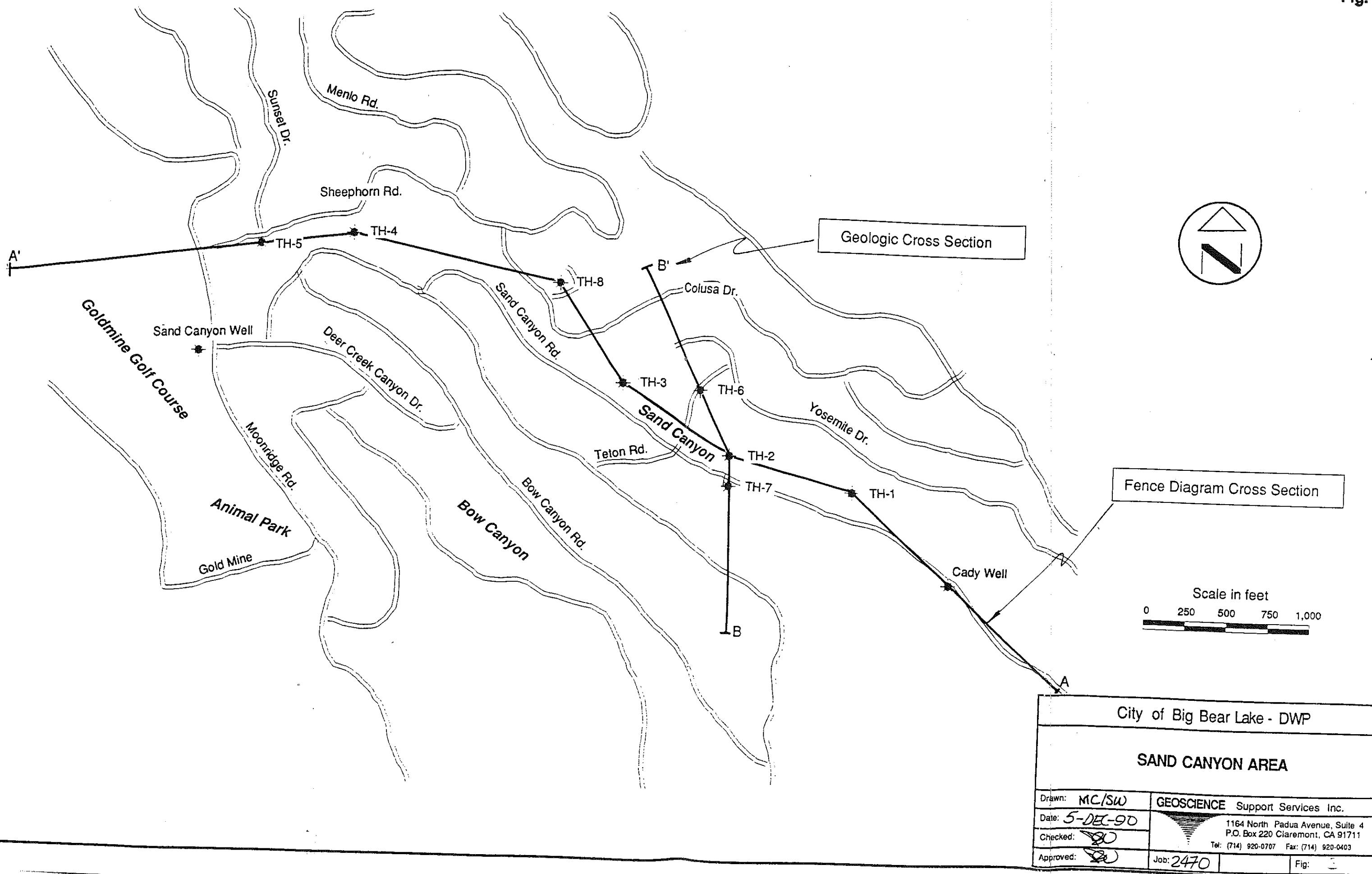


City of Big Bear Lake - DWP	
GENERAL LOCATION MAP	
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Date: <i>5-DEC-90</i>	1164 North Padua Avenue, Suite 4 P.O. Box 220 Claremont, CA 91711
Checked: <i>[Signature]</i>	Tel: (714) 920-0707 Fax: (714) 920-0403
Approved: <i>[Signature]</i>	Job: <i>2470</i> Fig: <i></i>

Fig. 2

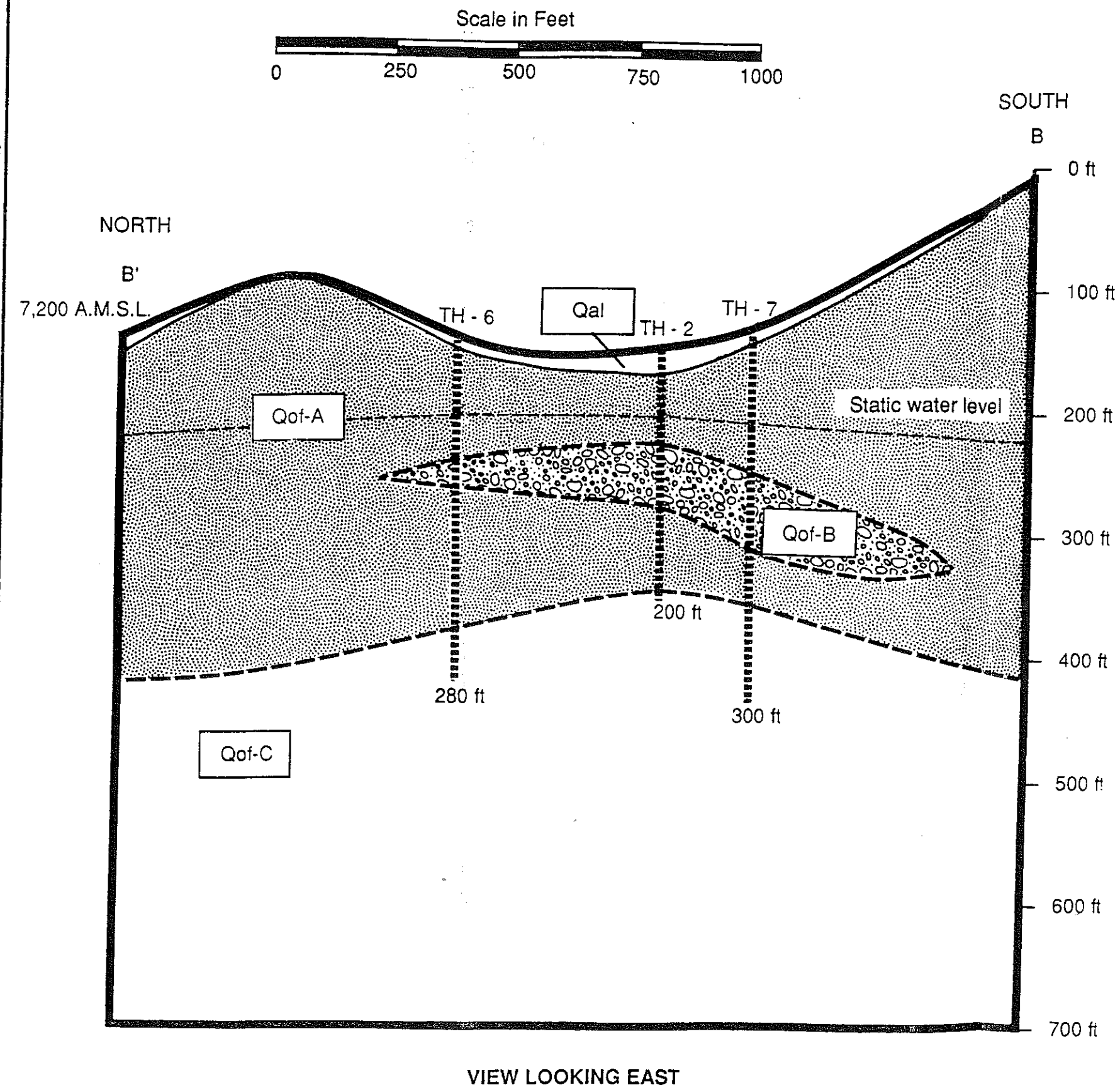


City of Big Bear Lake - DWP	
GEOLOGIC MAP	
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Checked: <i>[Signature]</i>	Tel: (714) 920-0707 Fax: (714) 920-0403
Approved: <i>[Signature]</i>	Job: 2470 Fig:



City of Big Bear Lake - DWP	
SAND CANYON AREA	
Drawn: MC/SW	GEOSCIENCE Support Services Inc.
Date: 5-DEC-90	1164 North Padua Avenue, Suite 4 P.O. Box 220 Claremont, CA 91711
Checked: [Signature]	Tel: (714) 920-0707 Fax: (714) 920-0403
Approved: [Signature]	Job: 2470 Fig: 3

EXPLANATION



Qal	Quaternary Alluvium. Recent stream channel deposits, consisting of unconsolidated sand and gravel.
Qof-A	Quaternary Fanglomerate. A-Zone, silty sand with gravel and thin clay layers.
Qof-B	Quaternary Fanglomerate. B-Zone, medium to coarse sand and gravel.
Qof-C	Quaternary Fanglomerate. C-Zone, predominately clays with thin layers of silt, sand and gravel.
	Formation Contact.
	Lithologic Unit Contact.
	Static Water Level.
TH - 2	Test Hole

City of Big Bear Lake - DWP			
CROSS SECTION OF SAND CANYON			
Drawn: SW	GEOSCIENCE Support Services Inc.		
Date: 5-DEC-90	1164 North Padua Avenue, Suite 4 P.O. Box 220 Claremont, CA 91711		
Checked:	Tel: (714) 920-0707 Fax: (714) 920-0403		
Approved:	Job: 2470	Fig: 2	

Fig. 5

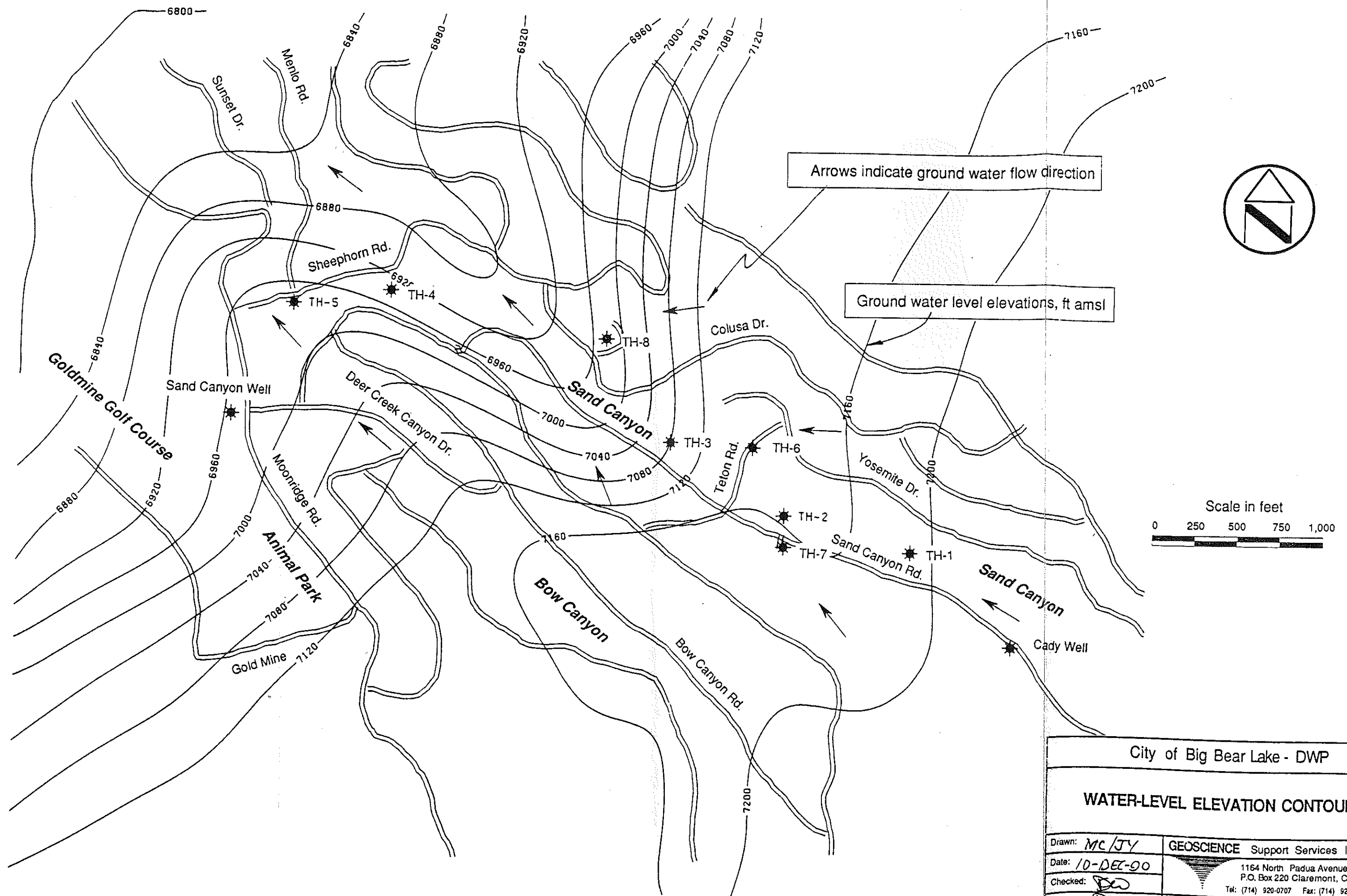


Fig. 6

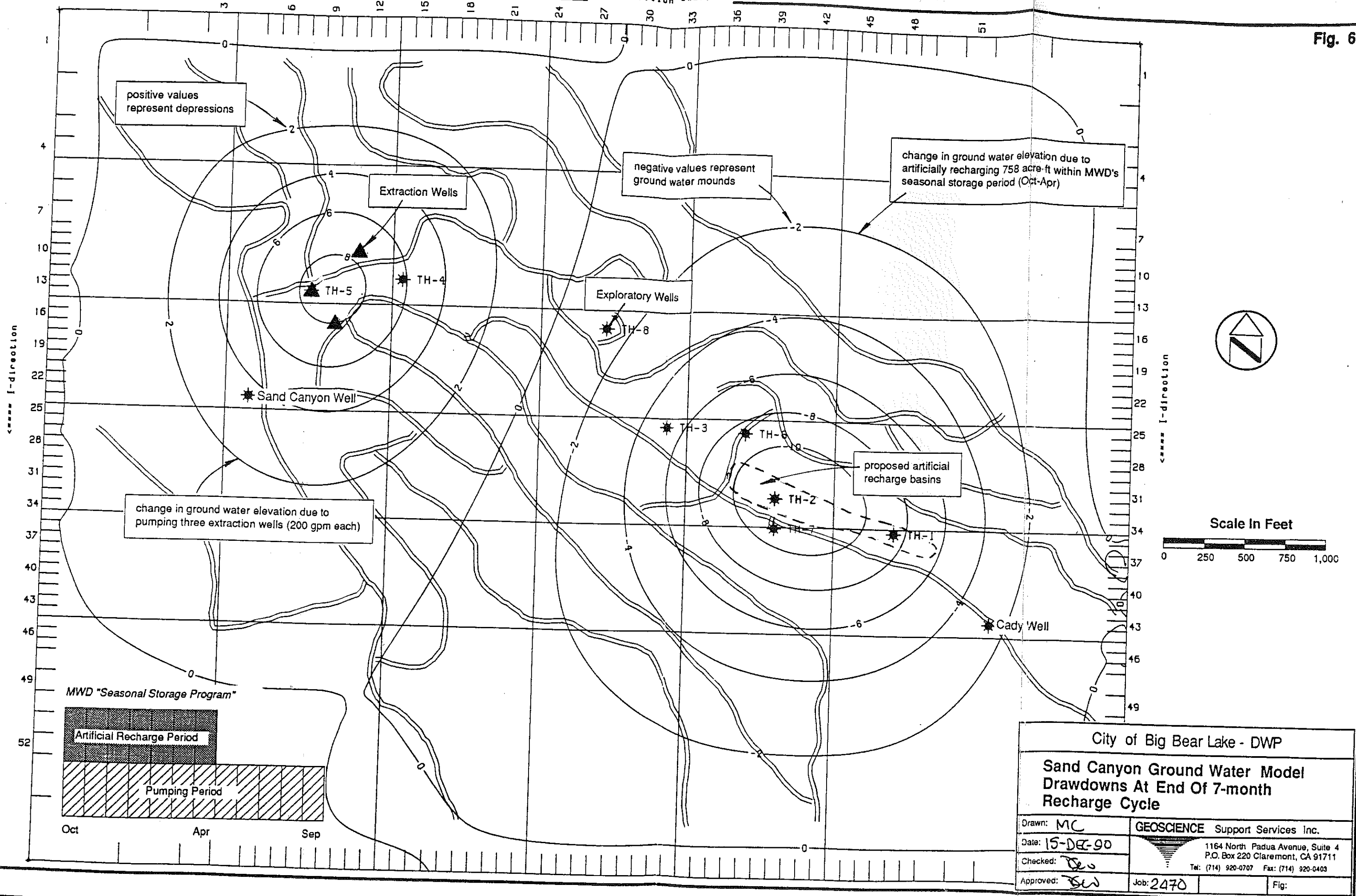
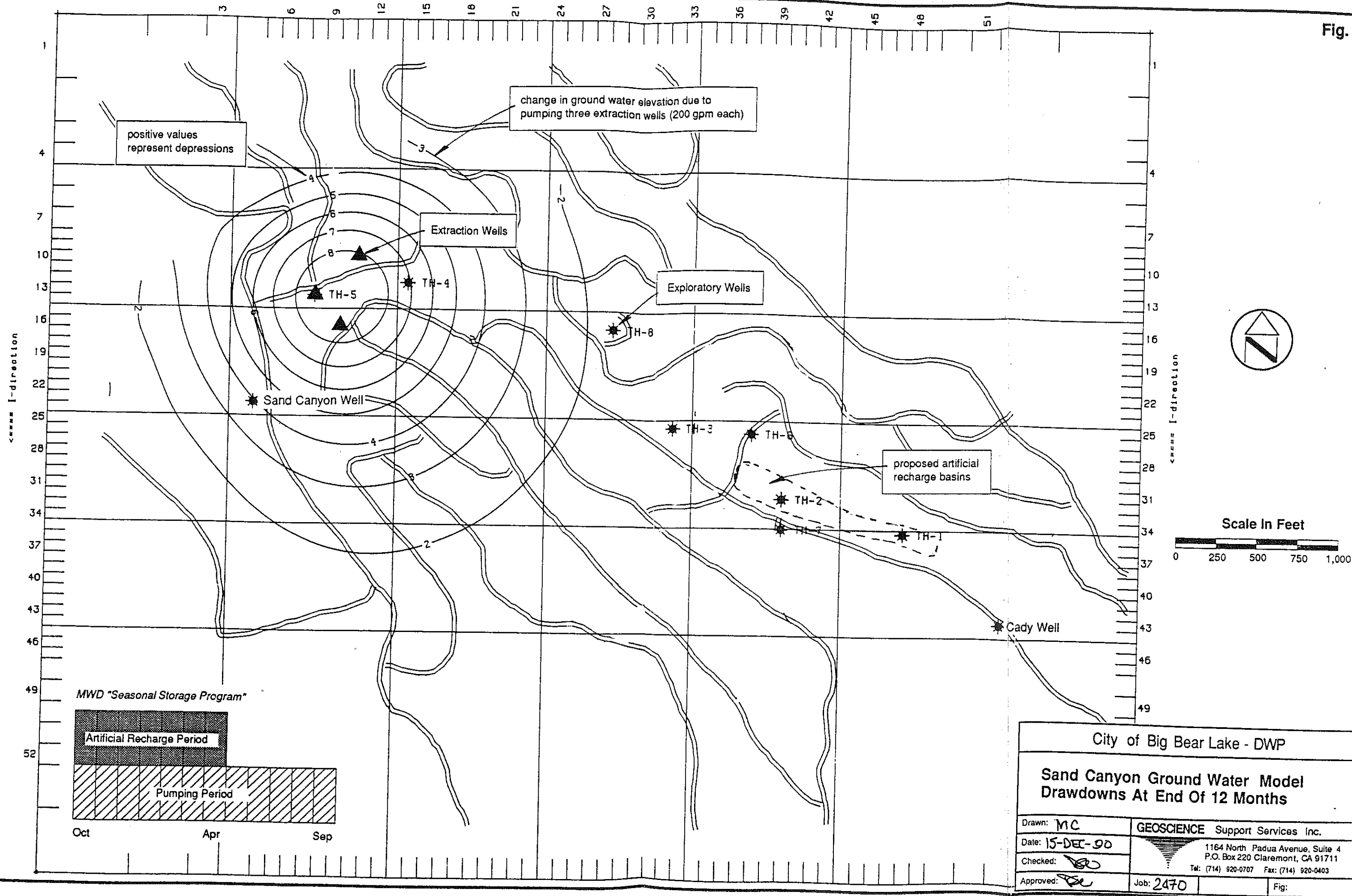
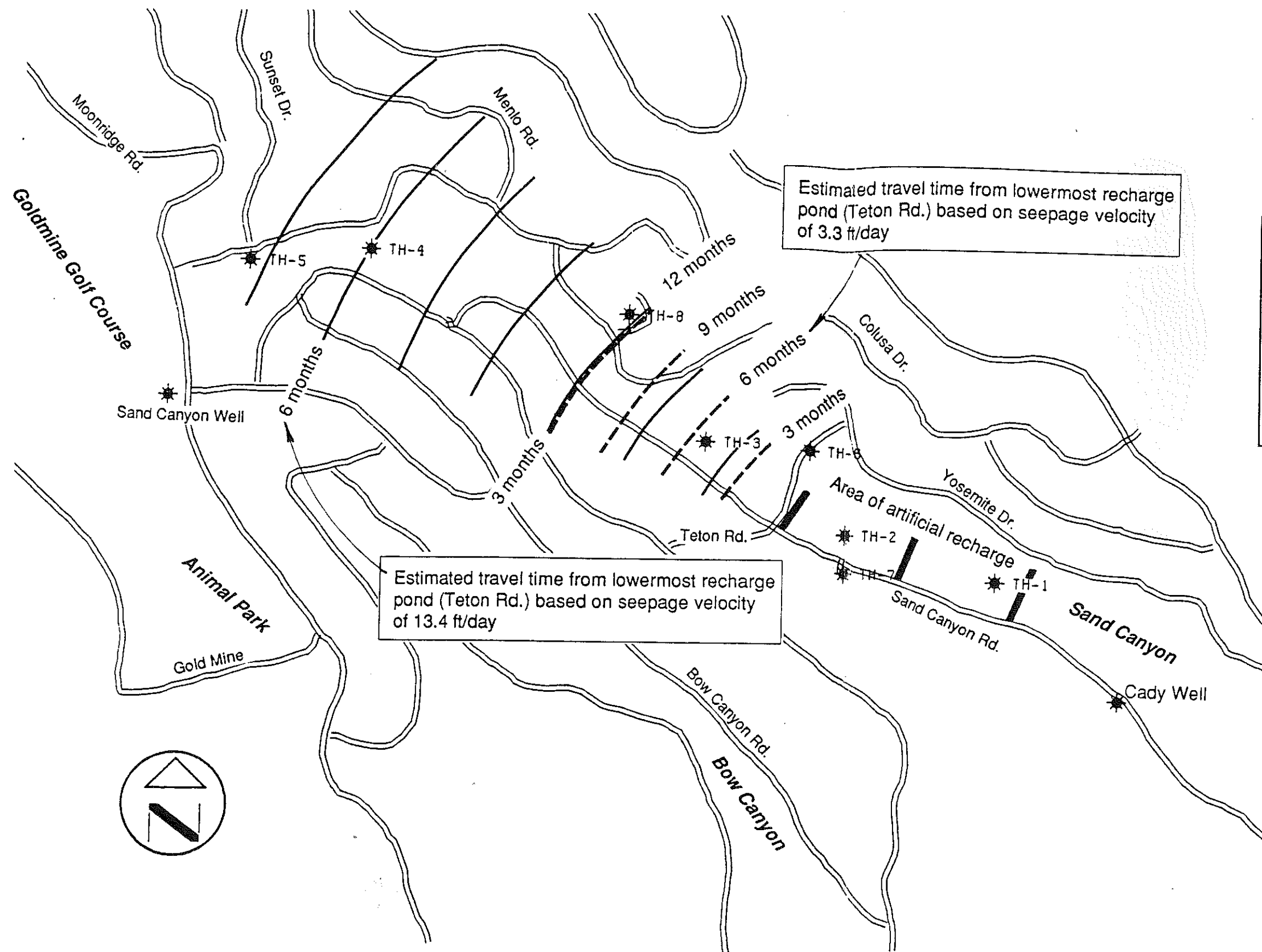


Fig.





City of Big Bear Lake - DWP

RESIDENCE TIME ISOPLETHS
FROM RECHARGE SITE

Drawn: MC/JY

Date: 15-DEC-90

Checked: JS

Approved: JS

GEOSCIENCE Support Services Inc.

1164 North Padua Avenue, Suite 4
P.O. Box 220 Claremont, CA 91711

Tel: (714) 920-0707 Fax: (714) 920-0403

Job: 2470

Fig:

TABLES

Tables 3-7

Table 3 - Calculation of Horizontal Seepage Velocity from Hydraulic Conductivity

Hydraulic Conductivity* [gpd/ft ²]	Effective Porosity**	Hydraulic Gradient [ft/ft]	Seepage Velocity*** [ft/day]
100	0.15	0.05	4.5
100	0.20	0.05	3.3
150	0.15	0.05	6.7
150	0.20	0.05	5.0
200	0.15	0.05	8.9
200	0.20	0.05	6.7
250	0.15	0.05	11.1
250	0.20	0.05	8.4
300	0.15	0.05	13.4
300	0.20	0.05	10.0

* Hydraulic conductivity was estimated from correlating grain size distribution of field samples

with Masch-Denny prediction curves (Masch and Denny, 1966 and Folk, 1974).

** Effective porosity was estimated from the relationship between grain size and effective porosity (Morris and Johnson, 1967).

*** Seepage Velocity = (Hydraulic Conductivity x Hydraulic Gradient) / (Effective Porosity x 7.48).

Values in **Bold** represent minimum and maximum ground water seepage velocities.

Table 4 - Calculation of Long-term Infiltration Rate from Hydraulic Conductivity

Hydraulic Conductivity [gpd/ft ²]	Sorptivity* [ft/day 1/2]	Time [days]	Vertical Infiltration Rate** [ft/day]
100	3.9	180	1.5
150	3.9	180	2.3
200	3.9	180	3.0
250	3.9	180	3.8
300	3.9	180	4.5

*Sorptivity is a function of pore geometry and initial water content.

**Long-term infiltration rate calculated using Philip equation (Philip, 1969) and values $\times 1/3$.
Shaded value used in ground water model simulation.

Table 5 - Summary of Water Quality in Sand Canyon Exploratory Wells

Constituent	Units	Test Hole 1 sample at 140 ft		Test Hole 2 sample at 60 ft		Test Hole 3 sample at 140 ft		Test Hole 4 sample at 220 ft		Test Hole 5 sample at 300 ft	
		Measured	MCL	Measured	MCL	Measured	MCL	Measured	MCL	Measured	MCL
Total Hardness	mg/l	218		150		184		249		204	
Calcium	mg/l	68		45		54		65		51	
Magnesium	mg/l	12		9		12		21		19	
Sodium	mg/l	10		9		10		12		9	
Potassium	mg/l	1		4		5		5		2	
Total Alkalinity	mg/l	226		165		202		250		209	
Hydroxide	mg/l	<1		<1		<1		<1		<1	
Carbonate	mg/l	<1		<1		<1		<1		<1	
Bicarbonate	mg/l	276		201		246		306		255	
Sulfate	mg/l	6	250*	6	250*	7	250*	10	250*	9	250*
Chloride	mg/l	8	250*	8	250*	8	250*	13	250*	7	250*
Nitrate	mg/l	6	10**	1	10**	1	10**	17	10**	2	10**
Fluoride	mg/l	<0.1	4**	0.2	4**	0.2	4**	0.2	4**	<0.1	4**
pH	std UNITS	8	6.5-8.5*	7	6.5-8.5*	7	6.5-8.5*	7	6.5-8.5*	8	6.5-8.5*
Specific Conductance	umho/cm	480		370		440		570		470	
Total Filterable Residue	mg/l	288	500*	226	500*	255	500*	226	500*	282	500*
MBAS	mg/l	<0.02	0.5*	<0.02	0.5*	<0.02	0.5*	<0.02	0.5*	<0.02	0.5*
Copper	ug/l	<50	1000*	<50	1000*	<50	1000*	<50	1000*	<50	1000*
Iron	ug/l	<100	300*	440	300*	<100	300*	<100	300*	<100	300*
Manganese	ug/l	<30	50*	160	50*	620	50*	40	50*	<30	50*
Zinc	ug/l	<50	5000*	<50	5000*	<50	5000*	<50	5000*	<50	5000*

*Maximum contaminant level (MCL) as specified in EPA National Secondary Drinking Water Standards (1979).

**Maximum contaminant level (MCL) as specified in EPA National Primary Drinking Water Standards (1988).

Values in **Bold** represent data which exceed maximum contaminant levels.

Table 6 - Summary of Sand Canyon Ground Water Model Pumping and Recharge

Pumping Nodes

Model Node (i,j)	Period	Amount [acre-ft/yr]
(10,11)	Oct-Sep	320
(13,8)	Oct-Sep	320
(16,10)	Oct-Sep	320
Total		960 Acre-ft/yr*

Artificial Recharge Nodes

Model Node (i,j)	Period	Amount [acre-ft/yr]
(29,37)	Oct-Apr	46.7
(30,37)	Oct-Apr	46.7
(30,38)	Oct-Apr	46.7
(30,39)	Oct-Apr	40.8
(31,38)	Oct-Apr	46.7
(31,39)	Oct-Apr	40.8
(31,40)	Oct-Apr	40.8
(32,40)	Oct-Apr	40.8
(32,41)	Oct-Apr	40.8
(32,42)	Oct-Apr	40.8
(33,42)	Oct-Apr	40.8
(33,43)	Oct-Apr	40.8
(34,44)	Oct-Apr	40.8
(34,45)	Oct-Apr	40.8
(34,46)	Oct-Apr	40.8
(35,47)	Oct-Apr	40.8
(35,48)	Oct-Apr	40.8
(36,49)	Oct-Apr	40.8
Total		758 Acre-ft/yr

*Annual pumping exceeds annual recharge as the extraction wells also receive natural recharge from the Bow Canyon area.

Table 7 - Relation Between Seepage Velocity, Retention Time, and Down Gradient Extraction Wells

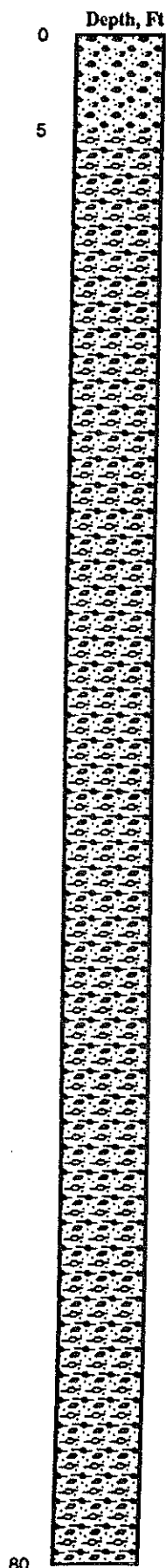
Horizontal Seepage Velocity [ft/day]	Vertical Infiltration Rate [ft/day]	Retention Time [days]			Minimum Distance Required Between Extraction Well(s) and Recharge Ponds [ft]
		Horizontal	Vertical	Total	
3.3	1.5	147	33	180*	500**
3.3	4.5	169	11	180	558
3.3	None	180	0	180	594
4.5	1.5	147	33	180	662
4.5	4.5	169	11	180	761
4.5	None	180	0	180	810
7.3	1.5	147	33	180	1073
7.3	4.5	169	11	180	1234
7.3	None	180	0	180	1314
10.0	1.5	147	33	180	1470
10.0	4.5	169	11	180	1690
10.0	None	180	0	180	1800
13.4	1.5	147	33	180	1970
13.4	4.5	169	11	180	2265
13.4	None	180	0	180	2412

*Six month retention time required by DOHS Guidelines.

** Minimum distance required by DOHS Guidelines.

Shaded values represent minimum and maximum values as shown on Figure 8.

APPENDIX A
Lithologic Logs of Test Wells



Med-Coarse Sand & Gravel

0- 5 Medium to Coarse Sand and Gravel--Grey to Brown. Medium to coarse sand and gravel, angular to sub-angular made mostly of quartz, feldspar and mafic rock fragments, .5-10mm with a few grains up to 40mm in size, with a slight amount of silty fine sand.

5-15 Silty Sand and Gravel--Brownish. 40% silty fine to med. sand less than 1mm. 60% med. to coarse sand and gravel, angular made mostly of quartz, feldspar and mafic rock fragments, 1-10mm in size.

15-20 Silty Sand and Gravel--Same as above except gravel increases to 15mm.

20-25 Silty Sand and Gravel--Tannish. 60%-70% medium to coarse sand and gravel, angular, made mostly of quartz, feldspar and mafic rock fragments, 1-15mm in size. 30%-40% silty fine to med. sand less than 1mm in size.

Silty Sand & Gravel

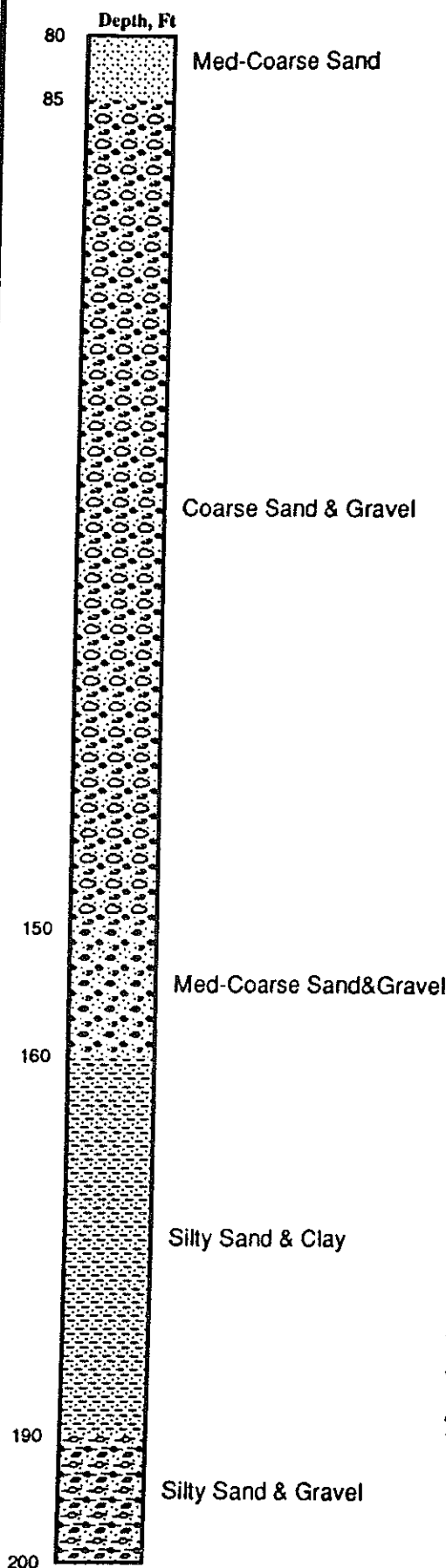
25-30 Silty Sand and Gravel--Tannish. 40%-60% medium to coarse sand and gravel, angular to sub-angular, made mostly of quartz, feldspar and mafic rock fragments, 1-20mm. 40%-60% silty fine sand less than 1mm, of which 80% is less than .5mm in size.

30-60 Silty sand and Gravel--Light Brown. 50%-70% silty fine to medium sand less than 1mm. 30%-50% coarse sand and gravel, sub-angular to angular made mostly of quartz, feldspar and mafic rock fragments, 1-15mm in size.

60-70 Silty Sand with some Gravel--Light grey. 80% silty fine to med. sand less than 1mm; The majority is silt and very fine sand. 20% medium to coarse sand with some gravel, sub-angular made mostly of quartz, feldspar and mafic rock fragments, mostly 1-2mm with some grains up to 10mm in size.

70-80 Silty Sand and Gravel--Light grey to grey-brown. 50%-60% silty fine to medium sand less than 1mm in size, more sand than silt. 40%-50% coarse sand and gravel, angular to sub-angular made mostly of quartz, feldspar and mafic rock fragments, 1-10mm in size.

Sand Canyon TH-1 Lithologic Log



80-85 Medium to Coarse Sand--Medium to coarse sand, sub-angular, made mostly of quartz, feldspar and mafic rock fragments, 1/2 -2mm in size.

85-145 Coarse Sand and Gravel--95% coarse sand and gravel, sub-angular made mostly of quartz, feldspar and mafic rock fragments, .5-10mm in size, at 115ft to 130ft gravel increases to 20mm in size. 5% fine to medium sand 1/16-1mm in size, at 140ft to 145ft fine to medium sand increases to 20%.

145-150 Silty Fine to Coarse Sand and Gravel--60% to 70% silty fine to medium sand less than 1mm in size. 30% to 40% coarse sand and gravel sub- angular to angular, made mostly of quartz, feldspar and mafic rock fragments, 1-5mm in size. Also a slight amount of clay.

150-155 Medium to Coarse Sand and Gravel with some Clay--80%-85% medium to coarse sand and gravel, sub-angular to angular made mostly of quartz, feldspar and mafic rock fragments, .5-10mm in size. 10%-15% clay. 5% silt and fine sand.

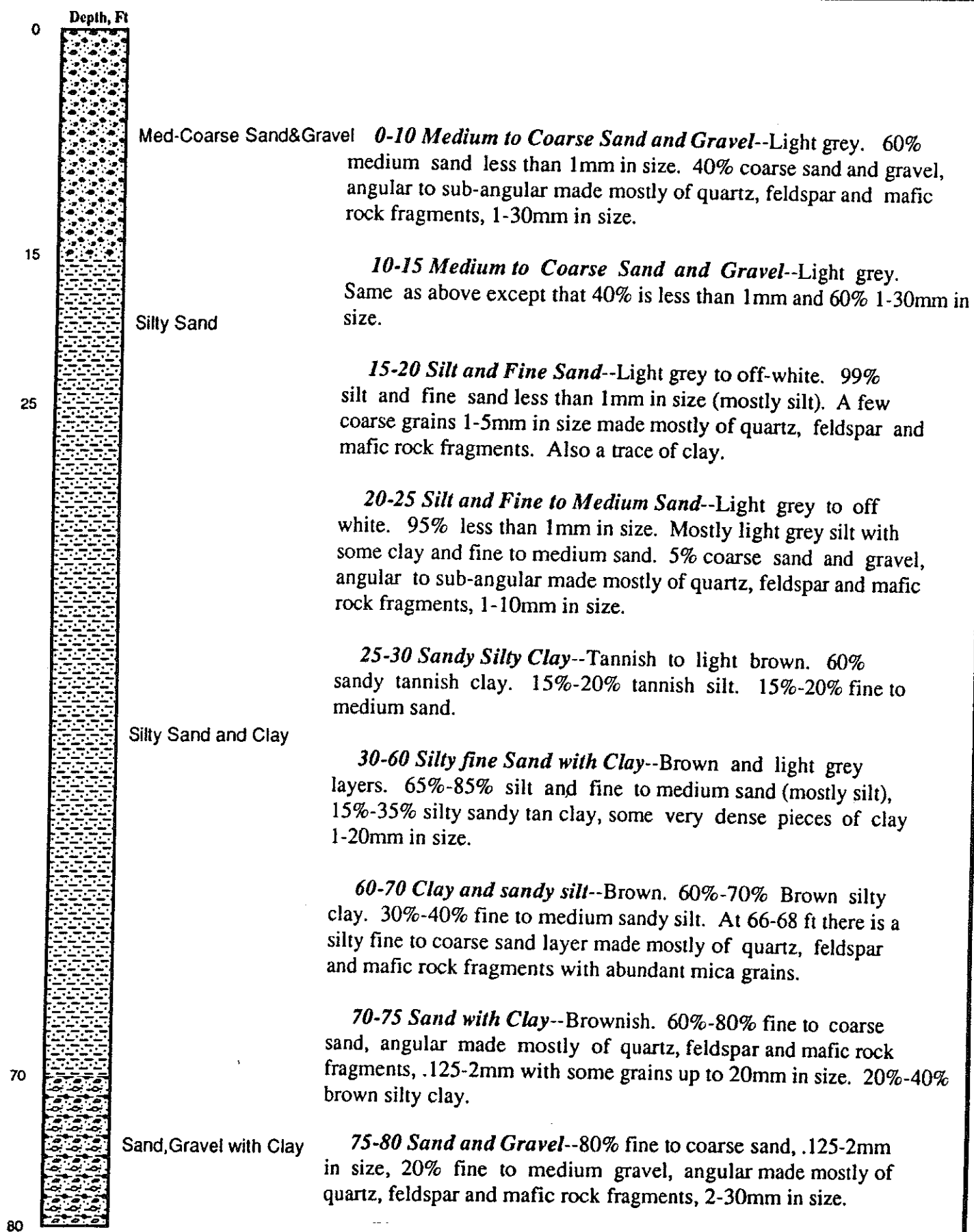
155-160 Fine to Coarse Sand and Gravel with some Clay--Tannish. 70% silty fine to medium sand less than 1mm in size. 25% coarse sand and gravel, angular made mostly of quartz, feldspar and mafic rock fragments, 1-10mm in size. 5% tannish sandy clay.

160-190 Silty Sand and Clay--Grey to off-white. 40%-60% off-white, light grey and light brown clay. At 170ft-180ft clay is grey and increases to 80%. 40%-60% silty fine to coarse sand less than 2mm in size, sub-angular made mostly of quartz, feldspar and mafic rock fragments.

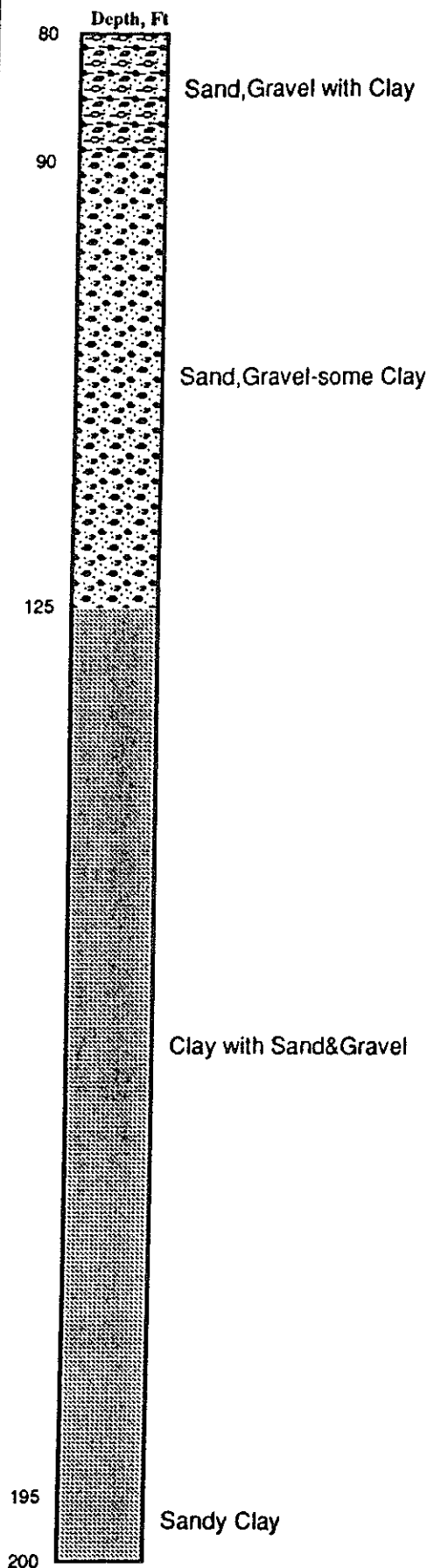
190-200 Silty Sand and gravel with Clay--Grey. 40%-60% silty fine to coarse sand and gravel,decreases to 40% at 200ft, angular, made mostly of quartz, feldspar and mafic rock fragments, .03-5mm in size increasing to 10mm at 200ft. 40%-60% grey sandy clay.

Total Depth 200ft

Sand Canyon TH-1 Lithologic Log



Sand Canyon TH-2 Lithologic Log



80-120 Medium to Coarse Sand and Gravel with some Clay--Light Brown. 70%-90% medium to coarse sand and gravel, angular to sub-angular made mostly of quartz, feldspar and mafic rock fragments, .5-10mm in size, at 105ft-110ft gravel increases to 20mm in size. Some thin sandy brown and rust-colored clay layers found at 83ft, 87ft, 97ft, and 117ft below ground surface.

120-125 Fine to Coarse Sand and Gravel with some Clay--Tannish. 50%-60% silt to medium sand less than .5mm in size. 40%-50% medium to coarse sand and gravel, angular made mostly of quartz, feldspar and mafic rock fragments 1-5mm in size.

125-130 Fine to Coarse Sand and Clay-- Tan. 40% fine to coarse sand, angular made mostly of quartz, feldspar and mafic rock fragments, .125-2mm in size. 60% light grey to tan clay.

130-140 Clay with some Fine to Coare Sand--Tan. 75%-80% tannish sandy clay, 20%-25% fine to coarse sand, angular to sub-angular made mostly of quartz, feldspar and mafic rock fragments .125-2mm in size.

140-145 Clay, Sand and Gravel--Tannish. 50% sandy tannish clay. 50% fine to coarse sand and gravel, angular to sub-angular made mostly of quartz, feldspar and mafic rock fragments, .125-5mm in size.

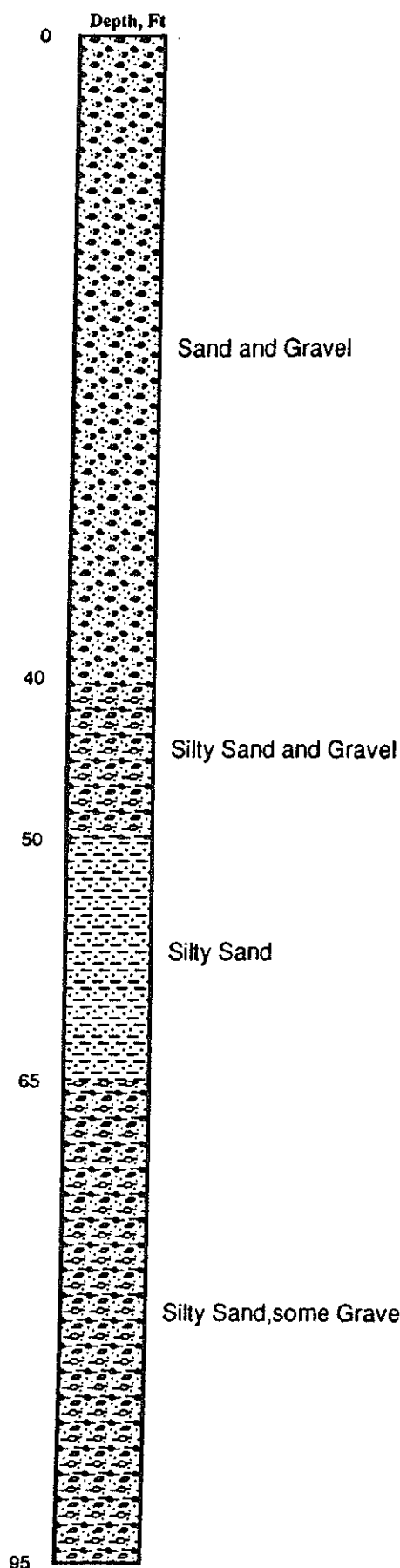
145-185 Clay with Sand and Gravel--Tannish to light brown. 70%-75% tannish sandy clay. 25%-30% sand and gravel layers angular to sub-angular made mostly of quartz, feldspar and mafic rock fragments, .125-5mm in size.

185-195 Clay and Silt with some Sand and Gravel--Tan. 95% tan silt and clay. 5% medium to coarse sand and gravel, angular to sub-angular made mostly of quartz, feldspar and mafic rock fragments, .125-5mm in size.

195-200 Sandy Clay--Tannish. 95% tan sandy clay with some interbedded silt. 5% coarse sand, sub-angular made mostly of quartz, feldspar and mafic rock fragments, 1-2mm in size.

200 Feet Total Depth

Sand Canyon TH-2 Lithologic Log



0-5 Coarse Sand and Gravel--Brown. 80%-90% coarse sand and gravel, sub-angular to angular made mostly of quartz, feldspar and mafic rock fragments, 1-40mm in size. 10%-20% fine to medium sand less than 1mm in size.

5-30 Fine to Coarse Sand and Gravel--Brown to light brown. 70% fine to medium sand less than 1mm in size. 30% coarse sand and gravel, angular made mostly of quartz, feldspar and mafic rock fragments, 1-20mm in size. At 25ft to 30ft gravel increases to 40mm in size.

30-35 Medium to Coarse Sand and Gravel--Brown. Medium to coarse sand and gravel, angular made mostly of quartz, feldspar and mafic rock fragments, 1/2-30mm in size.

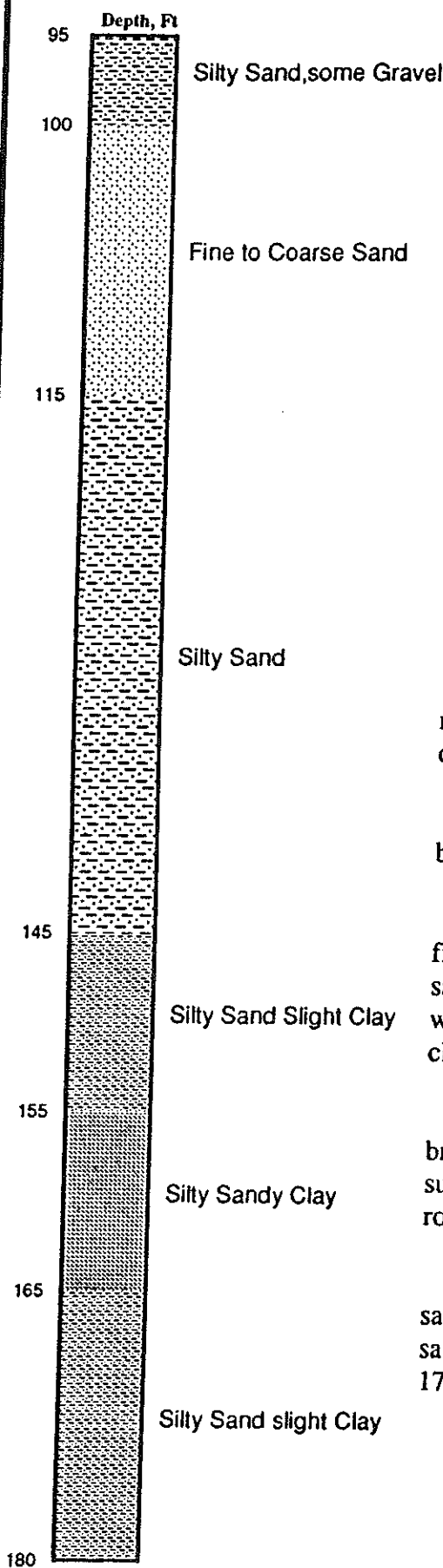
35-40 Fine to Coarse Sand and Gravel--Light brown. 60% fine to medium sand less than 1mm in size. 40% coarse sand and gravel, angular made mostly of quartz, feldspar and mafic rock fragments, 1-15mm in size.

40-50 Silty Fine to Coarse Sand with Gravel--Light brown turning to grey at 45ft. 70% to 80% silty fine to medium sand .03-1mm in size, overall finer at 45ft to 50ft. 20%-30% coarse sand and gravel, sub-angular to angular made mostly of quartz, feldspar and mafic rock fragments, also some very hard silt grains, 1-15mm in size at 40ft-45ft and 1-2mm in size at 45ft-50ft.

50-65 Silty Fine to Coarse Sand--Light grey to grey. Silty fine to coarse sand .03-2mm in size, overall very fine sand, sub-rounded to sub-angular. The coarser grains are more sub-angular, made mostly of quartz, feldspar and mafic rock fragments with some hard silty sandstone grains. At 55ft-65t there is a trace of grey clay.

65-95 Silty Very Fine to Coarse Sand with some Fine Gravel--Grey. 80% to 85% silty very fine to medium sand .01-1mm in size, mostly very fine sand. 15% to 20% medium to coarse sand and gravel, sub-angular to sub-rounded made mostly of quartz, feldspar and mafic rock fragments with some hard silty sandstone grains, 1-3mm in size, at 80ft-85ft gravel increases to 10mm in size. At 85ft-95ft there is a trace of clay.

Sand Canyon TH-3 Lithologic Log



95-100 Silty Fine to Coarse Sand with some Clay--Grey. 85% silty fine to medium sand less than 1mm in size. 10% medium to coarse sand, sub-angular made mostly of quartz, feldspar and mafic rock fragments with some hard silty sandstone grains, 1-2mm in size. 5% grey sandy clay.

100-115 Fine to Coarse Sand--Rusty-brown to light brown. fine to coarse sand, sub-angular made mostly of rock fragments, quartz and feldspar, .03-2mm in size.

115-135 Silty Fine to Coarse Sand--Brown to rusty-brown. 80% silty fine sand less than 1/4mm in size, 20% fine to coarse sand .25-2mm, mostly fine to medium in size, at 125ft-135ft coarse sand up to 1mm in size. Very fine material, grains are sub-rounded to sub-angular. The coarser grains are more sub-angular.

135-140 Sandy Silt--Brown. 90% fine sandy silt. 5% medium to coarse sand 0.25-2mm in size, sub-rounded made mostly of quartz, feldspar and mafic rock fragments. 5% sandy clay.

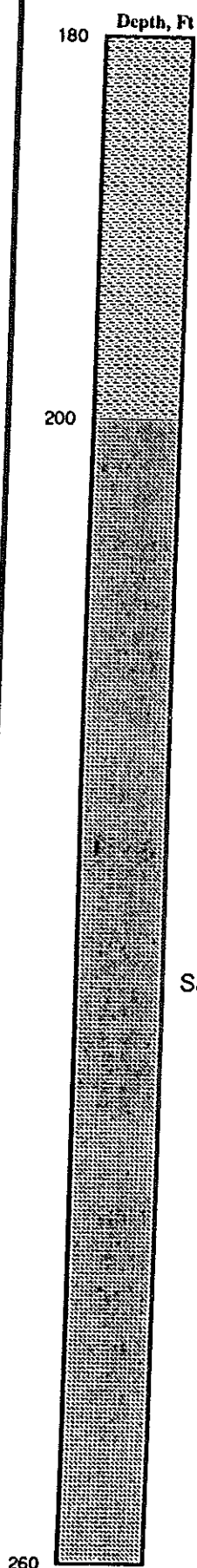
140-145 Sandy Silty Clay--Brownish. Sandy silty brownish clay.

145-155 Silty Sand with some clay--Brownish. 90% silty fine to medium sand .02-1/2mm in size. 5%-10% medium to coarse sand, sub-rounded made mostly of solid silty sandstone grains with very few quartz grains, 0.5-2mm in size. 0%-5% light brown clay.

155-165 Silty Sandy Clay--Brownish. 80% silty sandy brownish clay. 20% silt, sand and gravel, .03-4mm in size, sub-rounded to sub-angular made mostly of quartz, feldspar, mafic rock fragments and silty sandstone grains.

165-180 Sandy Silt with some Clay--Light brown. 80% sandy silt less than .125 mm in size. 20% Sandy grey clay. Some sand grains up to 2mm in size made mostly of quartz. At 177ft-180ft there is a solid sandy clay layer.

Sand Canyon TH-3 Lithologic Log



180-185 Silty Sand with some Clay--Brownish. 80% silty fine sand less than .125 mm in size. 10% fine to coarse sand, in size made mostly of quartz, feldspar, mafic rock fragments and silty sandstone grains, .25-2mm in size.

185-200 Silty Sand with Slight Clay--Brownish. 95% silty fine to medium sand .025-.5mm in size. 1-5% sandy brwnish clay. 1%-5% medium to coarse sand, sub-angular made mostly of quartz, feldspar and silty sandstone grains, .5-2mm in size.

200-215 Silty Sand and Sandy Clay--Brownish. 60% sandy brownish clay. 40% silty fine to medium sand .025-.5mm in size, at 205ft-210ft sandy silt increases to 70% and clay decreases to 30%.

215-220 Silt and Sandy Clay--Brownish. 75% sandy brown clay. 20% silt. 5% fine to medium sand made mostly of quartz, feldspar, mafic rock fragments and silty sandstone grains, .03-.5mm in size, sub-rounded.

220-225 Silty Clay--Brown. Silty clay.

225-330 Sandy Silt--Brownish. Fine sandy silt with a trace of clay.

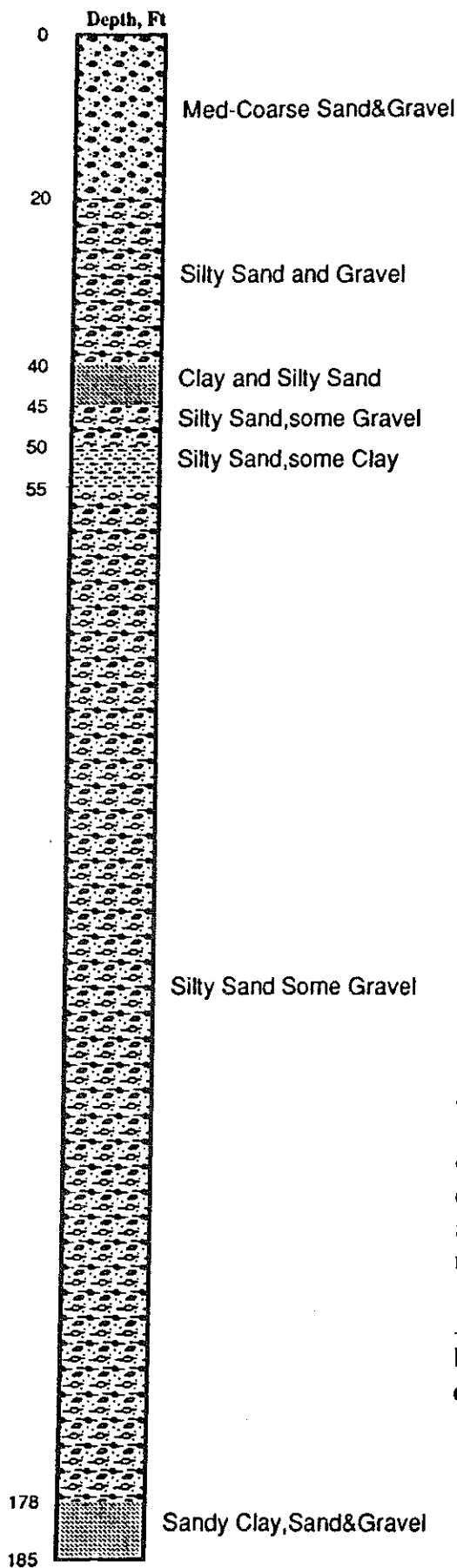
230-335 Sandy Silty Clay--Brownish. Silty sandy clay.

325-345 Clay--Brownish. Clay.

245-260 Silty Clay and Sandy Silt--Brownish. 60% brownish sandy clay. 40% fine sandy silt.

Total Depth 260ft

Sand Canyon TH-3 Lithologic Log



0-5 Medium to Coarse Sand and Gravel--Brownish. Medium to coarse sand and gravel, angular to sub-angular made mostly of quartz, feldspar and mafic rock fragments, .5-25mm in size.

5-20 Medium to Coarse Sand--Brown. Medium to coarse sand, sub-angular made mostly of quartz, feldspar and mafic rock fragments, .5-2mm in size. At 15ft-20ft there is an increase in fine material down to .1mm in size.

20-40 Silty Fine to Coarse Sand and Gravel--Brown. 30%-40% silty fine to medium sand less than 1mm in size. 60%-70% coarse sand and gravel, sub-angular made mostly of quartz, feldspar and mafic rock fragments with some mica, .03-4mm in size.

40-45 Silty Sand and Clay--Brown. 80% sandy brown clay. 20% silt to coarse sand, sub-angular made mostly of quartz, feldspar and mafic rock fragments, .03-2mm in size.

45-50 Silty Sand with some Gravel--Light brown. 80% silty fine to medium sand less than 1mm in size. 20% coarse sand and gravel, angular made mostly of quartz, feldspar and mafic rock fragments, 1-5mm in size.

50-55 Silty Sand with some Clay--Light brown. 80% silty fine to medium sand less than .5 mm in size. 10% coarse sand, angular made mostly of quartz, feldspar and mafic rock fragments, .5-2mm in size. 10% brown sandy clay.

55-178 Silty Sand with saome Gravel--light brownish-tan to brown. 80% silty fine to medium sand less than .5mm in size, 20% coarse sand and gravel, angular to sub-angular made mostly of quartz, feldspar and mafic rock fragments with mica, .5-10mm in size. At 55ft-65ft the silty sand is slightly coarser than the material below.

178-185 Sandy Clay with Silty Sand and Gravel--Brown. 60% brown sandy clay 40% silty sand and gravel, angular made mostly of quartz and feldspar, .02-10mm in size.

Sand Canyon TH-4 Lithologic Log

Depth, Ft

185

Silty Sand some Gravel

185-190 Silty Sand with some Gravel--Brown. 85% silty fine to medium sand less than .5mm in size. 15% coarse sand and gravel, sub-angular to angular made mostly of quartz, feldspar and mafic rock fragments, 1-5mm in size.

190

Sandy Clay

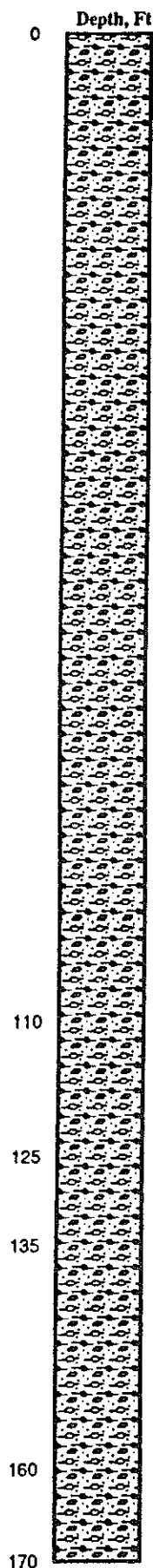
190-195 Sandy Clay and Silty Fine to Coarse Sand--Brown. 80%-85% brown sandy clay. 15%-20% silty fine to coarse sand, angular made mostly of quartz and feldspar, .02-2mm in size.

195-220 Sandy Gravely Clay--Brownish. Sand and gravel mixed with brown clay. Sand and gravel is angular to sub-angular made of mostly quartz and feldspar, .125-4mm in size.

Total Depth 220ft

220

Sand Canyon TH-4 Lithologic Log



Silty Sand and Gravel

some clay

Silty Sand and Gravel

less Gravel some Clay

increase in Gravel

0-20 Coarse Silty Sand and Gravel--Light brown to brown. 60% coarse silt to medium sand less than 1mm in size. 40% Coarse sand and gravel, sub-angular made mostly of quartz, feldspar and rock fragments, 1-20mm in size.

20-110 Coarse Silty Sand with some Gravel--Light brown to tannish. 50%-60% coarse silt to medium sand less than 1mm in size. 40%-50% coarse sand and gravel, sub-angular to angular made mostly of quartz, feldspar and rock fragments, 1-15mm in size. At 20ft-30ft gravel is 5mm and less. At 45ft-70ft gravel is 5mm and less. At 70ft-90ft gravel is 10mm and less and at 90ft-110ft gravel is 5mm and less in size.

110-120 Coarse Silty Sand with some Gravel and Clay--Brown. same as above except with 10%-20% of brown clay and the gravel increases to 30mm in size.

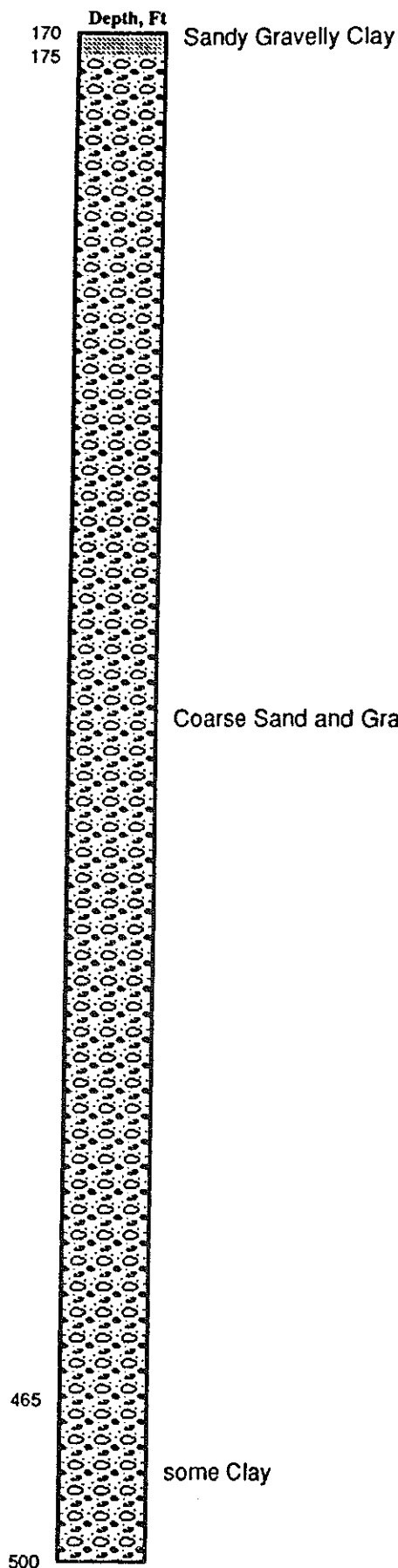
120-125 Sandy Gravelly Clay--Brown. 25% sand and gravel mixed with brown clay.

125-135 Coarse Silty Sand and Gravel--Light brown. 60% coarse silt to medium sand less than 1mm in size. 40% coarse sand and gravel, angular to sub-angular made mostly of quartz, feldspar and rock fragments. At 125ft-130ft gravel is 5mm and less and at 130ft-135ft gravel is 15mm and less in size.

135-160 Coarse Silty Sand with some Gravel and Clay--Brown to Light brown. 50%-60% coarse silt to medium sand less than 1mm in size. 10%-50% coarse sand and gravel, sub-angular to sub-rounded made mostly of quartz, feldspar, rock fragments and densely cemented sandstone grains, 1-10mm in size. 5%-40% sandy brown clay, at 140ft-145ft clay is up to 40%.

160-170 Coarse Silty Sand and Gravel with some Clay--Light brown. 30%-50% coarse sand and gravel, sub-angular to angular made mostly of quartz, feldspar, rock fragments and densely cemented sandstone grains, 1-10mm in size. 20%-40% coarse silt to medium sand less than 1mm in size. 50% brown sand clay at 160ft-165ft Clay decreases to 10%.

Sand Canyon TH-5 Lithologic Log



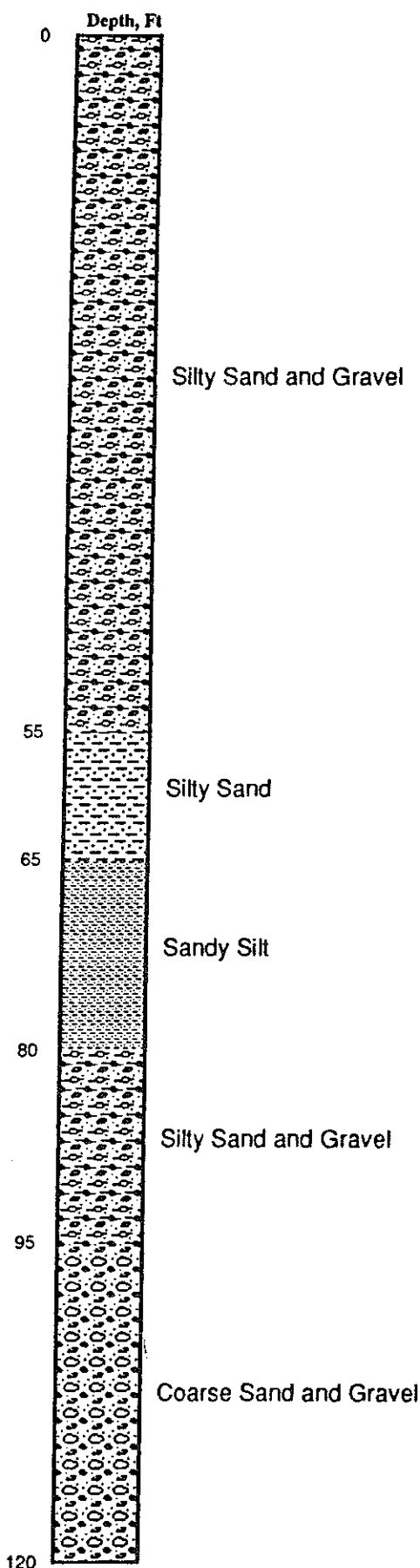
170-175 Sandy Gravelly Clay--Light brown. 70% brown sandy clay. 30% coarse sand and gravel stringers, sub-angular made mostly of quartz, feldspar and rock fragments, 1-15mm in size.

175-465 Coarse Sand and Gravel--Tannish. 80% coarse sand and gravel, angular to sub-angular made mostly of quartz, feldspar, rock fragments and densely cemented sandstone grains with some mica, 1-20mm in size. 20% medium to coarse sand less than 1mm in size.

465-500 Coarse Sand and Gravel with some Clay--Tannish turning to dark grey at 495ft to 500ft. 75% coarse sand and gravel, sub-angular to angular made mostly of quartz, feldspar, rock fragments and densely cemented sandstone grains, 1-20mm in size. 20% fine to coarse sand less than 1mm in size. 1-10% brown to dark grey clay. At 495ft-500ft clay increases to 10% and turns dark grey.

Total Depth 500ft

Sand Canyon TH-5 Lithologic Log



0-20 Coarse Silty Sand and Gravel--Brownish to dark grey. 50% coarse silt to medium sand less than 1mm in size. 50% coarse sand and gravel, sub-angular to sub-rounded made mostly of quartz, feldspar and rock fragments, 1-15mm in size.

20-25 Silty Sand with some Gravel and Clay--Tan. 80% silty fine sand. 15% medium sand and gravel, sub-angular made mostly of quartz and feldspar, 0.5-5mm in size.

25-35 Silty Fine to Coarse Sand and Gravel--Rusty-tan to tan. 40%-50% coarse silt to medium sand less than 1mm in size. 50%-60% coarse sand and gravel, sub-angular made mostly of quartz, feldspar and rock fragments, 1-20mm in size. Also a trace of tannish clay.

35-55 Silty Sand with some Gravel--Tan to rusty-tan. 80%-90% silty fine to medium sand less than 1mm in size. 10%-20% coarse sand and gravel, sub-angular made mostly of quartz, feldspar and rock fragments, 1-15mm in size. Also a trace of rusty-tan clay.

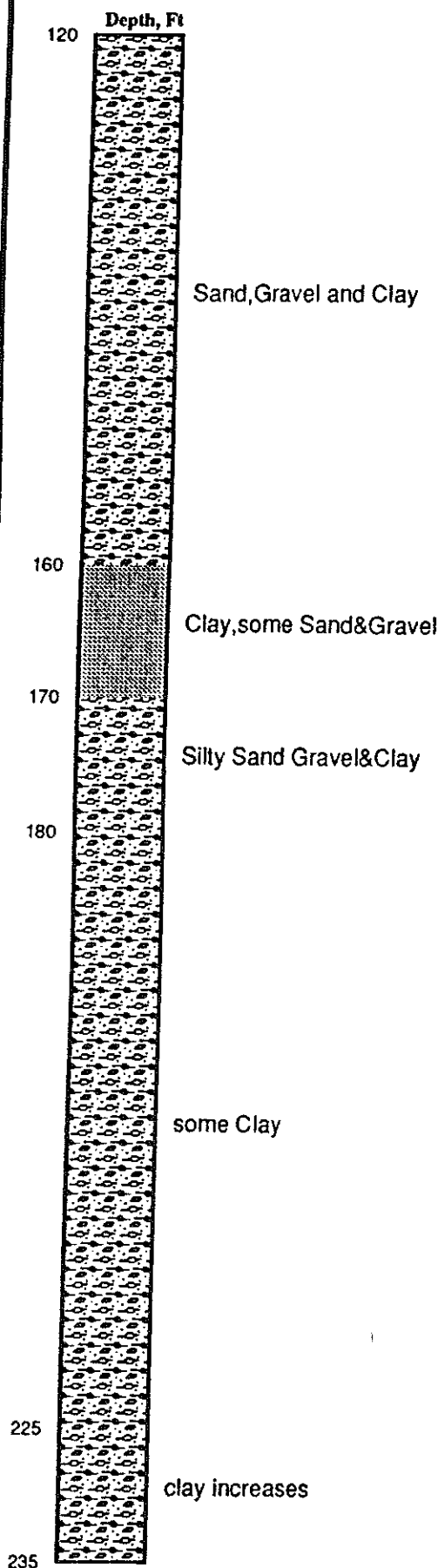
55-65 Silty Sand--Tan. 90% silty fine sand less than .25mm in size. 5% medium to coarse sand, sub-rounded made mostly of sandstone grains with some quartz and feldspar, 0.5-2mm in size. 5% tannish clay.

65-80 Sandy Silt--Rusty-tan. 90% fine sandy silt less than 0.25mm in size. 5% medium to coarse sand, made mostly of dense sandstone grains 0.5-2mm in size. 5% tannish clay.

80-95 Coarse Silty Sand and Gravel--Brown to tannish. 40%-60% coarse silt to medium sand less than 1mm in size. 40%-60% coarse sand and gravel, sub-angular made mostly of quartz, feldspar and rock fragments, 1-40mm in size. At 80ft-85ft gravel is 20mm and less in size.

95-120 Coarse Sand and Gravel--Tannish changing to grey-white at 110ft- 115ft. 85%-99% coarse sand and gravel, angular to sub-angular made mostly of quartz, feldspar and mafic rock fragments, 1-25mm in size. At 110ft-120ft material increases to 99%. 1%-15% fine to medium sand less than 1mm in size. At 106ft-110ft there is a grey-white clay layer.

Sand Canyon TH-6 Lithologic Log



120-160 Sand, Gravel and Clay--Grey changing to tan at 155ft. 30%-70% greyish to tan sandy clay. At 120ft-130ft there is 30%-50% greyish clay increasing to 70% at 130ft-135ft, then decreasing again to 30%-50% at 135ft-145ft with some rusty-tan streaks and at 145ft-160ft increasing up to 70% and changing to tan in color. 15%-50% coarse sand and gravel, sub-angular to angular made mostly of quartz, feldspar and mafic rock fragments, 1-5mm in size, at 120ft-125ft gravel is up to 25mm in size, decreasing to 5mm at 125ft and 3mm at 150ft. 10%-30% coarse silt to medium sand less than 1mm in size.

160-170 Clay with some sand and gravel--Tan. 90% tan sandy clay. 10% fine to coarse sand and gravel, sub-angular made mostly of quartz and feldspar, 0.125-3mm in size.

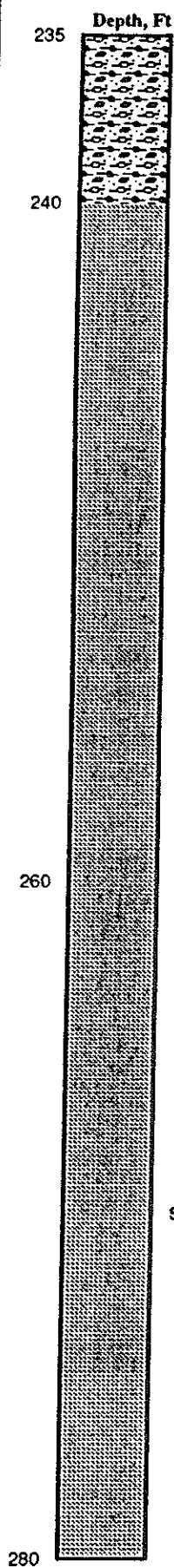
170-175 Sand Gravel and Clay--Tan. 40% tan sandy clay. 30% coarse silt to medium sand. 30% coarse sand and gravel sub-angular made mostly of quartz, feldspar and mafic rock fragments with some limestone, 1-5mm in size.

175-180 Coarse Silty Sand and Gravel with some Clay--50% coarse sand and gravel, sub-angular made mostly of quartz, feldspar and mafic rock fragments with some limestone, 1-3mm in size. 45% coarse silt to medium sand less than 1mm in size. 5% tannish clay.

180-225 Coarse Silty Sand and Gravel--Tan. 30%-60% coarse silt to medium sand less than 1mm in size. At 180ft-185ft material is at 30% then increases to 50%-60% at 185ft-225ft. 40%-70% coarse sand and gravel, sub-angular made mostly of quartz, feldspar and mafic rock fragments with limestone. At 190ft-225ft there is abundant sandstone grains, 1-3mm in size. 1%-3% tan clay.

225-235 Sandy Clay with Coarse Silty Sand and Gravel--Brown. 40%-65% brown sandy clay. 25%-40% coarse silt to medium sand less than 1mm in size. 10%-20% coarse sand and gravel, sub-angular made mostly of quartz, feldspar, mafic rock fragments, limestone and dense sandstone grains.

Sand Canyon TH-6 Lithologic Log



Silty Sand Gravel & Clay

235-240 Coarse Silty Sand and Gravel--Brown. 50% coarse silt to medium sand less than 1mm in size. 50% coarse sand and gravel, sub-angular made mostly of dense sandstone, quartz, feldspar, mafic rock fragments and some limestone, 1-5mm in size.

Sandy Clay

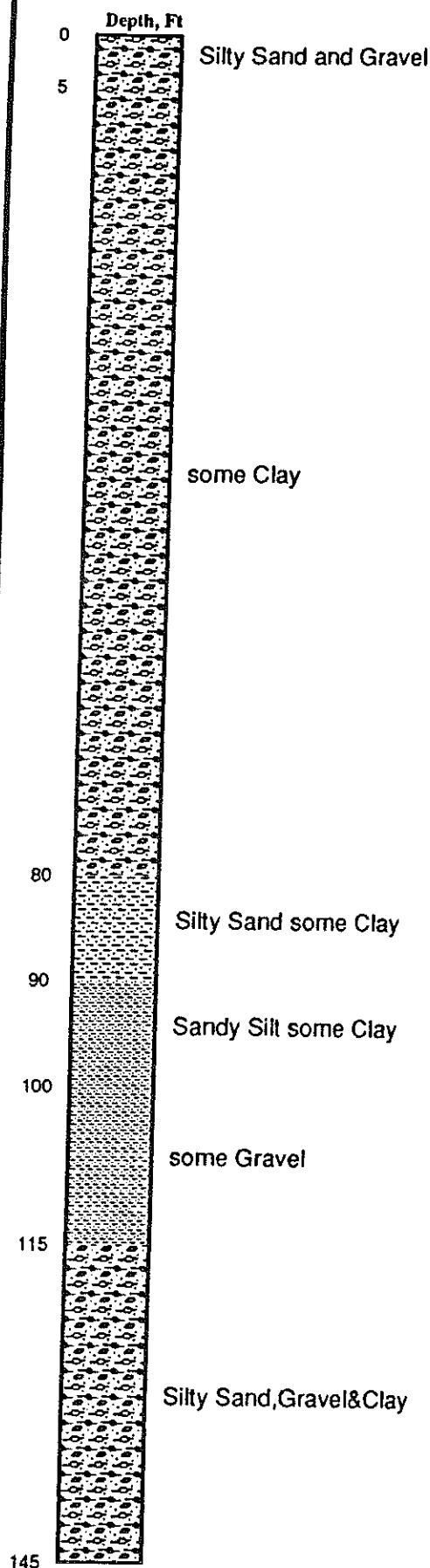
240-260 Sandy Clay--Brown. 90% brown sandy clay. 10% fine sand and gravel, sub-angular made mostly of quartz and feldspar, 1-5mm in size.

some Sand and Gravel

260-280 Sandy Clay with Coarse Silty Sand and Gravel--Brown. 30%-85% brown sandy clay, 85% at 270ft-275ft. 25%-40% coarse silt to medium sand less than 1mm in size. 10%-40% coarse sand and gravel, sub-angular made mostly of quartz, feldspar and mafic rock fragments, 1-5mm in size.

Total Depth 280ft

Sand Canyon TH-6 Lithologic Log



0-5 Coarse Silty Fine to Coarse Sand and Gravel--Grey. 60% coarse silt to medium sand less than 1mm in size. 40% coarse sand and gravel, angular made mostly of quartz, feldspar and mafic rock fragments, 1-20mm in size.

5-80 Coarse Silty Sand and gravel with some Clay--Tannish changing to grey at 45ft-80ft. 60%-80% coarse silt to medium sand less than 1mm in size. 10%-30% coarse sand and gravel, angular to sub-angular made mostly of quartz, feldspar and mafic rock fragments. At 35ft-80ft there is some limestone and at 50ft-80ft there are grey dense sandstone grains. At 5ft-20ft size is 1-30mm. At 20ft-35ft size is 1-5mm. At 35ft-65ft size is 1-10mm and from 65ft-80ft size is 1-5mm. 0%-20% brown and grey sandy clay. At 5ft-15ft there is 10%-20% brown sandy clay. At 30ft-35ft there is 10% brown sandy clay. At 45ft-50ft there is 10% grey sandy clay. At 20ft-25ft a trace of brown sandy clay and at 65ft-70ft a trace of grey sandy clay.

80-90 Silty Sand and some Clay--Rusty-brown to light brown. 85% coarse silty sand less than 1mm in size. 10%-15% sandy tannish clay. 1%-5% gravel sized grains of dense brown sandstone.

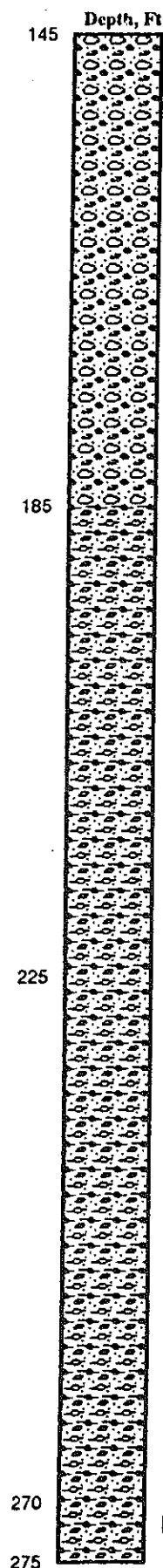
90-100 Sandy Silt with some Clay--Light brown. 85% fine to medium sandy silt. 15% brown sandy clay.

100-115 Sandy Silt with some Clay and Gravel--Brown. 90% brown fine to medium sandy silt less than 1mm in size. 10% coarse sand and gravel with clay. The sand and gravel is sub-angular made mostly of quartz, feldspar with white rock fragments, 1-5mm in size.

115-120 Coarse Silty Sand, Gravel and Clay--40% sandy brown clay. 40% coarse sand and gravel, sub-angular made mostly of quartz, feldspar and white rock fragments, 1-5mm in size. 20% coarse silt to medium sand less than 1mm in size.

120-145 Coarse Silty Sand and Gravel--Brown. 15%-40% coarse silt to medium sand less than 1mm in size. 60%-85% coarse sand and gravel, sub-angular made mostly of brown and grey dense sandstone with lesser amounts quartz, feldspar and mafic rock fragments, 1-20mm in size at 120ft-130ft and 1-5mm from 130ft-145ft.

Sand Canyon TH-7 Lithologic Log



Coarse Sand and Gravel

Silty Sand, Gravel & Clay

Clay increases

less Clay

145-185 Sand and Gravel--Brown changing to tannish at 160ft. 10%-20% fine to medium sand less than 1mm in size. 80%-90% coarse sand and gravel, sub-angular to sub-rounded made mostly of quartz, feldspar and mafic rock fragments with grey and brown dense sandstone, abundant with abundant brown dense sandstone at 180ft-185ft, 1-15mm in size. At 155ft-160ft size decreases to 5mm and increases to 25mm at 165ft-170ft.

185-195 Coarse Silty Fine to Coarse Sand and Gravel with Clay--Tannish. 40%-50% sandy tannish clay. 35%-40% coarse sand and gravel, sub-rounded made mostly grey and brown dense sandstone, quartz and feldspar with some limestone, 1-10mm in size. 15%-20% coarse silt to medium sand less than 1mm in size.

195-200 Coarse Silty Sand and Gravel--Tannish. 75% coarse sand and gravel, sub-angular made mostly of quartz, feldspar and grey dense sandstone with some brown dense sandstone and mafic rock fragments, 20% coarse silt to medium sand less than 1mm in size. 5% brownish sandy clay.

200-225 Coarse Silty Sand, Gravel and Clay--Tannish. 20%-50% coarse silt to medium sand less than 1mm in size. 30%-50% coarse sand and gravel, sub-angular made mostly of quartz, feldspar and grey dense sandstone with some brown dense sandstone and mafic rock fragments, 1-15mm in size, mostly 1-4mm. 10%-40% tannish sandy clay.

225-270 Sandy Clay with Coarse Silty Sand and Gravel--Tannish. 50%-80% tannish sandy clay. At 250ft-255ft clay decreases to 20%. 10%-25% coarse silt to medium sand less than 1mm in size, increases to 60% at 250ft-255ft. 10%-25% coarse sand and gravel, sub-angular made mostly of quartz, feldspar and mafic rock fragments with some brown and grey dense sandstone, 1-10mm in size, at 225ft-250ft mostly 1-4mm.

270-275 Coarse Silty Sand and Gravel with some Clay--Tannish. 40% coarse silt to medium sand less than 1mm in size. 40% coarse sand and gravel, sub-angular made mostly of quartz, feldspar and mafic rock fragments, 1-10mm in size. 20% tannish sandy clay.

Sand Canyon TH-7 Lithologic Log

275 Depth, Ft

275-280 Coarse Silty Fine to Coarse Sand and Gravel--Tannish. 60% coarse silt to medium sand less than 1mm in size, 35% coarse sand and gravel, sub-angular made mostly of quartz, feldspar and mafic rock fragments, 1-8mm in size. 5% tannish sandy clay.

Silty Sand, Gravel & Clay

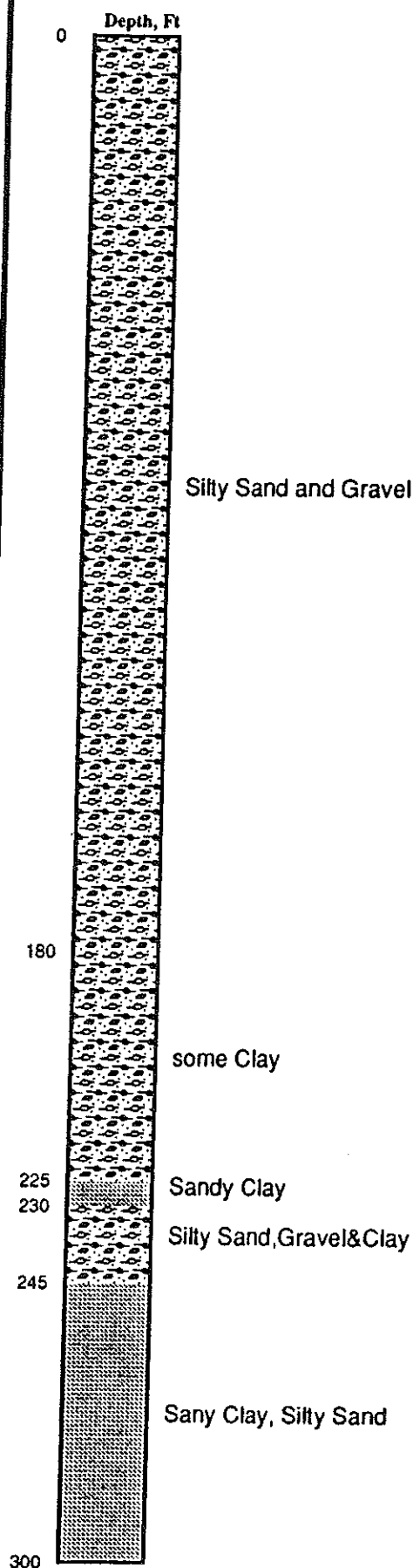
280-290 Sandy Clay with Coarse Silty Sand and Gravel--Tannish. 50%-70% Sandy Tannish Clay. 10%-30% coarse silt to medium sand less than 1mm in size. 15%-20% coarse sand and gravel, sub-angular made mostly of quartz, feldspar and mafic rock fragments, 1-5mm in size.

290-300 Sand, Gravel with some Clay--20%-30% fine to medium sand less than 1mm in size. 65%-70% coarse sand and gravel, sub-angular made mostly of quartz, feldspar and mafic rock fragments, 1-5mm in size. 5%-10% brownish sandy clay.

Total Depth 300ft

300

Sand Canyon TH-7 Lithologic Log



0-20 Coarse Silty Sand and Gravel--Tannish. 50%-80% coarse silt to medium sand less than 1mm in size. 20%-50% coarse sand and gravel, sub-angular to sub-rounded made mostly of quartz, feldspar and mafic rock fragments, 1-20mm in size.

20-180 Coarse Silty Sand and Gravel--Greyish changing into greyish-tan at 125ft. 70%-90% coarse silt to medium sand less than 1mm in size, from 20ft-25ft and 35ft-40ft there is 20% silt to medium sand. 10%-30% coarse sand and gravel, sub-angular to sub-rounded made mostly of quartz, feldspar, mafic rock fragments with lesser amounts of brown and grey sandstone up to 90ft where the composition changes to mostly brown and grey dense sandstone, 1-10mm in size.

180-205 Coarse Silty Sand with Gravel and Clay--Tannish. 75%-85% coarse silt to medium sand less than 1mm in size. 10%-25% coarse sand and gravel, sub-angular to sub-rounded made mostly of brown dense sandstone with lesser amounts of quartz and feldspar, 1-5mm in size. 10%-15% tannish sandy clay.

205-225 Coarse Silty Sand, Gravel and Clay--Tannish. 50%, increasing to 80% at 215ft, coarse silt to medium sand less than 1mm in size. 10%-30% tannish to brown sandy clay. 10%-20% coarse sand and gravel, sub-angular to sub-rounded made mostly of brown dense sandstone with lesser amounts of quartz and feldspar, 1-5mm in size.

225-230 Clay with Sand and Gravel--Tannish. 70% brown sandy clay. 30% fine to coarse sand and gravel sub-angular to sub-rounded made mostly of brown dense sandstone with lesser amounts of quartz and feldspar, 1-5mm in size.

230-245 Coarse Silty Sand and Gravel--Tannish. 40%-60% coarse silt to medium sand less than 1mm in size. 35%-60% coarse sand and gravel sub-angular to sub-rounded made mostly of brown dense sandstone with lesser amounts of quartz and feldspar with mica, 1-5mm in size.

245-300 Sandy Clay with Coarse Silty Sand--Tannish. 80% tannish sandy gravelly clay. 20% coarse silt to medium sand less than 1mm in size.

Sand Canyon TH-8 Lithologic Log

Depth, Ft

300

Coarse Silty Sand

300-310 Coarse Silty Sand--Dark grey. 95% coarse silt to medium sand less than 1mm in size. 5% coarse sand made mostly of quartz, feldspar and grey to brown dense sandstone with mica, 1-2mm in size.

310

Sandy Clay

310-345 Sandy Clay--Tan. Tannish sandy clay.

Total Depth 345ft

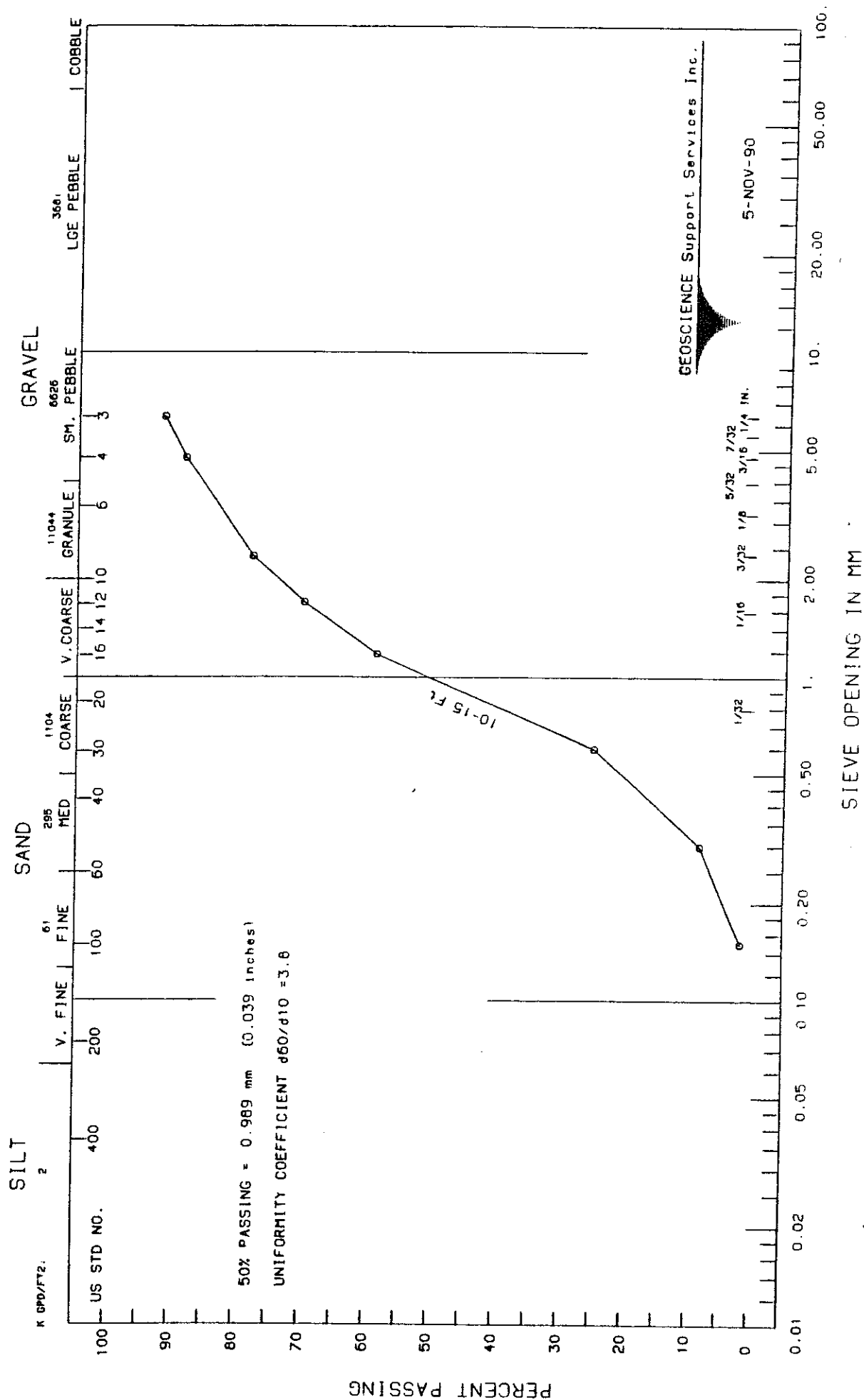
345

Sand Canyon TH-8 Lithologic Log

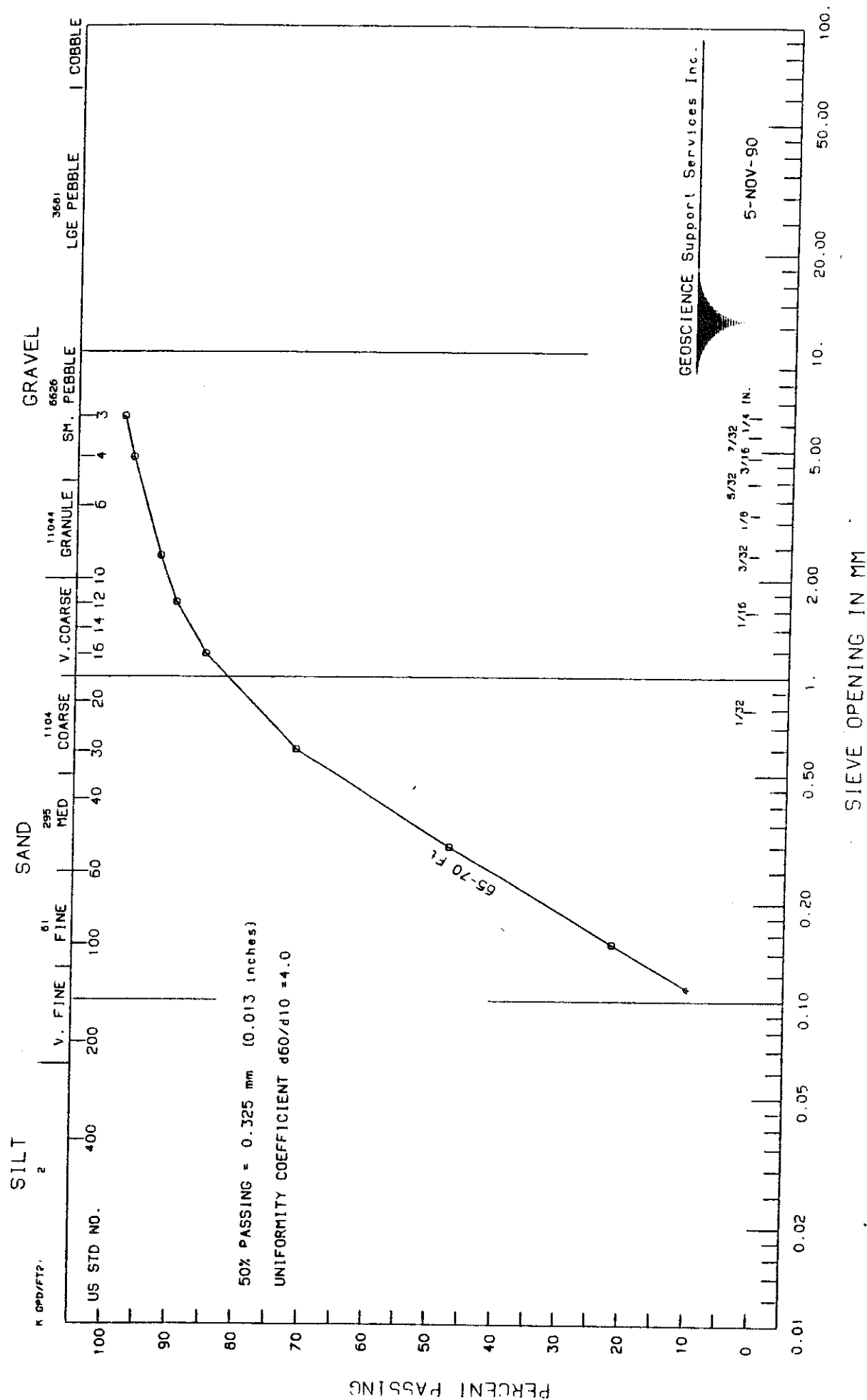
APPENDIX B
Mechanical Grading Analyses

MECHANICAL GRADING ANALYSIS

Sand Canyon well no. 1 - 10-15 feet

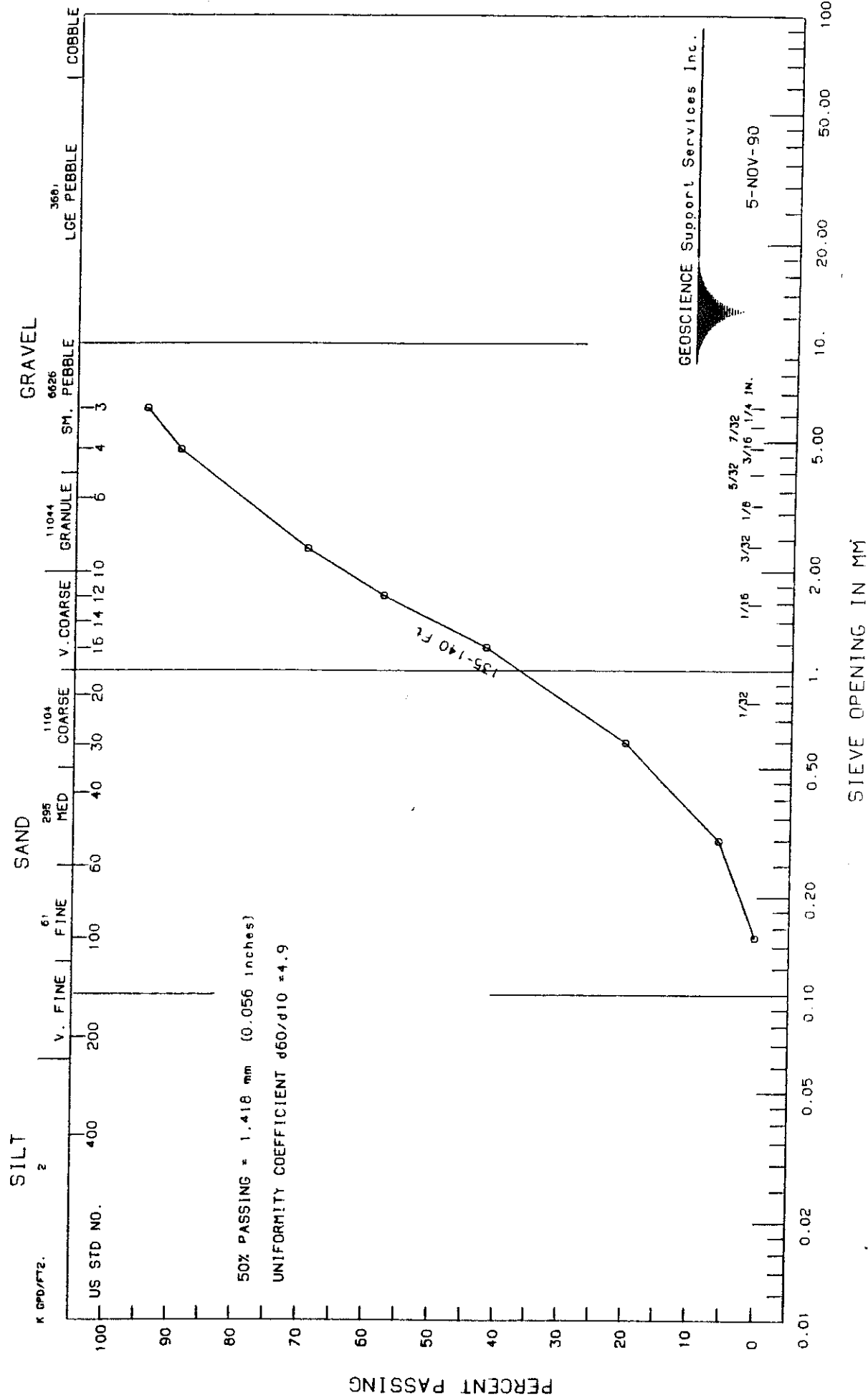


Sand Canyon well no. 1 - 65-70 feet

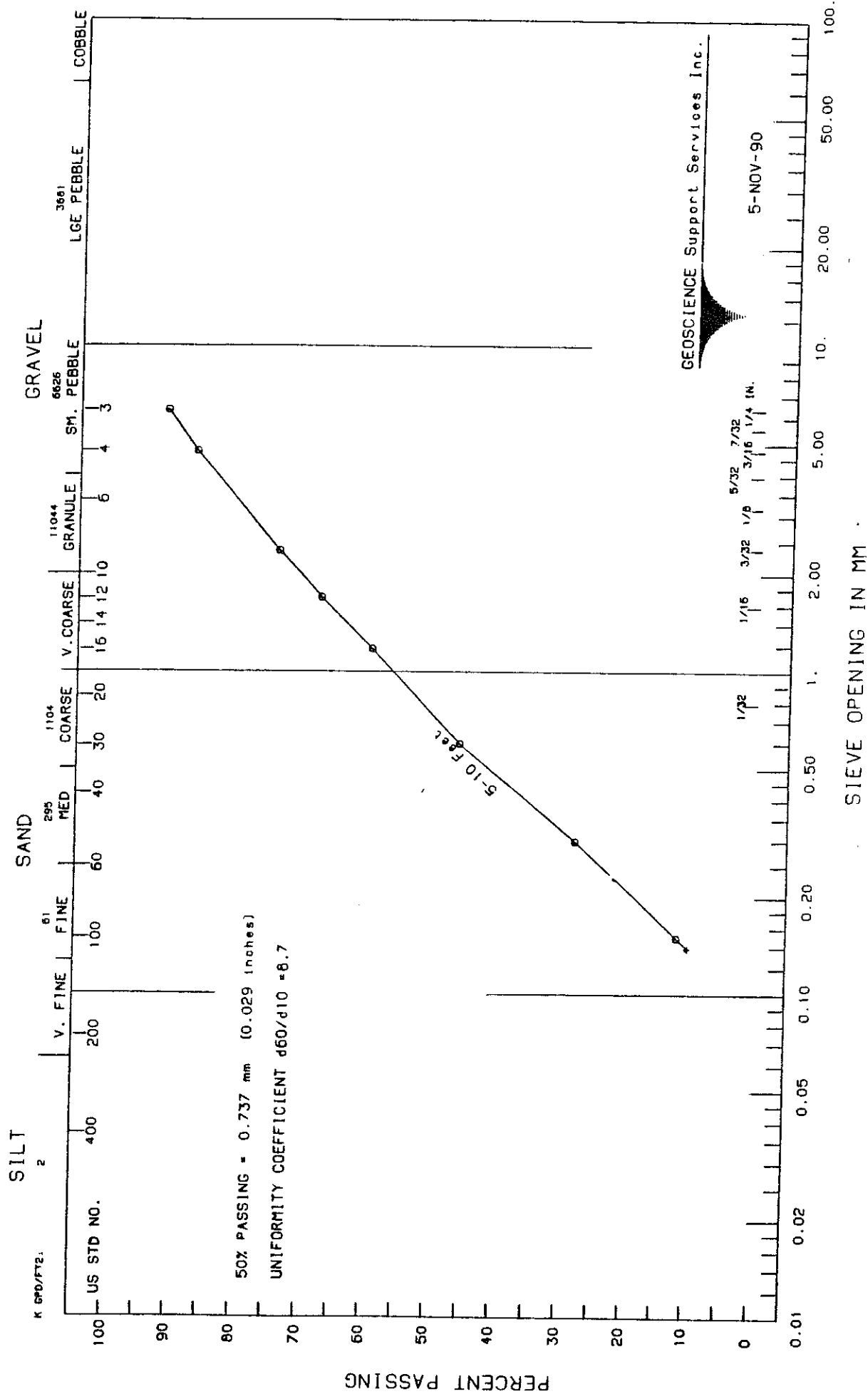


MECHANICAL GRADING ANALYSIS

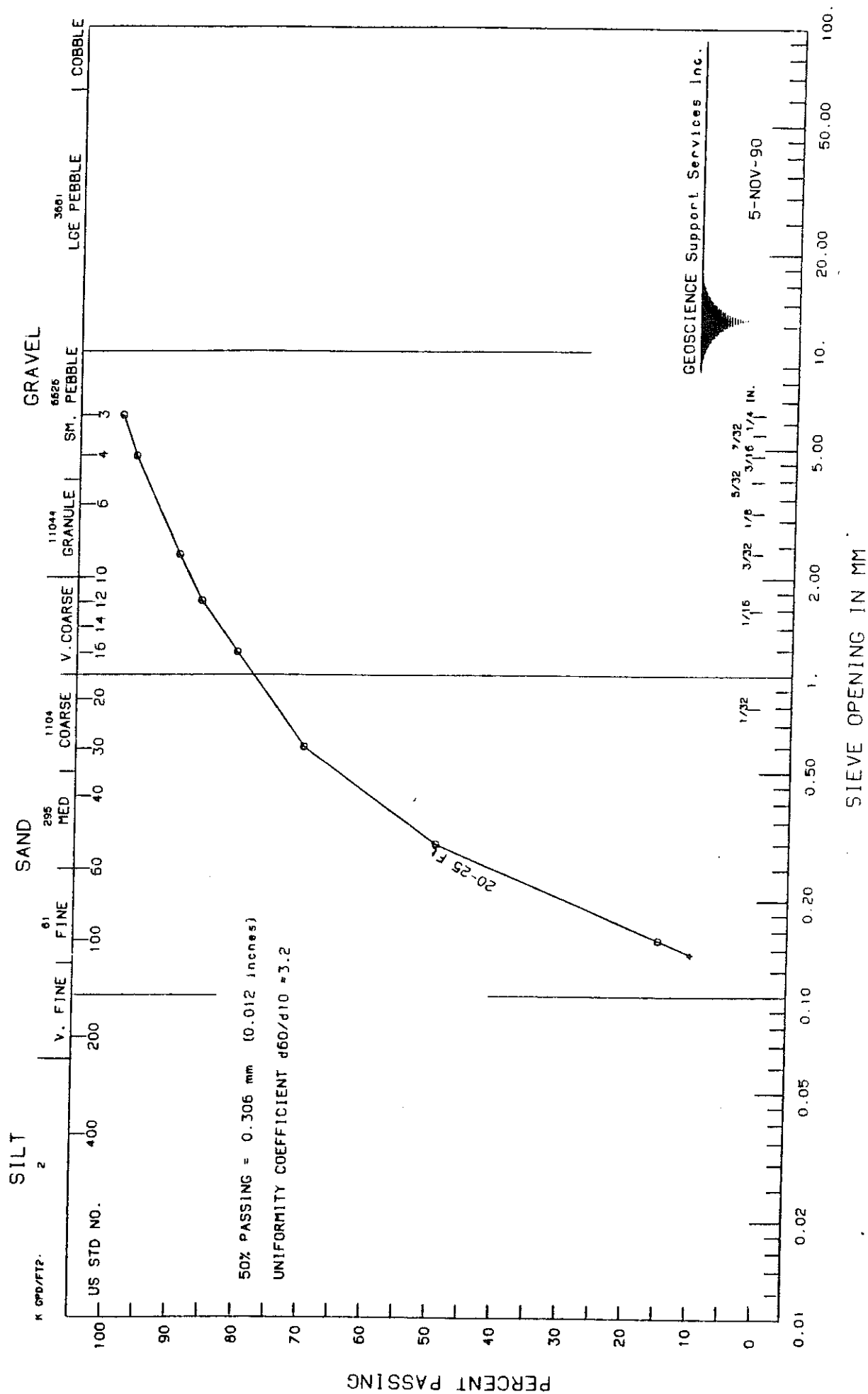
Sand Canyon well no. 1 - 135-140 feet



Sand Canyon well no. 2 - 5-10 feet

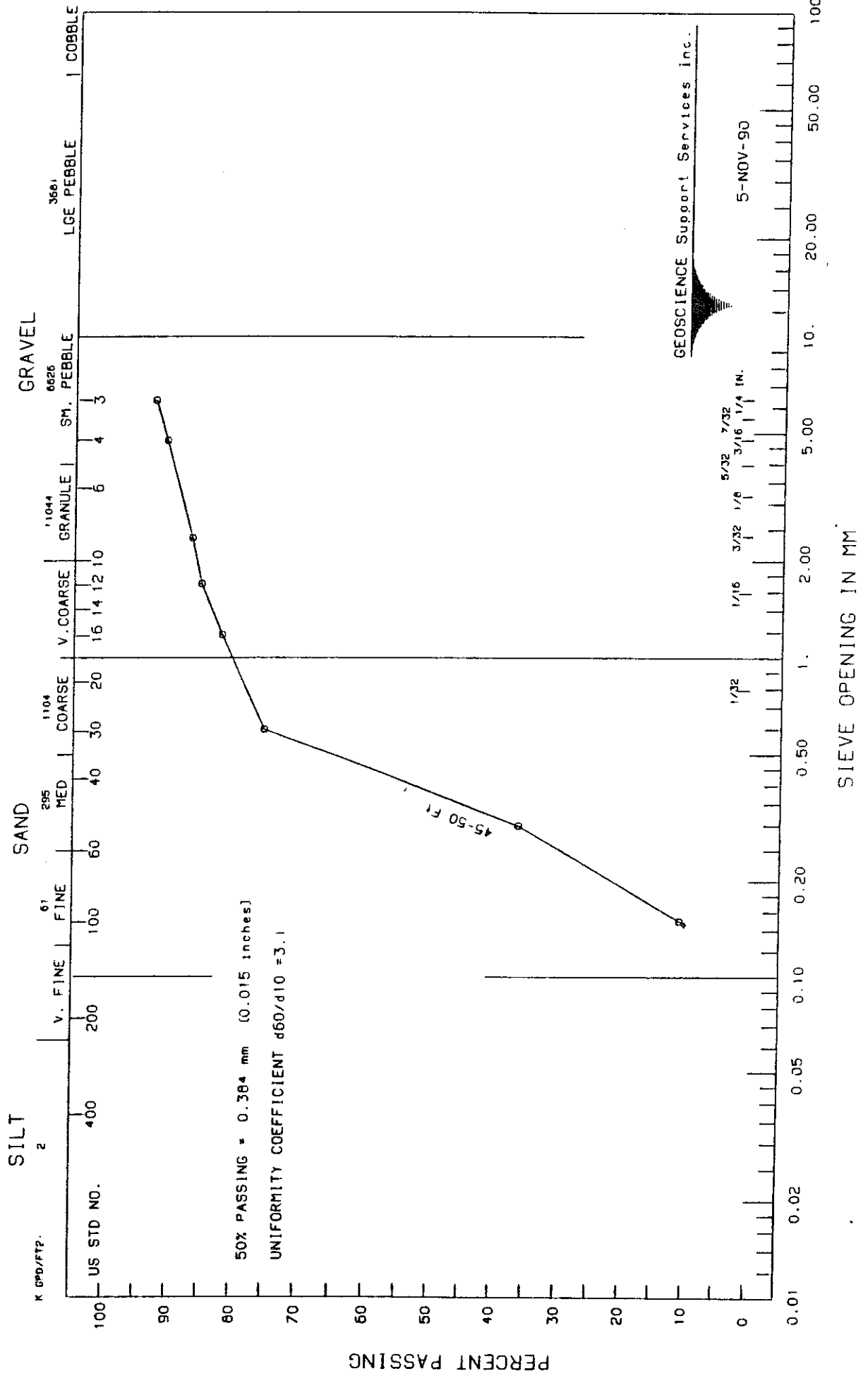


Sand Canyon well no. 2 - 20-25 feet



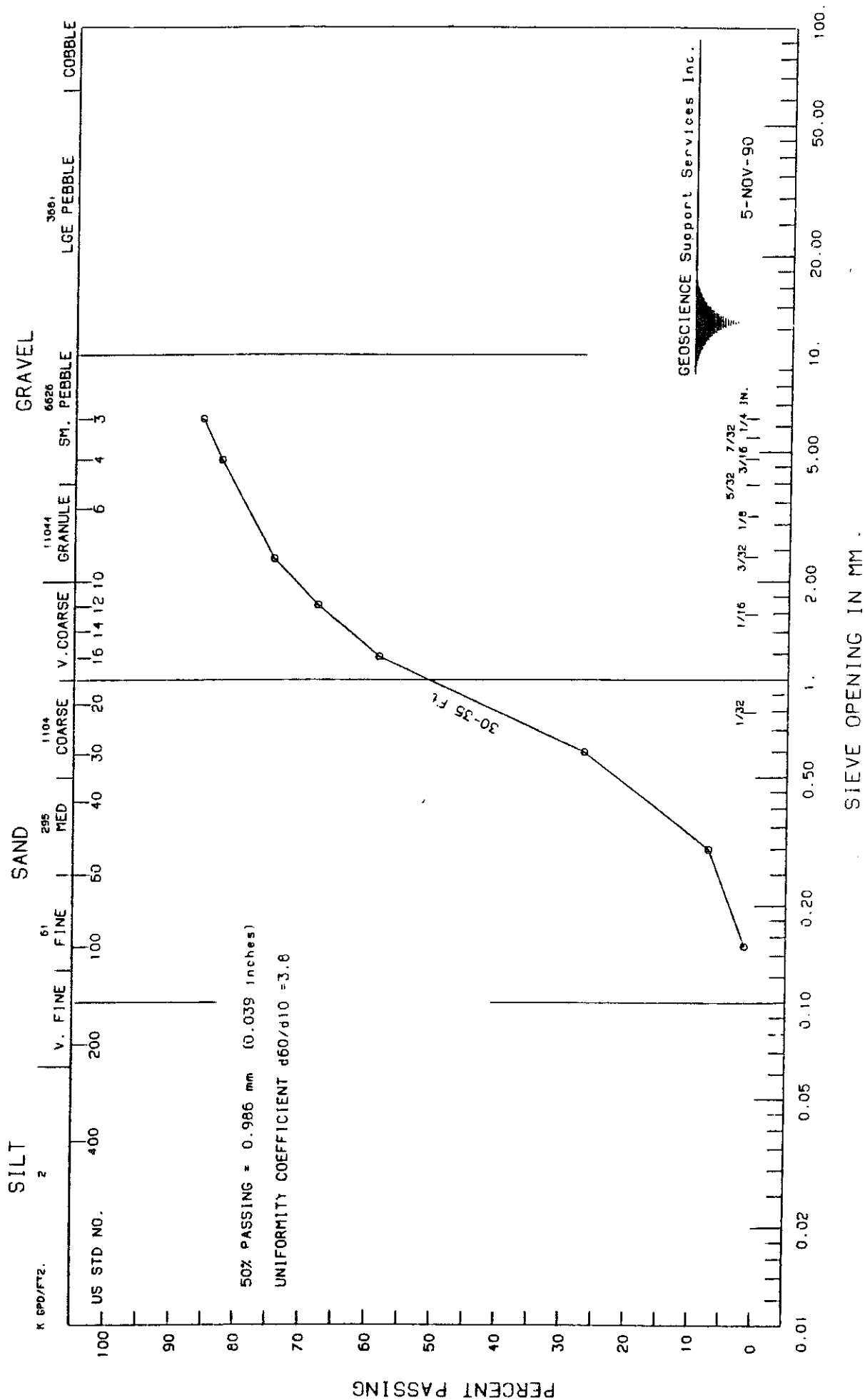
MECHANICAL GRADING ANALYSIS

Sand Canyon well no. 2 - 45-50 feet



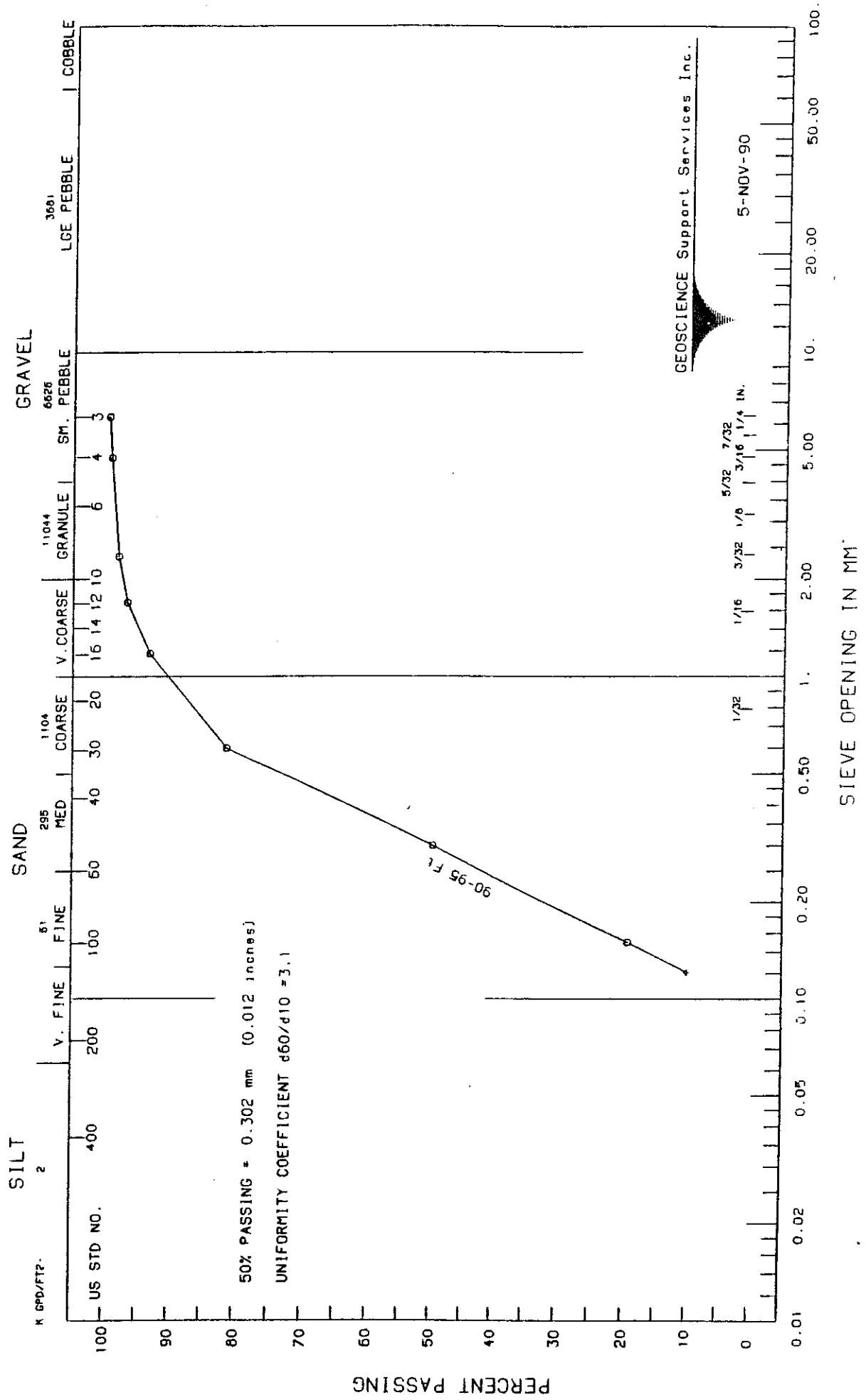
MECHANICAL GRADING ANALYSIS

Sand Canyon well no. 3 - 30-35 feet



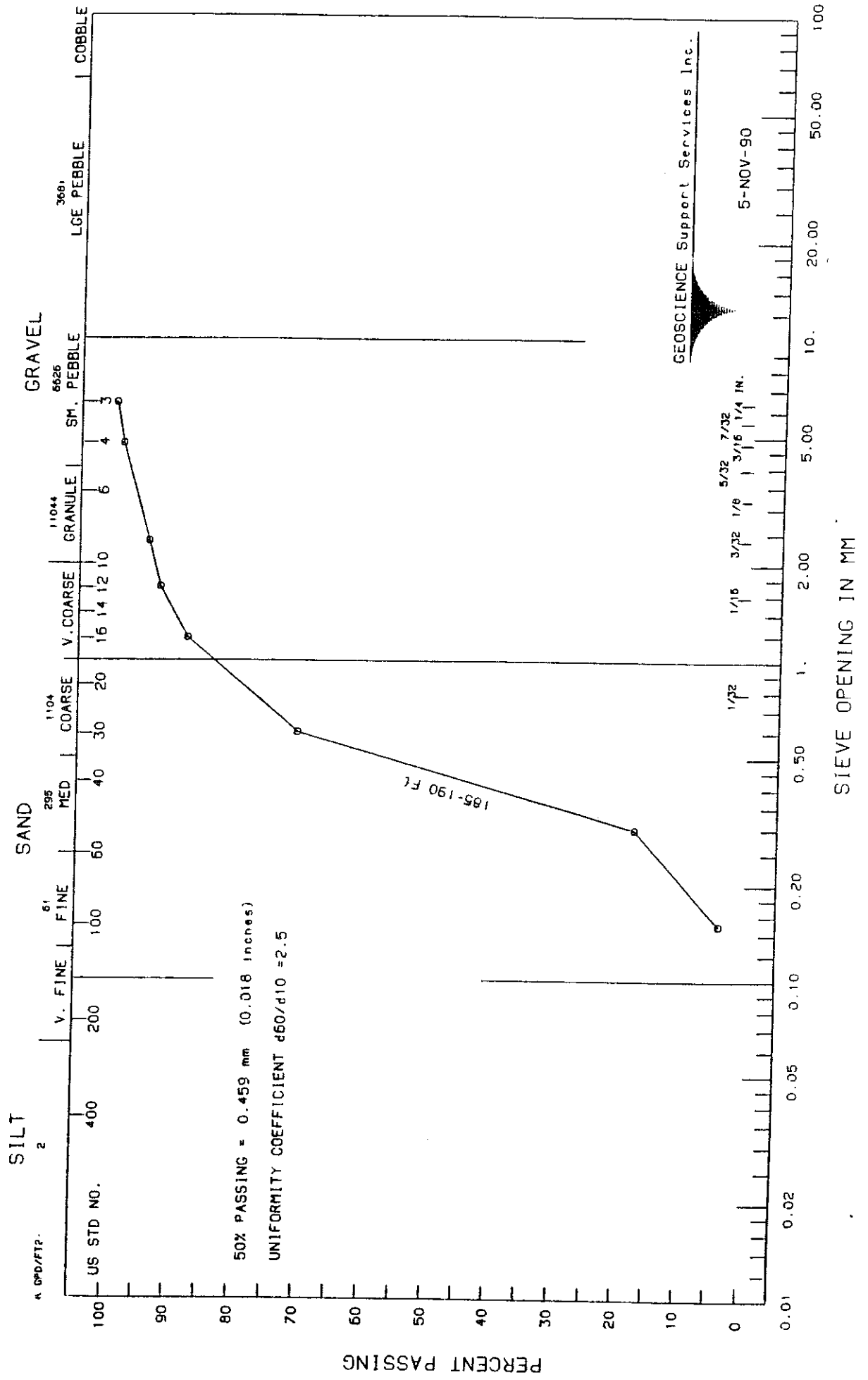
MECHANICAL GRADING ANALYSIS

Sand Canyon well no. 3 - 90-95 feet



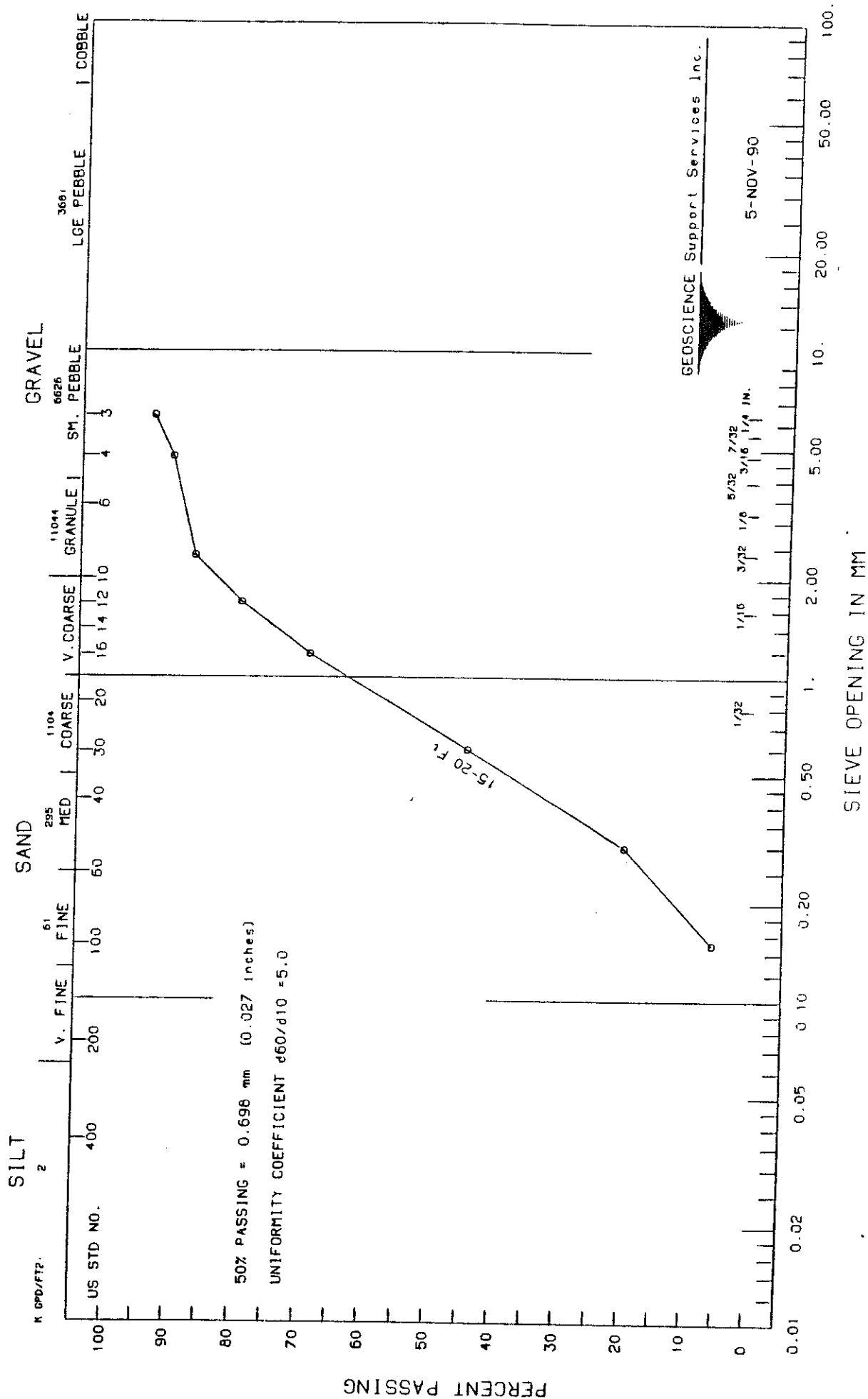
MECHANICAL GRADING ANALYSIS

Sand Canyon well no. 3 - 185-190 feet



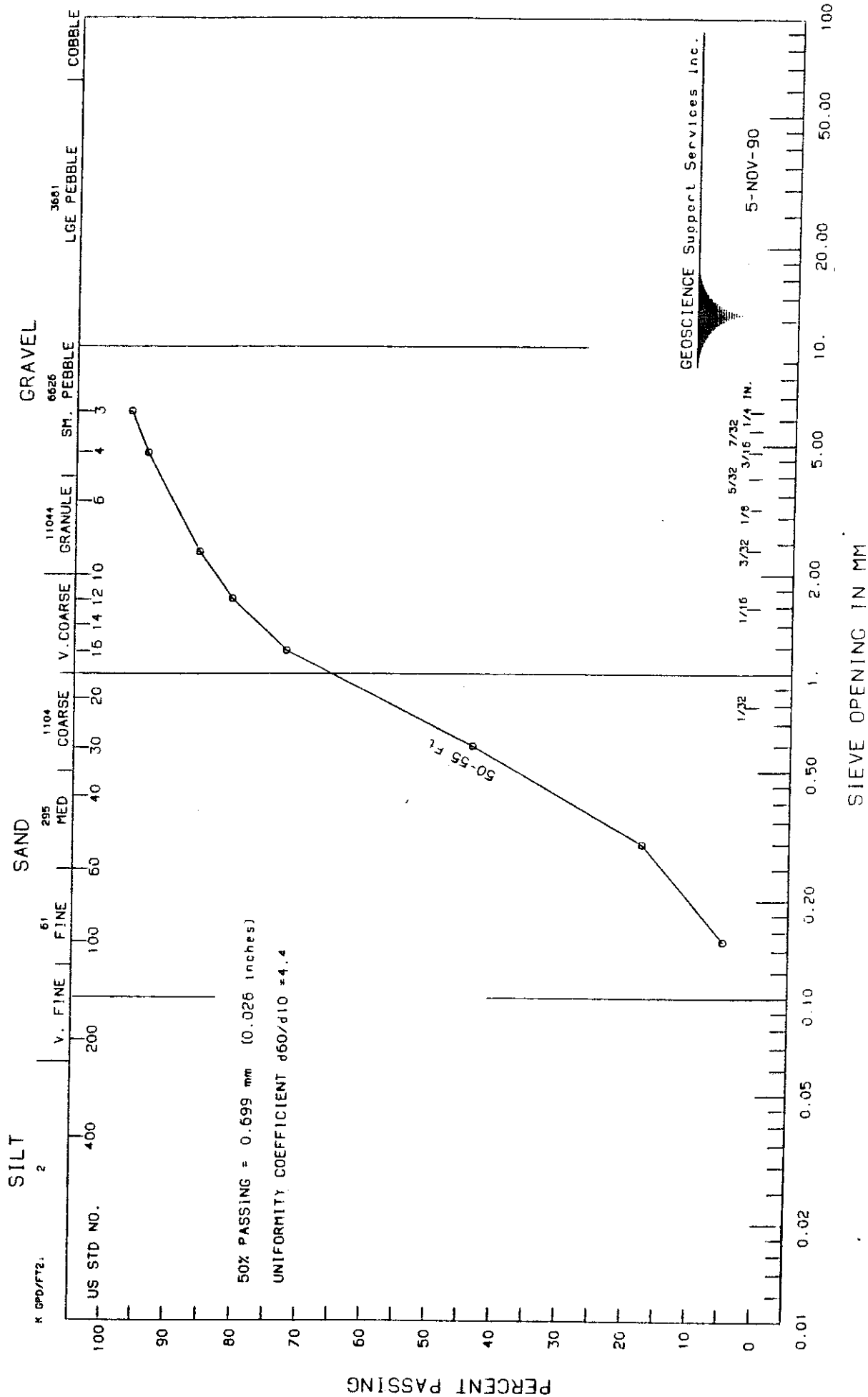
MECHANICAL GRADING ANALYSIS

Sand Canyon well no. 4 - 15-20 feet



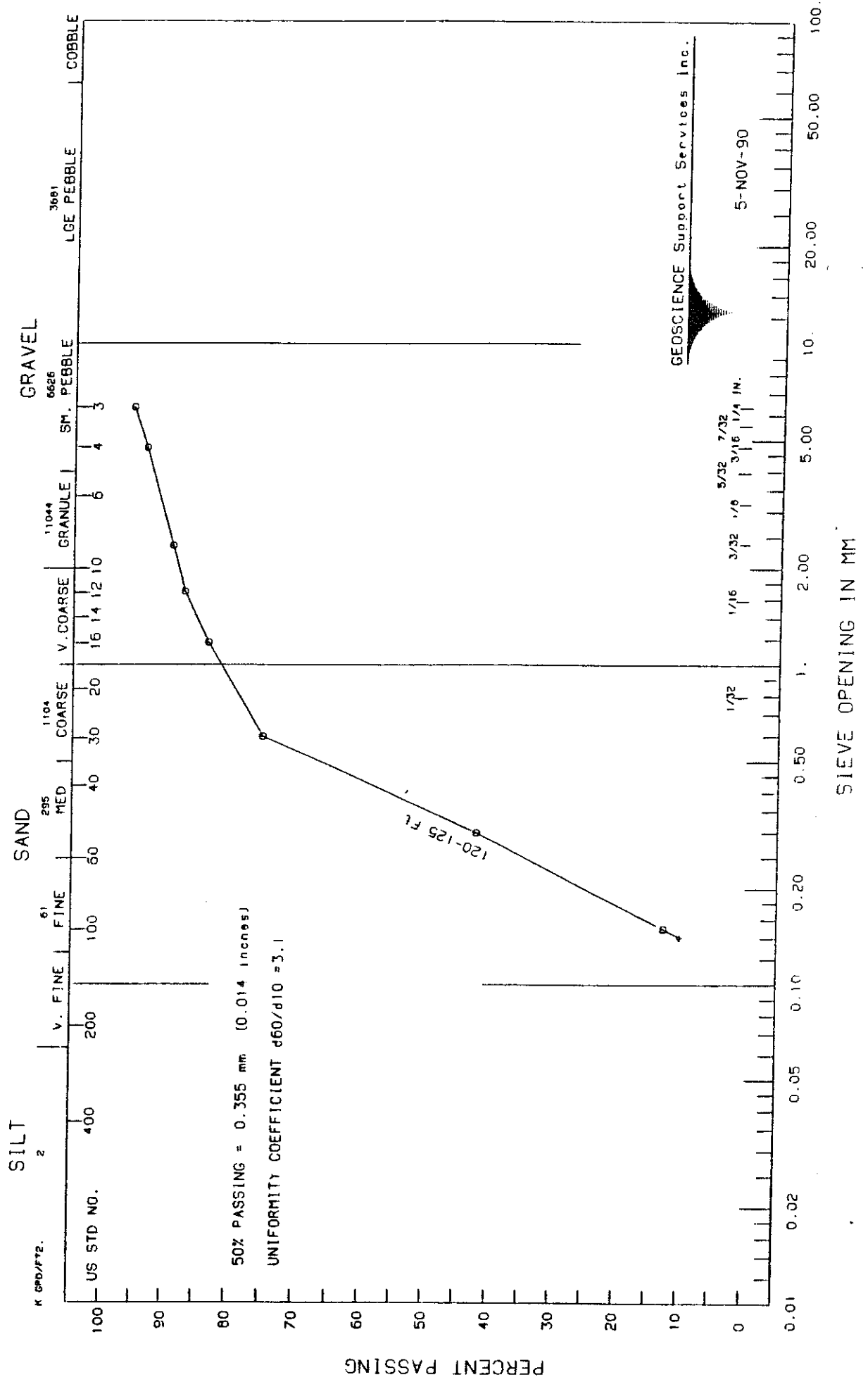
MECHANICAL GRADING ANALYSIS

Sand Canyon well no. 4 - 50-55 feet



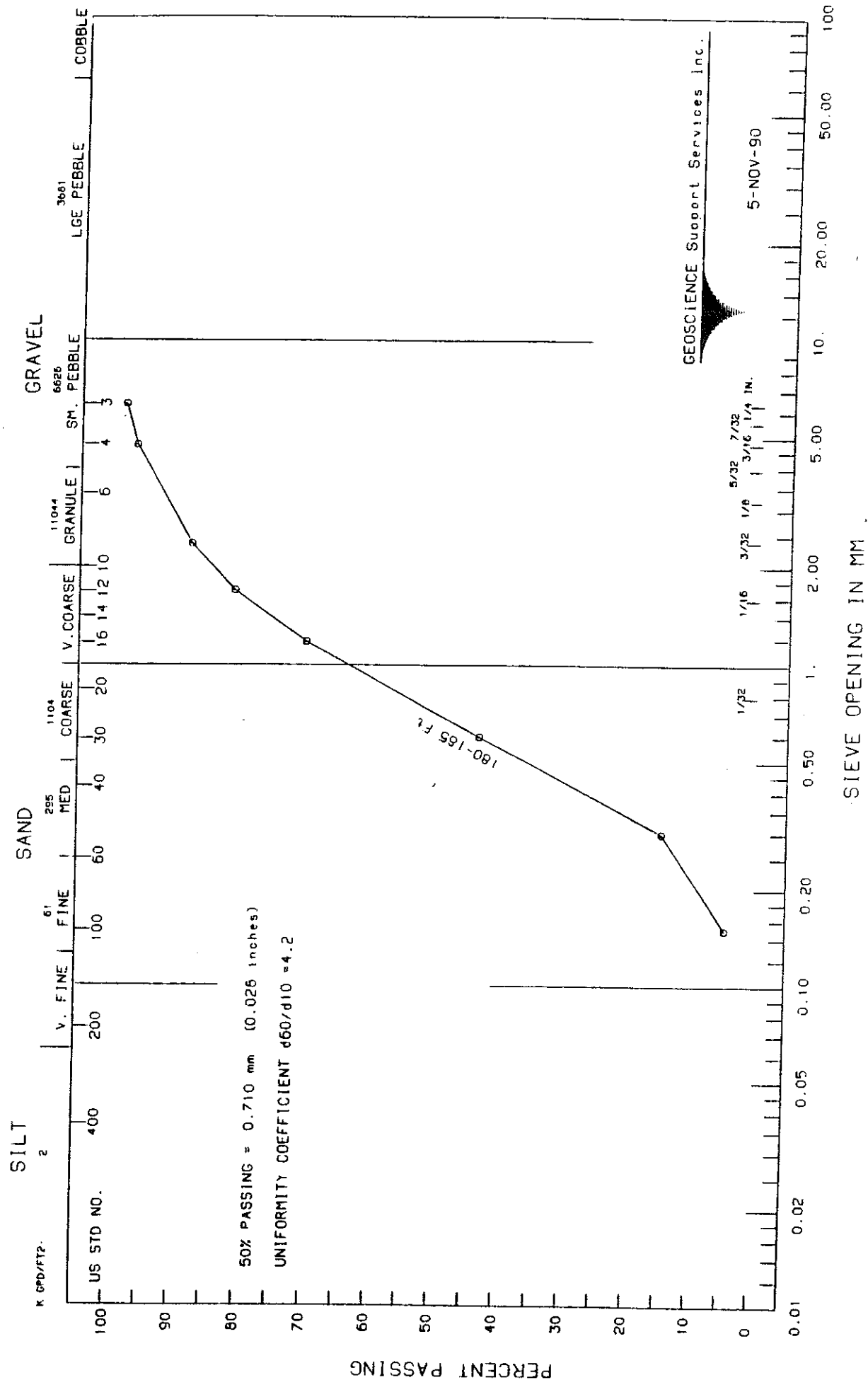
MECHANICAL GRADING ANALYSIS

Sand Canyon well no. 4 - 120-125 feet



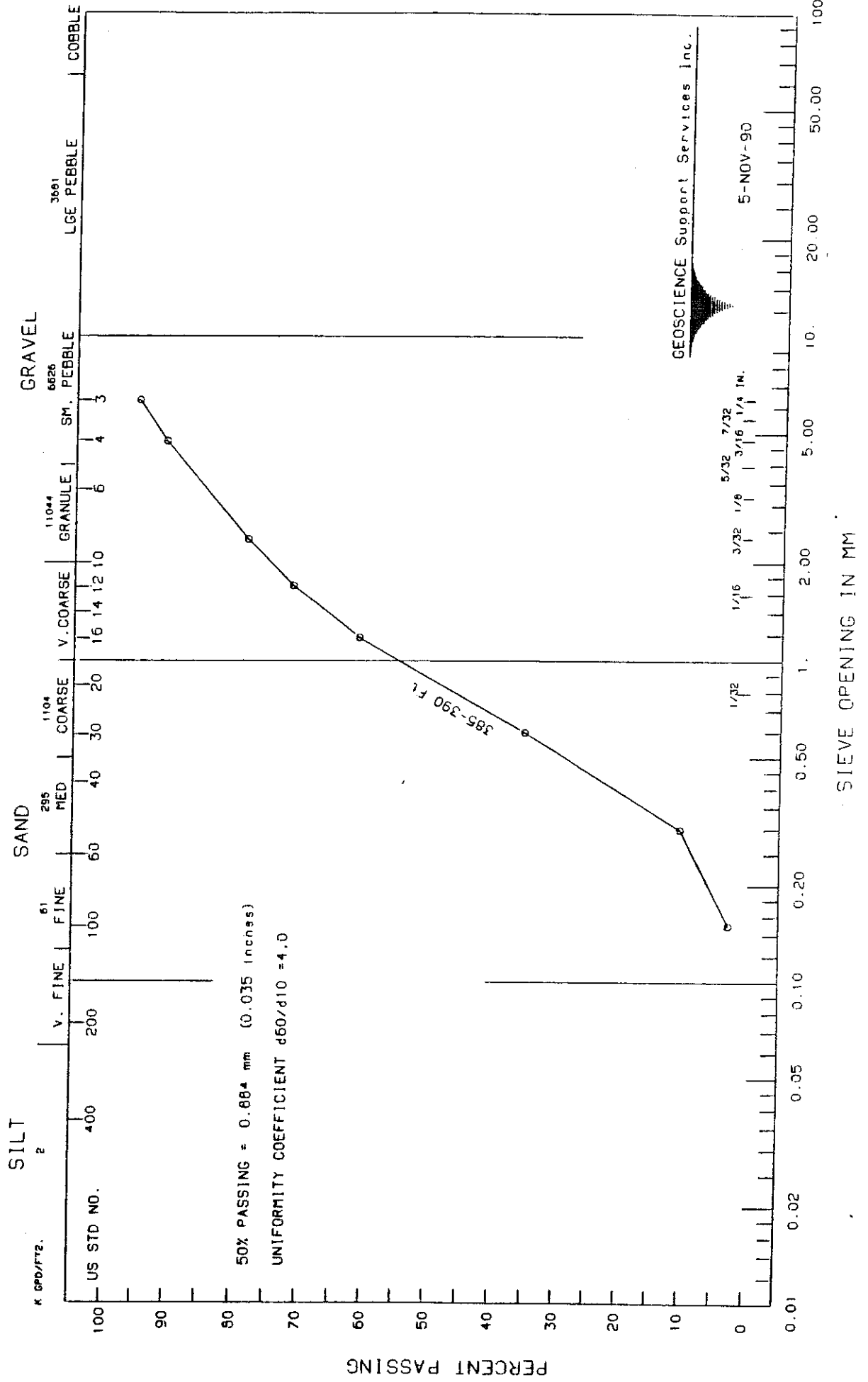
MECHANICAL GRADING ANALYSIS

Sand Canyon well no. 5 - 180-185 feet



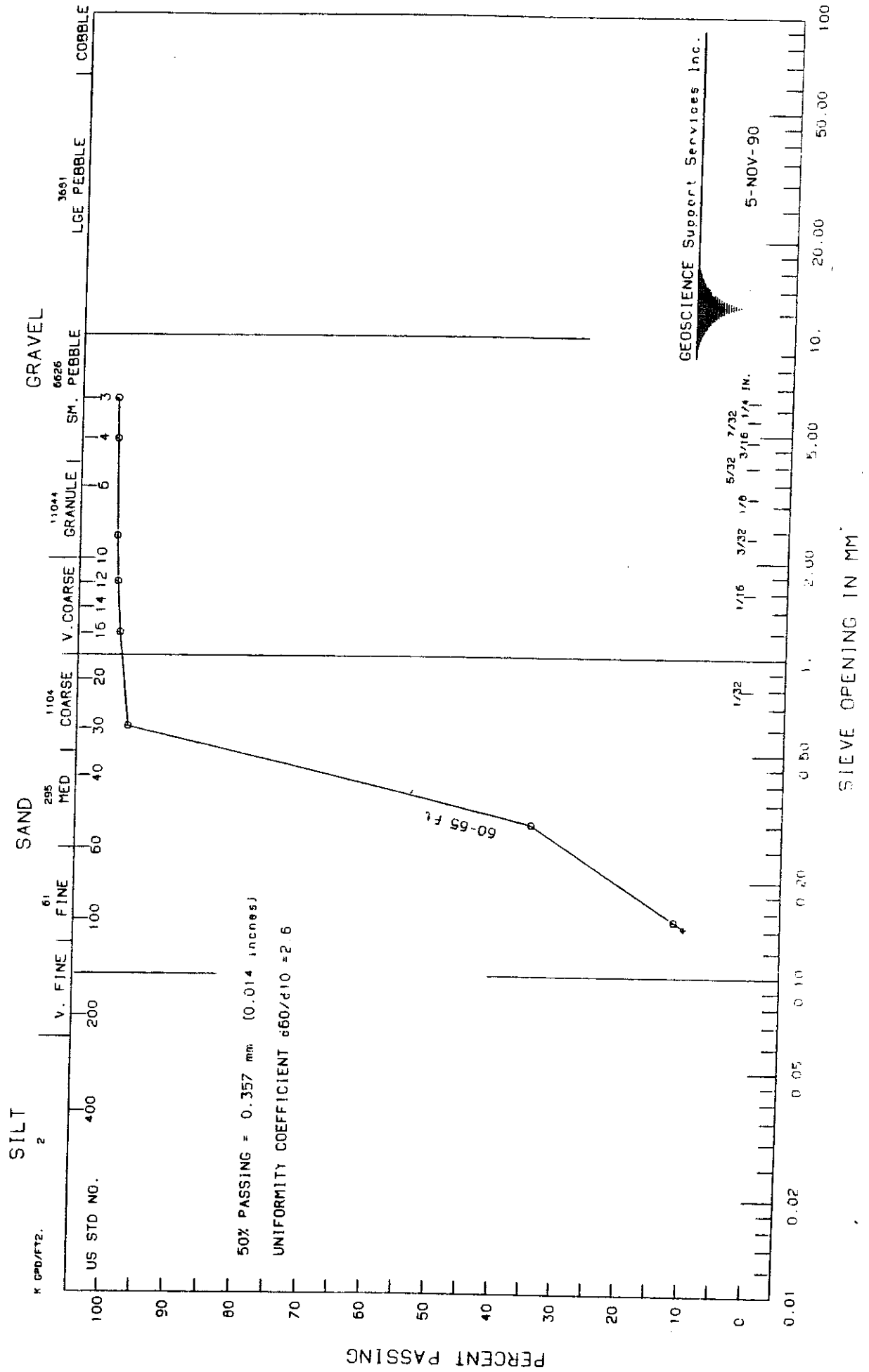
MECHANICAL GRADING ANALYSIS

Sand Canyon well no. 5 - 385-390 feet



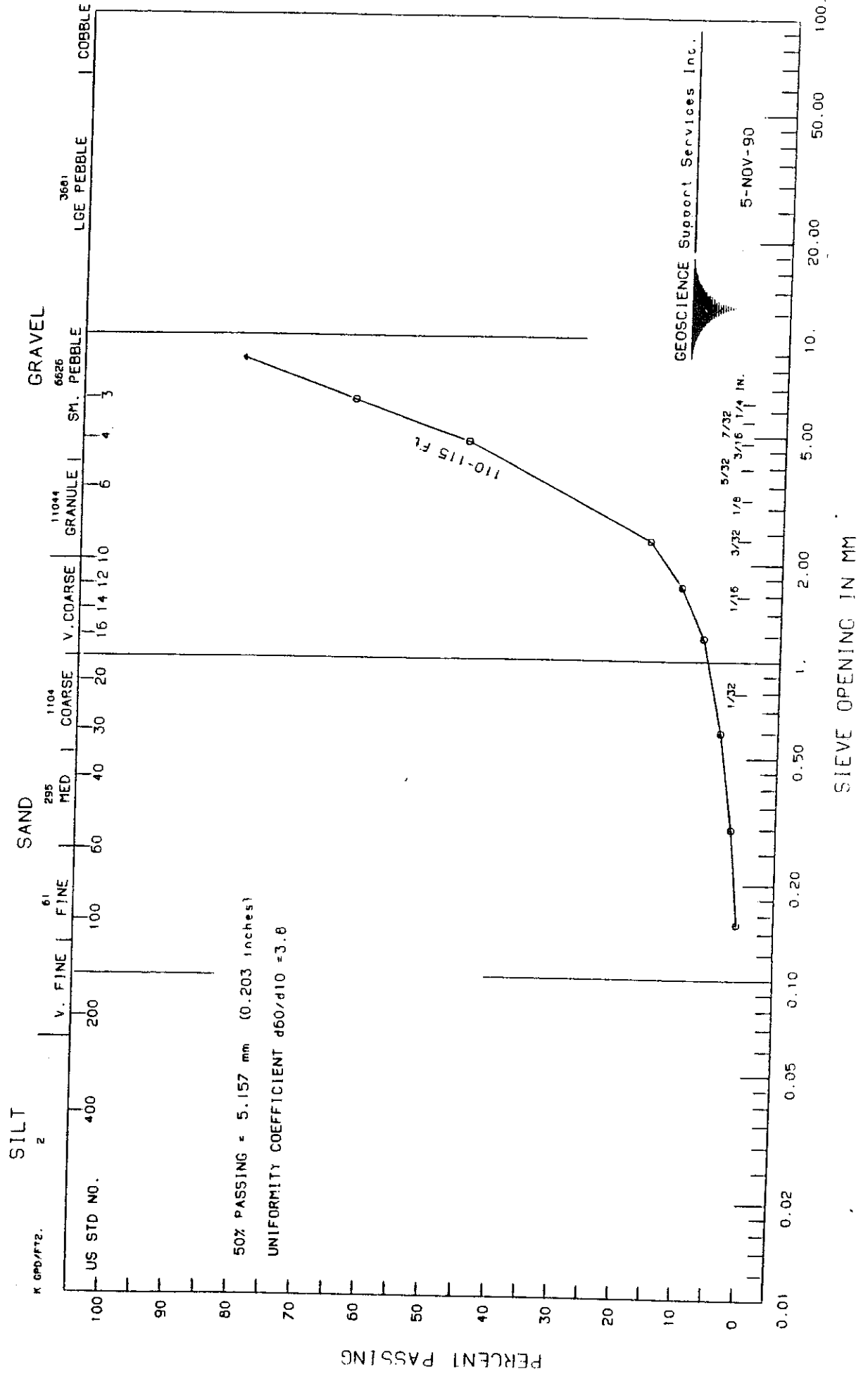
MECHANICAL GRADING ANALYSIS

Sand Canyon well no. 6 - 60-65 feet



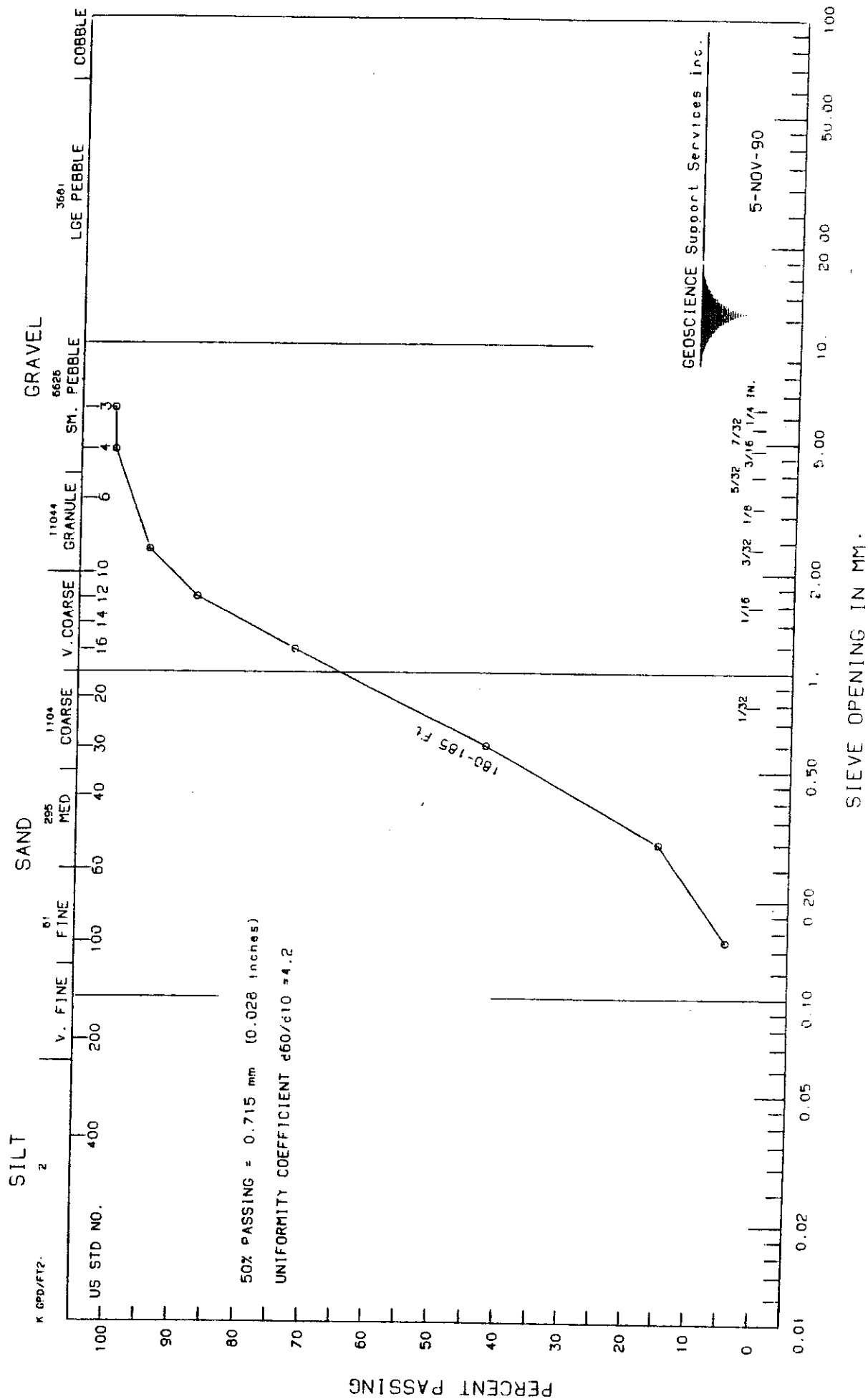
MECHANICAL GRADING ANALYSIS

Sand Canyon well no. 6 - 110-115 feet



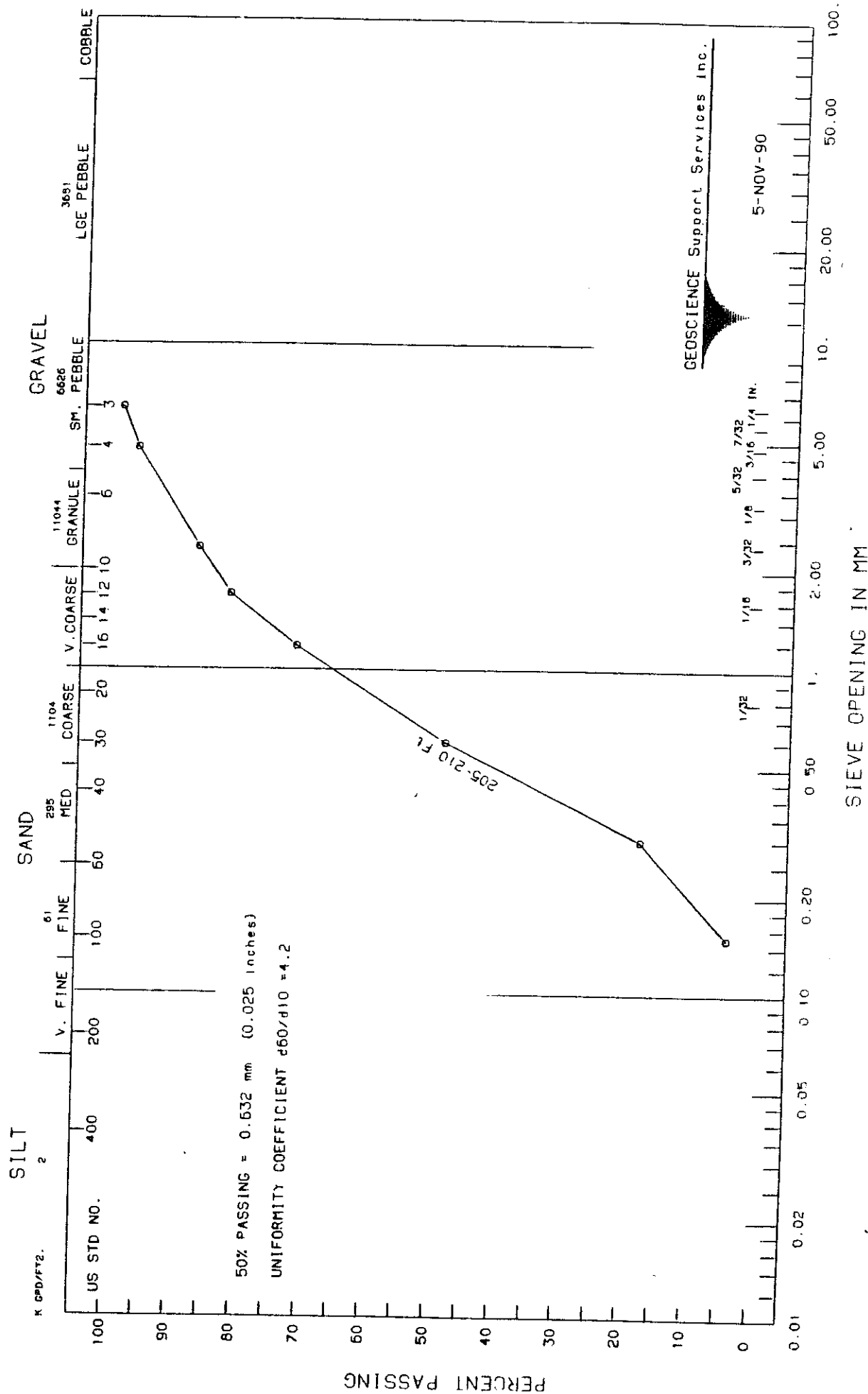
MECHANICAL GRADING ANALYSIS

Sand Canyon well no. 6 - 180-185 feet



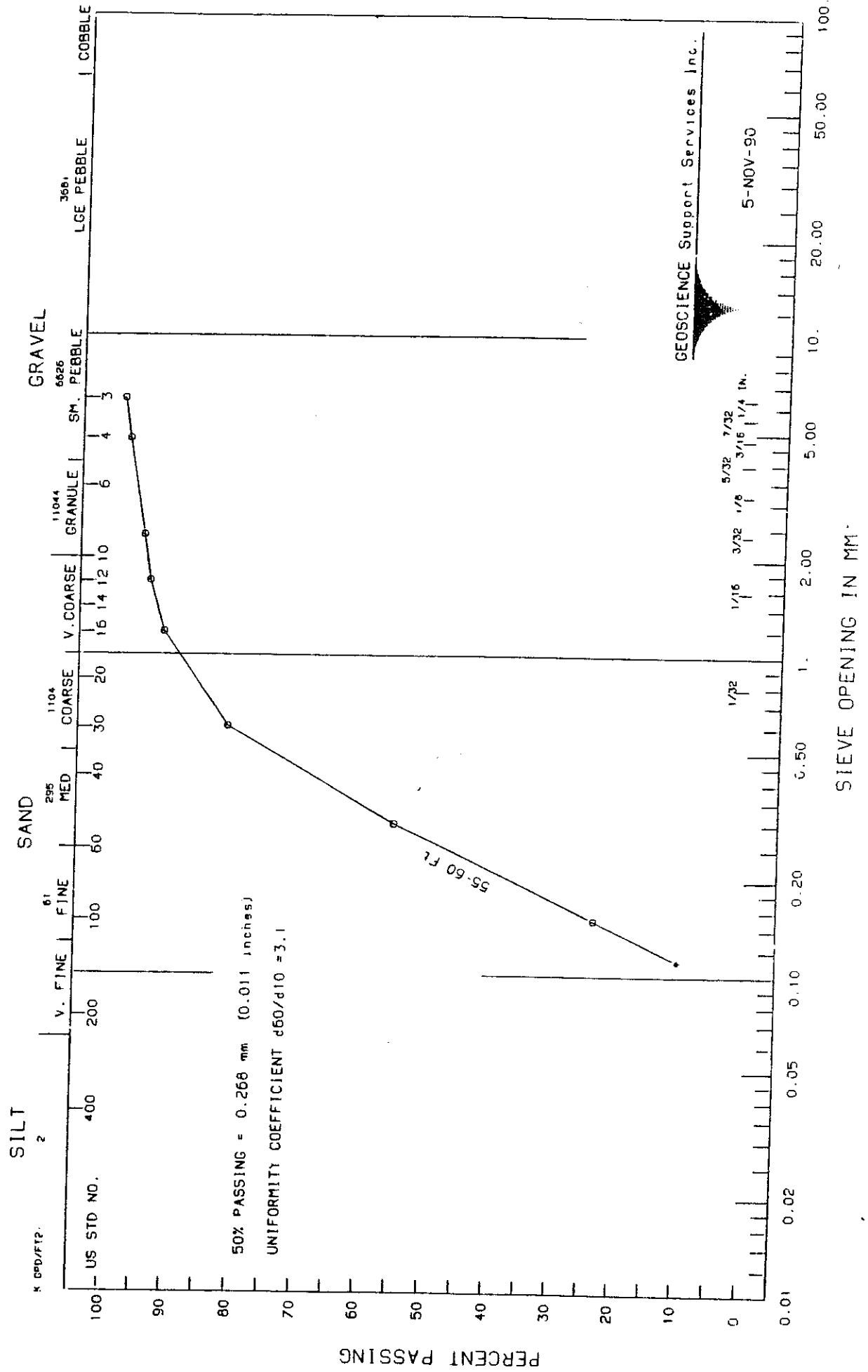
MECHANICAL GRADING ANALYSIS

Sand Canyon well no. 6 - 205-210 feet



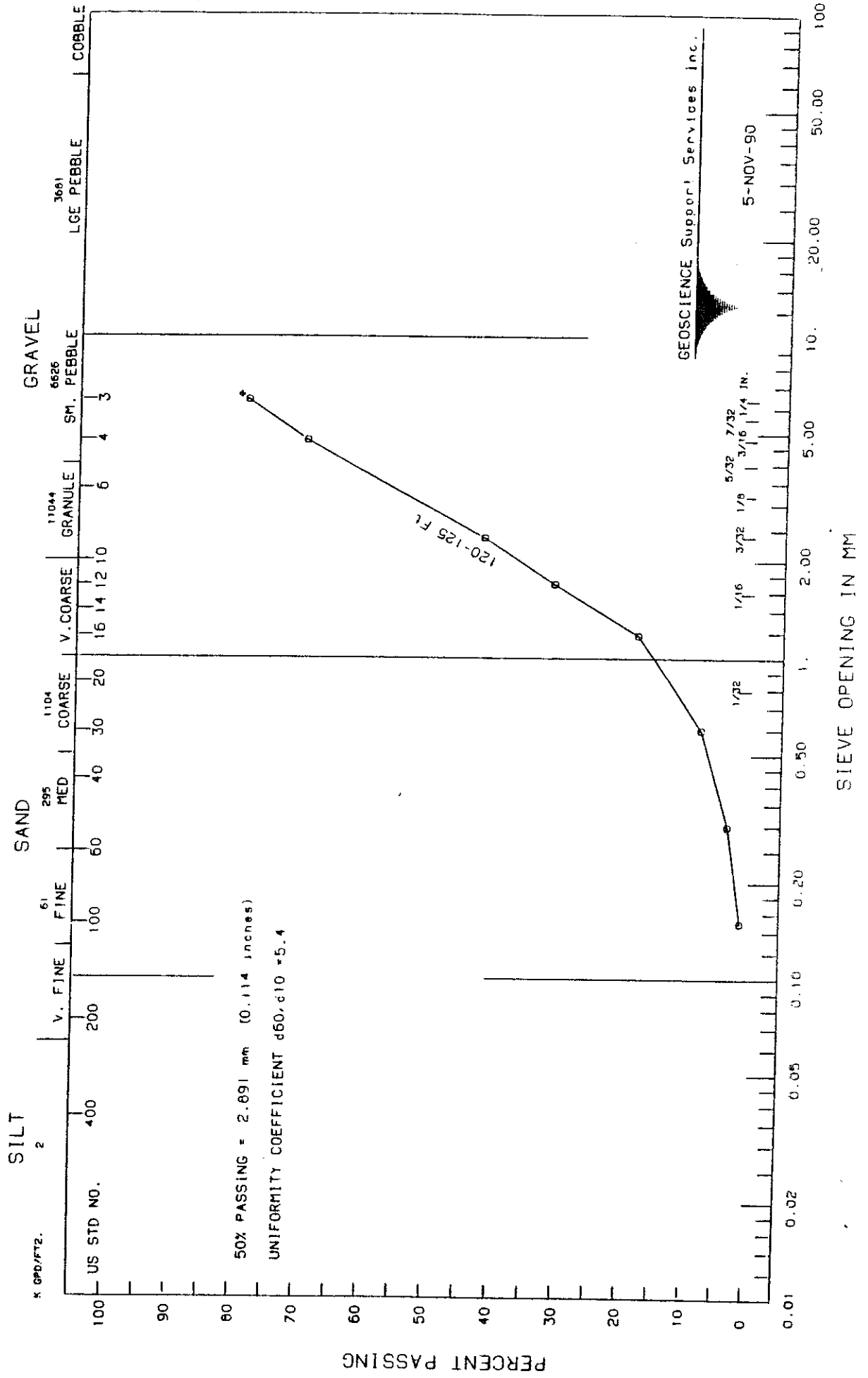
MECHANICAL GRADING ANALYSIS

Sand Canyon well no. 7 - 55-60 feet

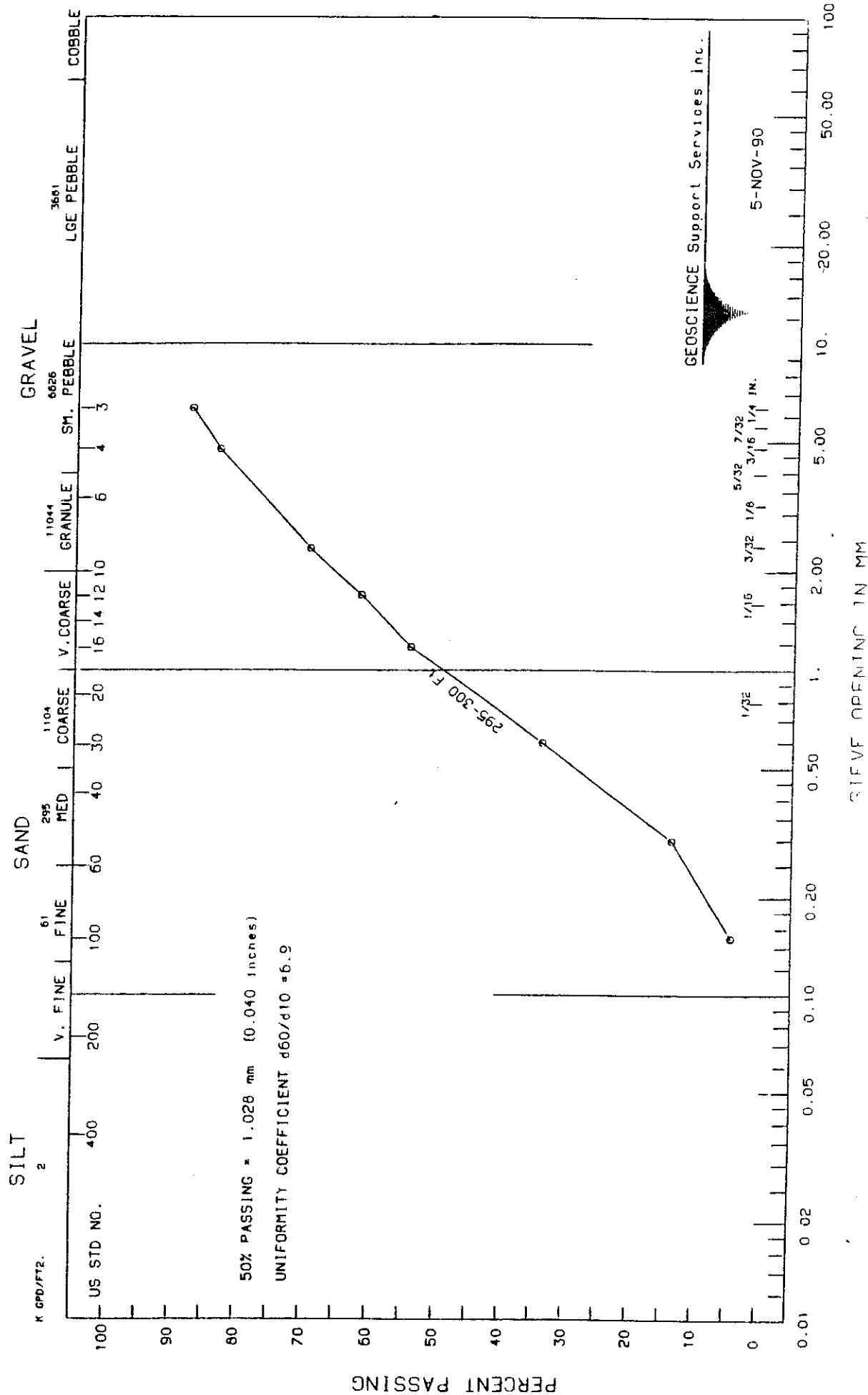


MECHANICAL GRADING ANALYSIS

Sand Canyon well no. 7 - 120-125 feet

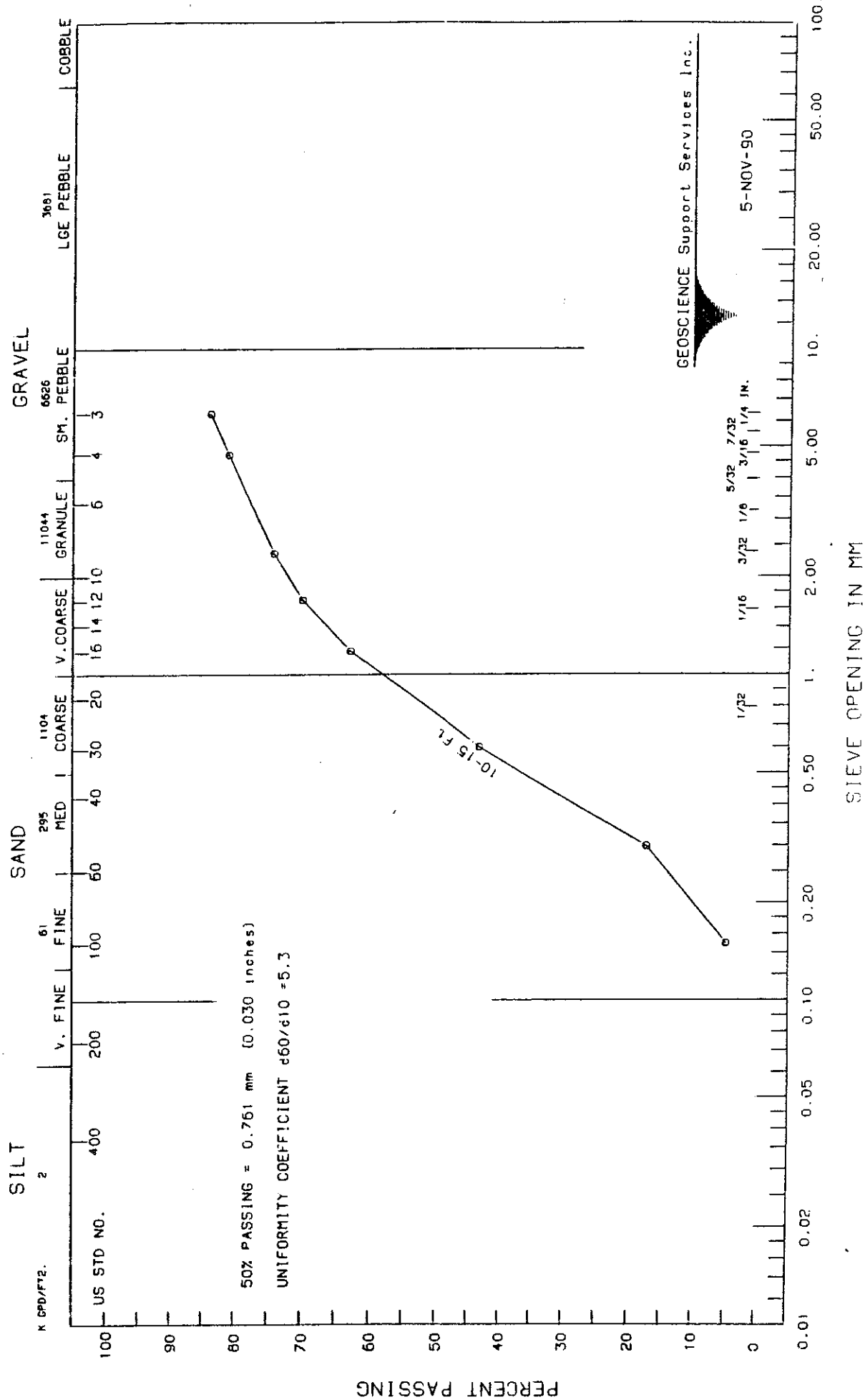


Sand Canyon well no. 7 - 295-300 feet



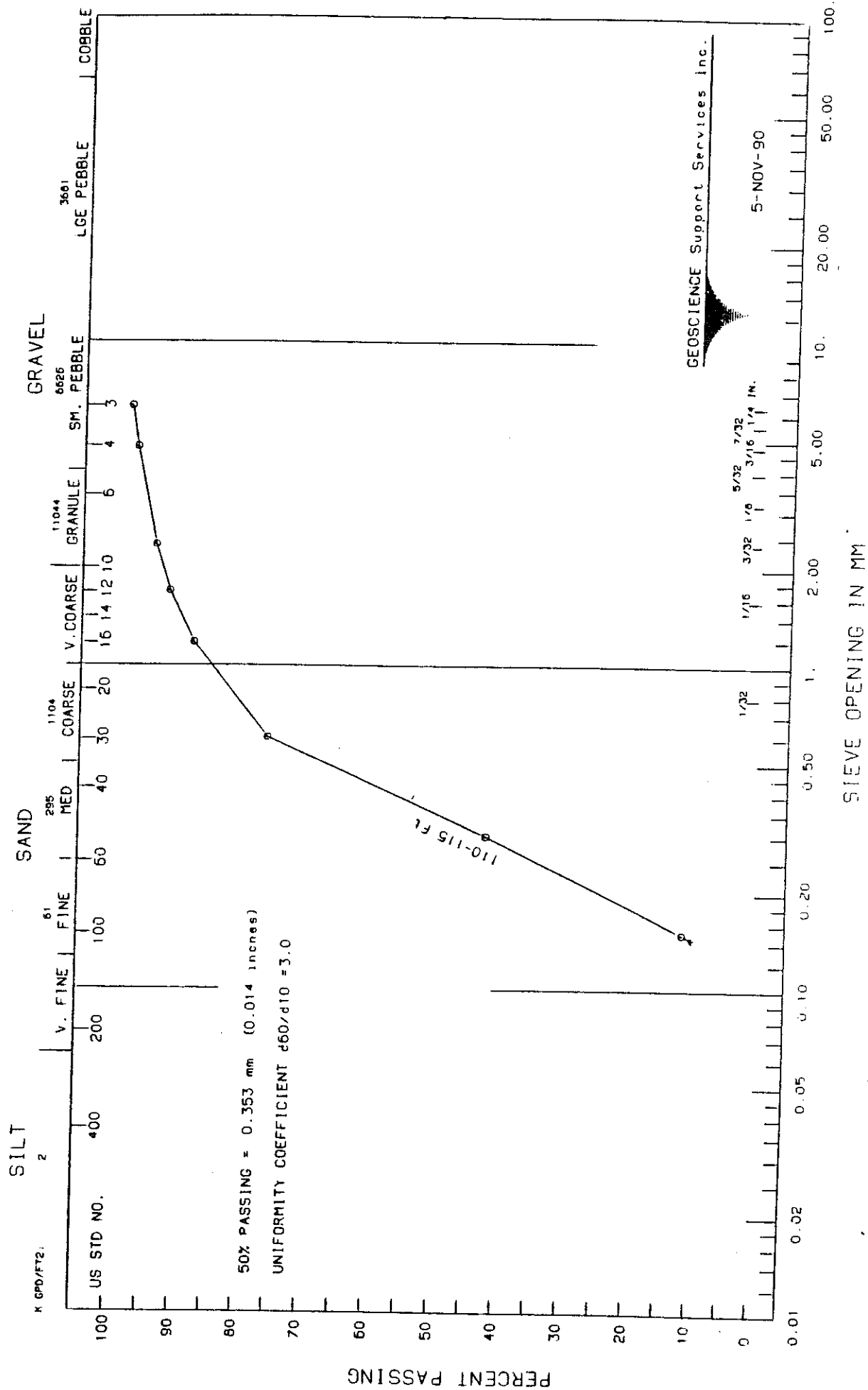
MECHANICAL GRADING ANALYSIS

Sand Canyon well no. 8 - 10-15 feet

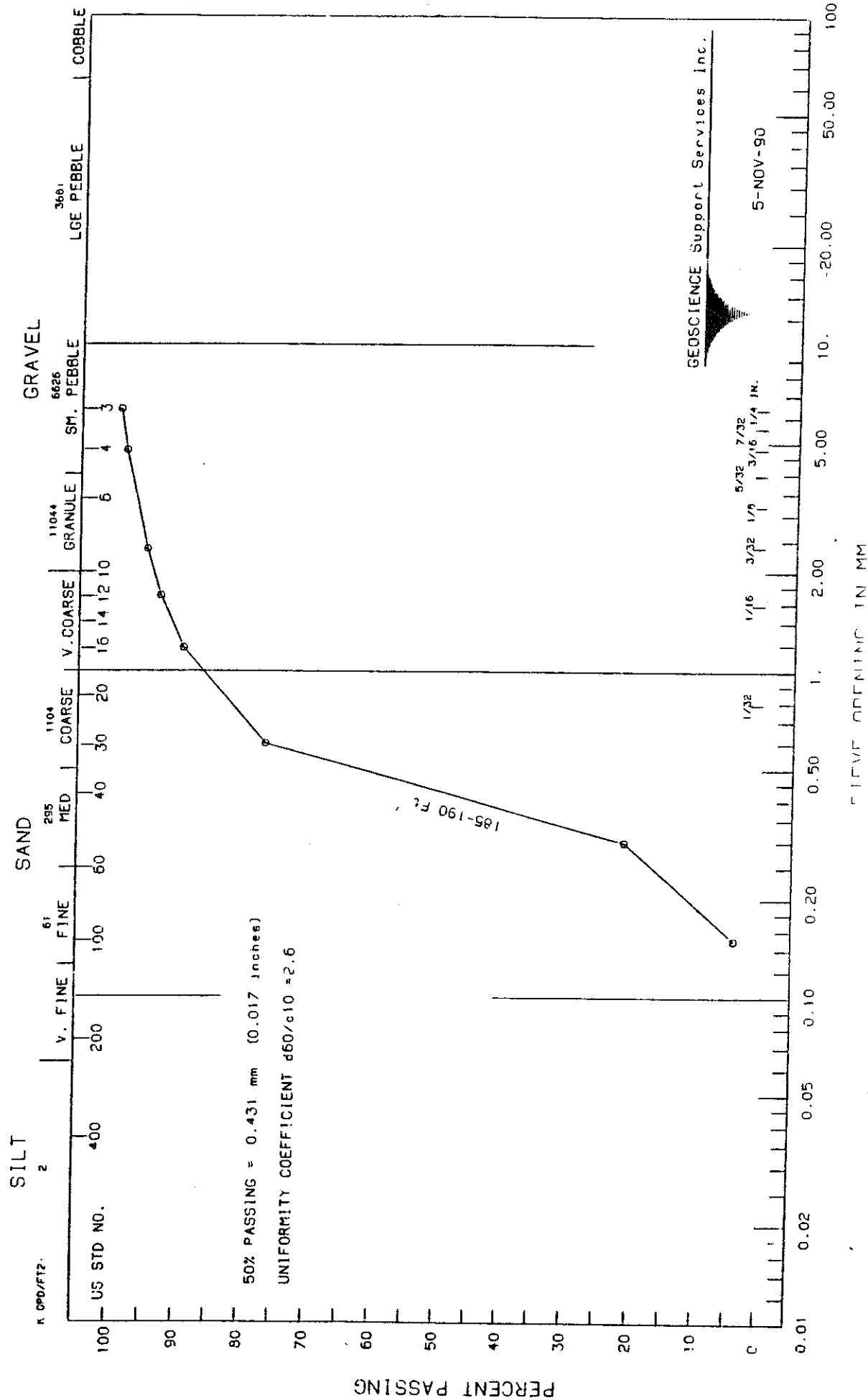


MECHANICAL GRADING ANALYSIS

Sand Canyon well no. 8 - 110-115 feet

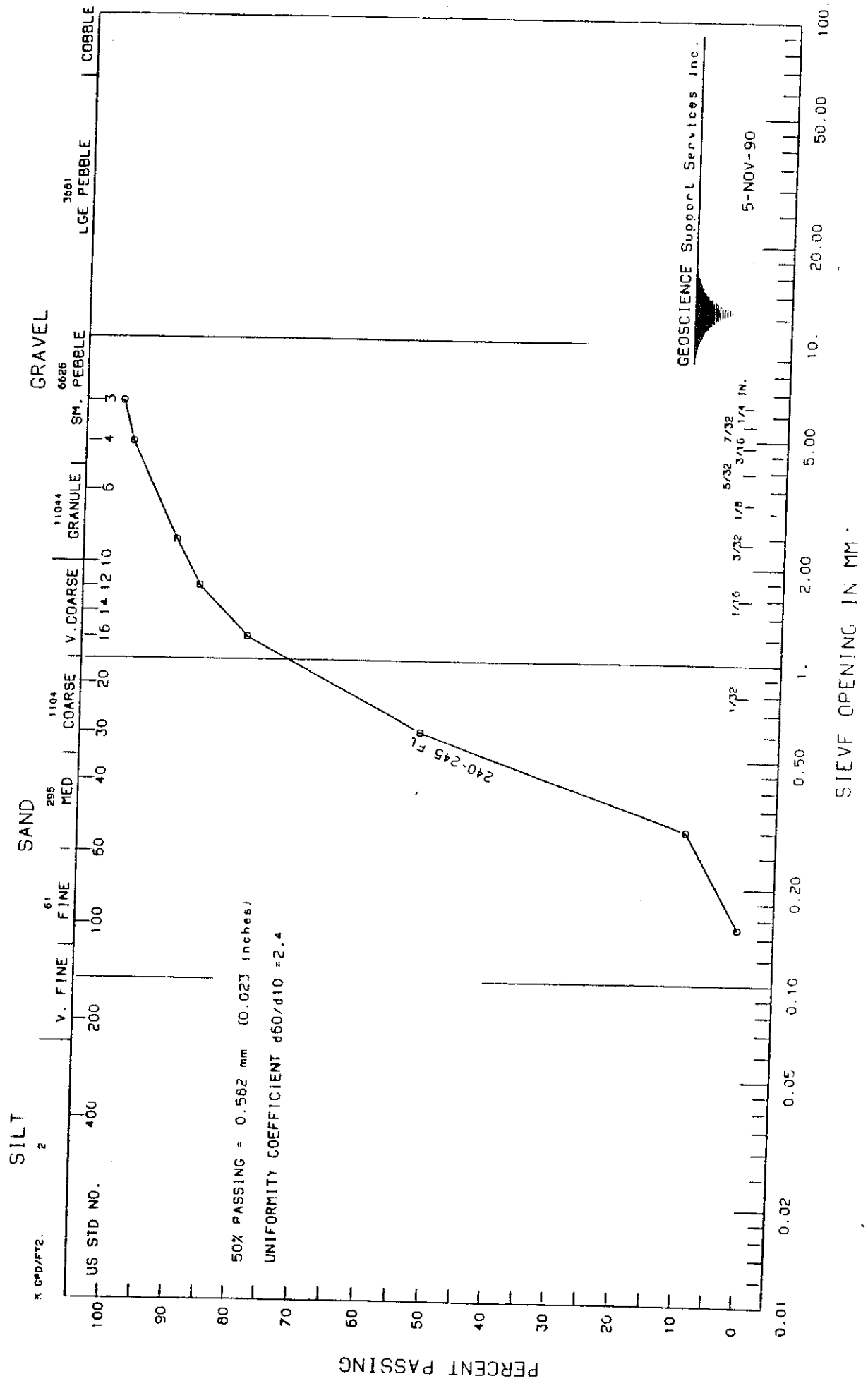


Sand Canyon well no. 8 - 185-190 feet



MECHANICAL GRADING ANALYSIS

Sand Canyon well no. 8 - 240-245 feet



APPENDIX C
Water Quality Analyses

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TITLE 22 CHEMICAL ANALYSES

G

Description of Sampling Point																
Name/Number of Sample Source SAND CANYON #1 140 FT										Station Number						
Date and Time of Sample 9 0 1 1 1 1 Y Y M M D D T T T T										Water Type G/S		User I.D.		Submitted to SWGIS By		

(Cations, Anions) 3.0 % Meg Difference.									
mg/L	Total Alkalinity (as CaCO3)		410	2	2	6	.	0	
mg/L	Hydroxide (OH)		71830		<	1	.	0	
mg/L	Carbonate (CO3)		445		<	1	.	0	
mg/L	Bicarbonate (HCO3)		440	2	7	5	.	7	
* mg/L +	Sulfate (SO4)		945			6	.	0	
* mg/L +	Chloride (Cl)		940			7	.	6	
45 mg/L	Nitrate (NO3)		71850			5	.	9	
1.4 - 2.4 mg/L	Fluoride(F) Temp. Depend.		951		<	0	.	1	
Total Anions	meg/L	Value:	5.0						

* 250-500-600

**** 900-1600-2200**

*** 500-1000-1500

SEE OTHER SIDE

SYSTEM NAME AND NUMBER GEOSCIENCE SUPPORT SERVICES INC

No Entry

* THE FOLLOWING CONSTITUENTS ARE REPORTED IN UG/L *

90/C/5482

MCL Reporting Units	Constituent	T T	Storet Code	Analyses Results
50 ug/L	Arsenic(As)		1002	
1000 ug/L	Barium(Ba)		1007	
10 ug/L	Cadmium(Cd)		1027	
50 ug/L	Chromium(Total Cr)		1034	
1000 ug/L +	Copper(Cu)		1042	
300 ug/L +	Iron(Fe)		1045	
50 ug/L	Lead(Pb)		1051	
50 ug/L +	Manganese(Mn)		1055	
2 ug/L	Mercury(Hg)		71900	
10 ug/L	Selenium(Se)		1147	
50 ug/L	Silver(Ag)		1077	
5000 ug/L	Zinc(Zn)		1092	

ORGANIC CHEMICALS

0.2 ug/L	Endrin		39390	
4 ug/L	Lindane		39340	
100 ug/L	Methoxychlor		39480	
5 ug/L	Toxaphene		39400	
100 ug/L	2,4-D		39730	
10 ug/L	2,4,5-TP Silvex		39045	
Date ORGANIC Analysis Completed			73672	

Y Y M M D D

ADDITIONAL ANALYSES

NTU	Field Turbidity		82078	
C	Source Temperature		10	
	Langlier Index Source Temp.		71814	
	Langlier Index at 60°C		71813	
Std. Units	Field pH		00400	
	Aggressive Index		82383	
mg/L	Silica		00955	
mg/L	Phosphate		00650	

RADIOLOGICAL

5 pC/L	Gross Alpha		1501	
pC/L	Counting Error 95%		1502	
50 pC/L	Gross Beta		3501	
pC/L	Counting Error 95%		3502	

+ Indicates Secondary Drinking Water Standards

9999

TITLE 22 CHEMICAL ANALYSES

G

Std UNITS	pH(Laboratory)	403	7	4	0
** umho/cm +	Specific Conductance(E.C.)	95	3	7	0
*** mg/L +	Total Filterable Residue at 180° C (TDS)	70300	2	2	5 . 7
UNITS	Apparent Color (Unfiltered)	81			
TON	Odor Threshold at 60° C	86			
NTU	Lab Turbidity	82079			
0.5 mg/L +	MBAS	38260	< 0	0	2

*** 500-1000-1500

SYSTEM NAME AND NUMBER GEOSCIENCE SUPPORT SERVICES INC

No Entry

* THE FOLLOWING CONSTITUENTS ARE REPORTED IN UG/L *

90/C/5480

MCL Reporting Units	Constituent	T T	Storet Code	Analyses Results
50 ug/L	Arsenic(As)		1002	
1000 ug/L	Barium(Ba)		1007	
10 ug/L	Cadmium(Cd)		1027	
50 ug/L	Chromium(Total Cr)		1034	
1000 ug/L +	Copper(Cu)		1042	< 5 0
300 ug/L +	Iron(Fe)		1045	4 4 0
50 ug/L	Lead(Pb)		1051	
50 ug/L +	Manganese(Mn)		1055	1 6 0
2 ug/L	Mercury(Hg)		71900	
10 ug/L	Selenium(Se)		1147	
50 ug/L	Silver(Ag)		1077	
5000 ug/L	Zinc(Zn)		1092	< 5 0

ORGANIC CHEMICALS

0.2 ug/L	Endrin		39390	
4 ug/L	Lindane		39340	
100 ug/L	Methoxychlor		39480	
5 ug/L	Toxaphene		39400	
100 ug/L	2,4-D		39730	
10 ug/L	2,4,5-TP Silvex		39045	
Date ORGANIC Analysis Completed			73672	Y Y M M D D

ADDITIONAL ANALYSES

NTU	Field Turbidity		82078	
C	Source Temperature		10	
	Langlier Index Source Temp.		71814	
	Langlier Index at 60°C		71813	
Std. Units	Field pH		00400	
	Aggressive Index		82383	
mg/L	Silica		00955	
mg/L	Phosphate		00650	

RADIOLOGICAL

5 pC/L	Gross Alpha		1501	
pC/L	Counting Error 95%		1502	
50 pC/L	Gross Beta		3501	
pC/L	Counting Error 95%		3502	

+ Indicates Secondary Drinking Water Standards

Clinical Laboratory of San Bernardino, Inc.

9999

Post Office Box 329
1595 North "D" Street
San Bernardino, California 92402
Phone (714) 885-3216

TITLE 22 CHEMICAL ANALYSES

G

Date Of Report 12/06/1990	Lab Sample I.D. Number. 90/C/5478
Laboratory Name Clinical Laboratory of San Bernardino, Inc.	Signature Lab Director <i>C. J. Jelliff</i>
Name of Sampler MICHAEL J MENDEZ	Sampler Employed By GEOSCIENCE SUPPORT SERVICES INC.
Date/Time Sample Collected 11/12/1990	Date / Time Sample Received at Lab. 11/30/1990
Were Holding Times Observed? Yes	
System Name GEOSCIENCE SUPPORT SERVICES INC	System Number
Description of Sampling Point	

Name/Number of Sample Source SAND CANYON FIRST WATER @140 FT	Station Number
Date and Time of Sample 9 0 1 1 1 2 Y Y M M D D T T T T	Water Type G/S
User I.D. 	Submitted to SWGIS By

MCL Reporting Units	Constituent	T T	Storet Code	Analyses Results
	Analyzing Agency (Laboratory)		28	3 7 6 1
mg/L	Total Hardness (as CaCO3)		900	1 8 4 . 0
mg/L	Calcium (Ca)		916	5 3 . 5
mg/L	Magnesium (mg)		927	1 2 . 3
mg/L	Sodium (Na)		929	1 0 . 2
mg/L	Potassium (K)		937	4 . 9
Total Cations	mg/L Value: 4.3			

(Cations, Anions) 4.1 % Meq Difference.

mg/L	Total Alkalinity (as CaCO3)		410	2 0 1 . 6
mg/L	Hydroxide (OH)		71830	< 1 . 0
mg/L	Carbonate (CO3)		445	< 1 . 0
mg/L	Bicarbonate (HCO3)		440	2 4 6 . 0
* mg/L +	Sulfate (SO4)		945	6 . 7
* mg/L +	Chloride (Cl)		940	8 . 2
45 mg/L	Nitrate (NO3)		71850	1 . 0
1.4 - 2.4 mg/L	Fluoride (F) Temp. Depend.		951	0 . 2
Total Anions	mg/L Value: 4.4			

Std UNITS	pH(Laboratory)		403	7 . 4 0
** umho/cm +	Specific Conductance(E.C.)		95	4 4 0
*** mg/L +	Total Filterable Residue at 180° C (TDS)		70300	2 5 5 . 2
UNITS	Apparent Color (Unfiltered)		81	
TON	Odor Threshold at 60° C		86	
NTU	Lab Turbidity		82079	
0.5 mg/L +	MBAS		38260	< 0 . 0 2

* 250-500-600

** 900-1600-2200

*** 500-1000-1500

8351(11/86)

SEE OTHER SIDE

SYSTEM NAME AND NUMBER GEOSCIENCE SUPPORT SERVICES INC

No Entry

* THE FOLLOWING CONSTITUENTS ARE REPORTED IN UG/L *

90/C/5478

MCL Reporting Units	Constituent	T T	Storet Code	Analyses Results					
50 ug/L	Arsenic(As)		1002						
1000 ug/L	Barium(Ba)		1007						
10 ug/L	Cadmium(Cd)		1027						
50 ug/L	Chromium(Total Cr)		1034						
1000 ug/L+	Copper(Cu)		1042						
300 ug/L+	Iron(Fe)		1045						
50 ug/L	Lead(Pb)		1051						
50 ug/L+	Manganese(Mn)		1055						
2 ug/L	Mercury(Hg)		71900						
10 ug/L	Selenium(Se)		1147						
50 ug/L	Silver(Ag)		1077						
5000 ug/L	Zinc(Zn)		1092						

ORGANIC CHEMICALS

0.2 ug/L	Endrin		39390						
4 ug/L	Lindane		39340						
100 ug/L	Methoxychlor		39480						
5 ug/L	Toxaphene		39400						
100 ug/L	2,4-D		39730						
10 ug/L	2,4,5-TP Silvex		39045						
Date ORGANIC Analysis Completed			73672						

Y Y M M D D

ADDITIONAL ANALYSES

NTU	Field Turbidity		82078						
C	Source Temperture		10						
	Langlier Index Source Temp.		71814						
	Langelier Index at 60°C		71813						
Sid. Units	Field pH		00400						
	Aggressive Index		82383						
mg/L	Silica		00955						
mg/L	Phosphate		00650						

RADIOLOGICAL

5 pC/L	Gross Alpha		1501						
pC/L	Counting Error 95%		1502						
50 pC/L	Gross Beta		3501						
pC/L	Counting Error 95%		3502						

+ indicates Secondary Drinking Water Standards

Clinical Laboratory of San Bernardino, Inc.

9999

Post Office Box 329
1595 North " D " Street
San Bernardino, California 92402
Phone (714) 885-3216

TITLE 22 CHEMICAL ANALYSES

G

Date of Report 12/06/1990		Lab Sample I.D. Number. 90/C/5481	
Laboratory Name Clinical Laboratory of San Bernardino, Inc.		Signature Lab Director <i>C. J. Kelly</i>	
Name of Sampler MICHAEL J MENDEZ		Sampler Employed By GEOSCIENCE SUPPORT SERVICES INC	
Date/Time Sample Collected 11/14/1990	Date / Time Sample Received at Lab. 11/30/1990	Were Holding Times Observed? Yes	
System Name GEOSCIENCE SUPPORT SERVICES INC			System Number

Description of Sampling Point

Name/Number of Sample Source SAND CANYON #4 220 FT		Station Number	
Date and Time of Sample 9 0 1 1 1 4 Y Y M M D D T T T T	Water Type G/S	User I.D.	Submitted to SWQIS By

MCL Reporting Units	Constituent	T T	Storet Code	Analyses Results
	Analyzing Agency (Laboratory)		28	3 7 6 1
mg/L	Total Hardness (as CaCO ₃)		900	2 4 9 . 2
mg/L	Calcium (Ca)		916	6 5 . 4
mg/L	Magnesium (mg)		927	2 0 . 9
mg/L	Sodium (Na)		929	1 1 . 5
mg/L	Potassium (K)		937	4 . . 8
Total Cations	meg/L Value: 5.6			

(Cations, Anions) 4.7 % Meg Difference.

mg/L	Total Alkalinity (as CaCO ₃)		410	2 5 0 . 4
mg/L	Hydroxide (OH)		71830	< 1 . 0
mg/L	Carbonate (CO ₃)		445	< 1 . 0
mg/L	Bicarbonate (HCO ₃)		440	3 0 5 . 5
* mg/L +	Sulfate (SO ₄)		945	1 0 . 4
* mg/L +	Chloride (Cl)		940	1 3 . 0
45 mg/L	Nitrate (NO ₃)		71850	1 7 . 0
1.4 - 2.4 mg/L	Fluoride (F) Temp. Depend.		951	0 . . 2
Total Anions	meg/L Value: 5.9			

Std UNITS	pH (Laboratory)		403	7 . 4 0
** umho/cm +	Specific Conductance (E.C.)		95	5 7 0
*** mg/L +	Total Filterable Residue at 180° C (TDS)		70300	2 2 6 . 3
UNITS	Apparent Color (Unfiltered)		81	
TON	Odor Threshold at 60° C		86	
NTU	Lab Turbidity		82079	
0.5 mg/L +	MBAS		38260	< 0 . 0 2

* 250-500-600

** 900-1600-2200

*** 500-1000-1500

SEE OTHER SIDE

SYSTEM NAME AND NUMBER GEOSCIENCE SUPPORT SERVICES INC

No Entry

* THE FOLLOWING CONSTITUENTS ARE REPORTED IN UG/L *

90/C/5481

MCL Reporting Units	Constituent	T T	Storet Code	Analyses Results
50 ug/L	Arsenic(As)		1002	
1000 ug/L	Barium(Ba)		1007	
10 ug/L	Cadmium(Cd)		1027	
50 ug/L	Chromium(Total Cr)		1034	
1000 ug/L +	Copper(Cu)		1042	
300 ug/L +	Iron(Fe)		1045	
50 ug/L	Lead(Pb)		1051	
50 ug/L +	Manganese(Mn)		1055	
2 ug/L	Mercury(Hg)		71900	
10 ug/L	Selenium(Se)		1147	
50 ug/L	Silver(Ag)		1077	
5000 ug/L	Zinc(Zn)		1092	

ORGANIC CHEMICALS

0.2 ug/L	Endrin		39390	
4 ug/L	Lindane		39340	
100 ug/L	Methoxychlor		39480	
5 ug/L	Toxaphene		39400	
100 ug/L	2,4-D		39730	
10 ug/L	2,4,5-TP Silvex		39045	
Date ORGANIC Analysis Completed			73672	

Y Y M M D D

ADDITIONAL ANALYSES

NTU	Field Turbidity		82078	
C	Source Temperature		10	
	Langlier Index Source Temp.		71814	
	Langelier Index at 60°C		71813	
Std. Units	Field pH		00400	
	Aggressive Index		82383	
mg/L	Silica		00955	
mg/L	Phosphate		00650	

RADIOLOGICAL

5 pC/L	Gross Alpha		1501	
pC/L	Counting Error 95%		1502	
50 pC/L	Gross Beta		3501	
pC/L	Counting Error 95%		3502	

+ indicates Secondary Drinking Water Standards

Clinical Laboratory of San Bernardino, Inc.

9999

Post Office Box 329
1595 North "D" Street
San Bernardino, California 92402
Phone (714) 885-3216

TITLE 22 CHEMICAL ANALYSES

G

Date Of Report 12/06/1990		Lab Sample I.D. Number. 90/C/5479	
Laboratory Name Clinical Laboratory of San Bernardino, Inc.		Signature Lab Director <i>C. J. Jelliff</i>	
Name of Sampler MICHAEL J MENDEZ		Sampler Employed By GEOSCIENCE SUPPORT SERVICES INC	
Date/Time Sample Collected 10/15/1990	Date / Time Sample Received at Lab. 11/30/1990	Were Holding Times Observed? Yes	
System Name GEOSCIENCE SUPPORT SERVICES INC			System Number
Description of Sampling Point			

Name/Number of Sample Source SAND CANYON EXTRACTION WELL 300 FT		Station Number	
Date and Time of Sample 9 0 1 0 1 5 Y Y M M D D T T T T		Water Type ☐ G/S	User I.D.
		Submitted to SWDIS By	

MCL Reporting Units	Constituent	T T	Storet Code	Analyses Results
	Analyzing Agency (Laboratory)		28	3 7 6 1
mg/L	Total Hardness (as CaCO3)		900	2 0 4 . 4
mg/L	Calcium (Ca)		916	5 0 . 8
mg/L	Magnesium (mg)		927	1 8 . 9
mg/L	Sodium (Na)		929	8 . 6
mg/L	Potassium (K)		937	1 . 9
Total Cations	meg/L Value: 4.5			

(Cations, Anions) 2.0 % Meg Difference.

mg/L	Total Alkalinity (as CaCO3)		410	2 0 8 . 8
mg/L	Hydroxide (OH)		71830	< 1 . 0
mg/L	Carbonate (CO3)		445	< 1 . 0
mg/L	Bicarbonate (HCO3)		440	2 5 4 . 7
* mg/L +	Sulfate (SO4)		945	9 . 1
* mg/L +	Chloride (Cl)		940	7 . 0
45 mg/L	Nitrate (NO3)		71850	2 . 2
1.4 - 2.4 mg/L	Fluoride (F) Temp. Depend.		951	< 0 . 1
Total Anions	meg/L Value: 4.6			

Std UNITS	pH (Laboratory)		403	7 . 5 0
** umho/cm +	Specific Conductance (E.C.)		95	4 7 0
*** mg/L +	Total Filterable Residue at 180°C (TDS)		70300	2 8 2 . 0
UNITS	Apparent Color (Unfiltered)		81	
TON	Odor Threshold at 60°C		86	
NTU	Lab Turbidity		82079	
0.5 mg/L +	MBAS		38260	< 0 . 0 2

* 250-500-600

** 900-1600-2200

*** 500-1000-1500

SYSTEM NAME AND NUMBER GEOSCIENCE SUPPORT SERVICES INC

No Entry

* THE FOLLOWING CONSTITUENTS ARE REPORTED IN UG/L *

90/C/5479

MCL Reporting Units	Constituent	T T	Storet Code	Analyses Results
50 ug/L	Arsenic(As)		1002	
1000 ug/L	Barium(Ba)		1007	
10 ug/L	Cadmium(Cd)		1027	
50 ug/L	Chromium(Total Cr)		1034	
1000 ug/L +	Copper(Cu)		1042	
300 ug/L +	Iron(Fe)		1045	
50 ug/L	Lead(Pb)		1051	
50 ug/L +	Manganese(Mn)		1055	
2 ug/L	Mercury(Hg)		71900	
10 ug/L	Selenium(Se)		1147	
50 ug/L	Silver(Ag)		1077	
5000 ug/L	Zinc(Zn)		1092	

ORGANIC CHEMICALS

0.2 ug/L	Endrin		39390	
4 ug/L	Lindane		39340	
100 ug/L	Methoxychlor		39480	
5 ug/L	Toxaphene		39400	
100 ug/L	2,4-D		39730	
10 ug/L	2,4,5-TP Silvex		39045	
Date ORGANIC Analysis Completed			73672	
				Y Y M M D D

ADDITIONAL ANALYSES

NTU	Field Turbidity		82078	
C	Source Temperature		10	
	Langlier Index Source Temp.		71814	
	Langelier Index at 60°C		71813	
Std. Units	Field pH		00400	
	Aggressive Index		82383	
mg/L	Silica		00955	
mg/L	Phosphate		00650	

RADIOLOGICAL

5 pC/L	Gross Alpha		1501	
pC/L	Counting Error 95%		1502	
50 pC/L	Gross Beta		3501	
pC/L	Counting Error 95%		3502	

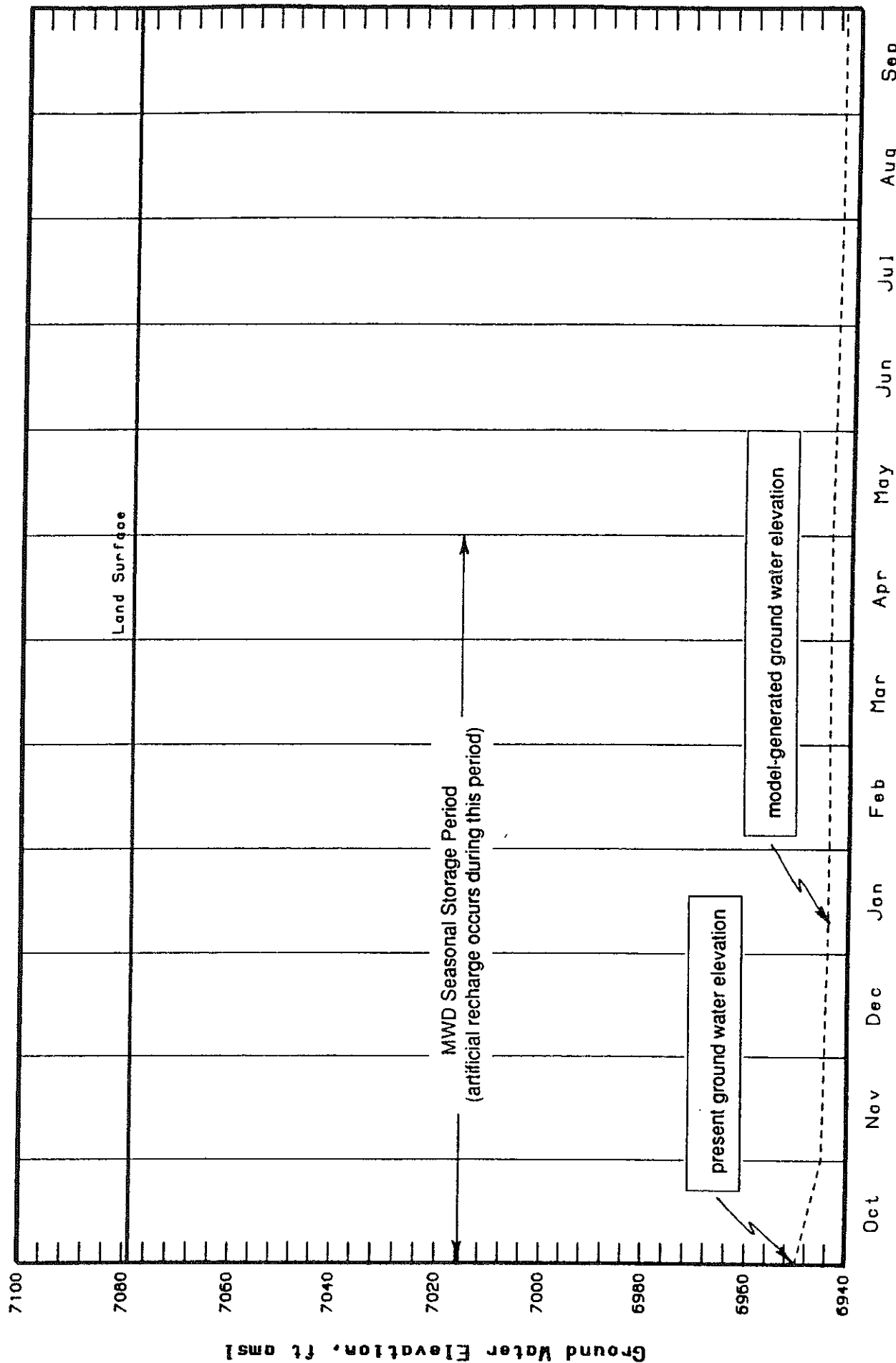
+ Indicates Secondary Drinking Water Standards

APPENDIX D
Selected Ground Water Model Hydrographs

CITY OF BIG BEAR LAKE DWP - Sand Canyon Model

Hydrograph of Model Node (1,j): 12.14

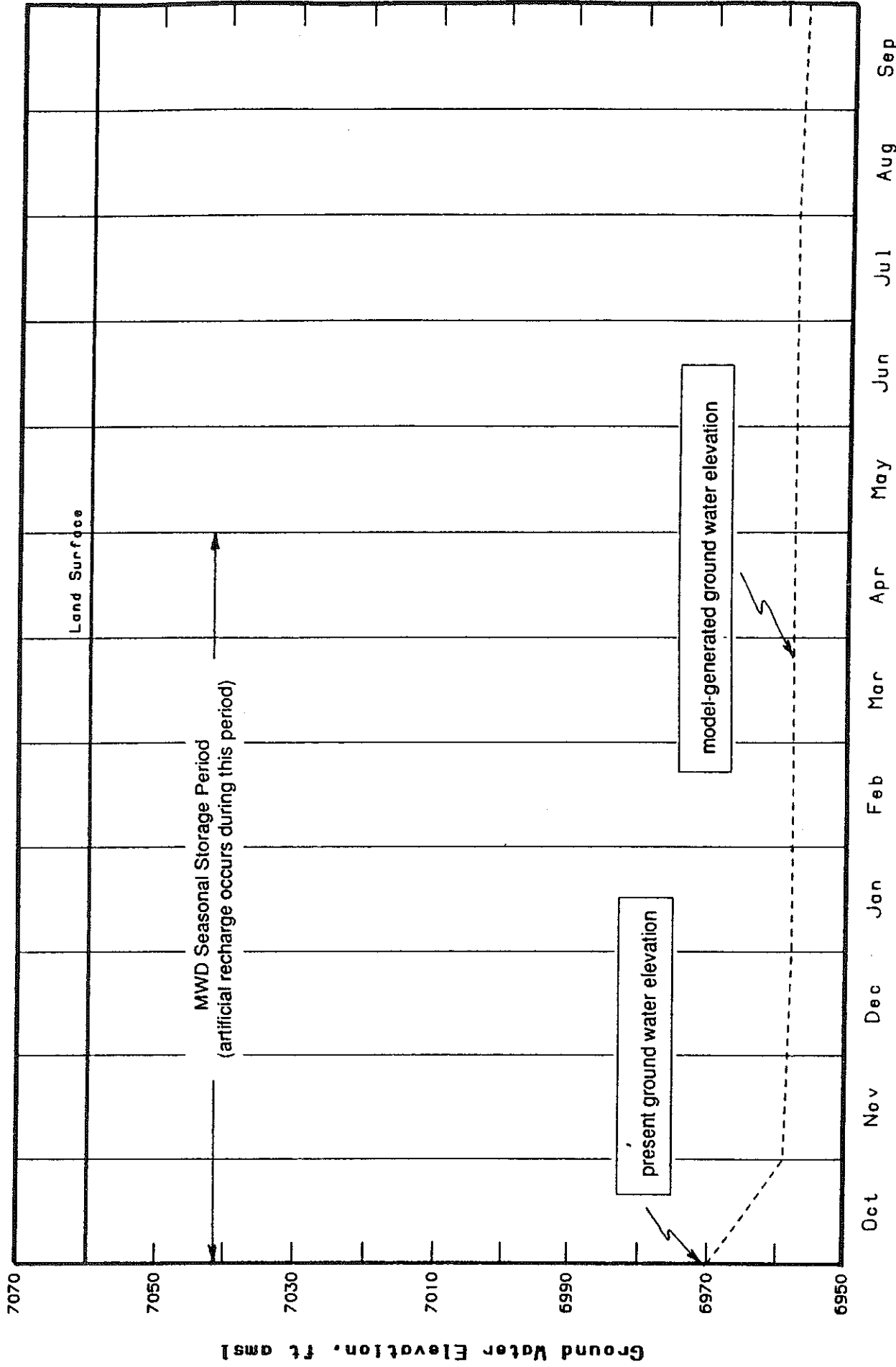
NEAR WELL TH - 4



CITY OF BIG BEAR LAKE DWP - Sand Canyon Model

Hydrograph of Model Node (1,J): 13.8

NEAR WELL TH-5

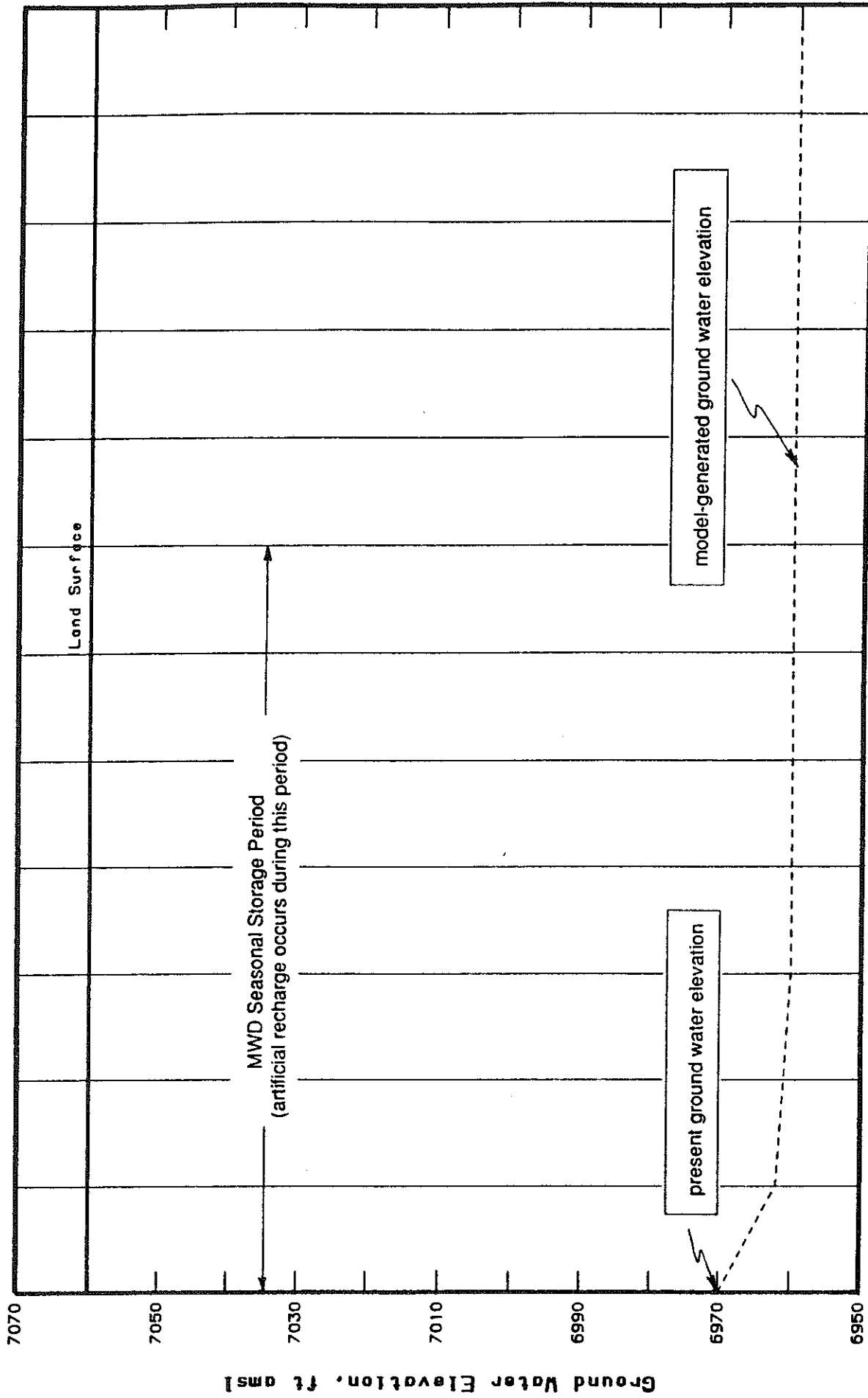


Time in Months

CITY OF BIG BEAR LAKE DWP - Sand Canyon Model

Hydrograph of Model Node (1,j): 13.10

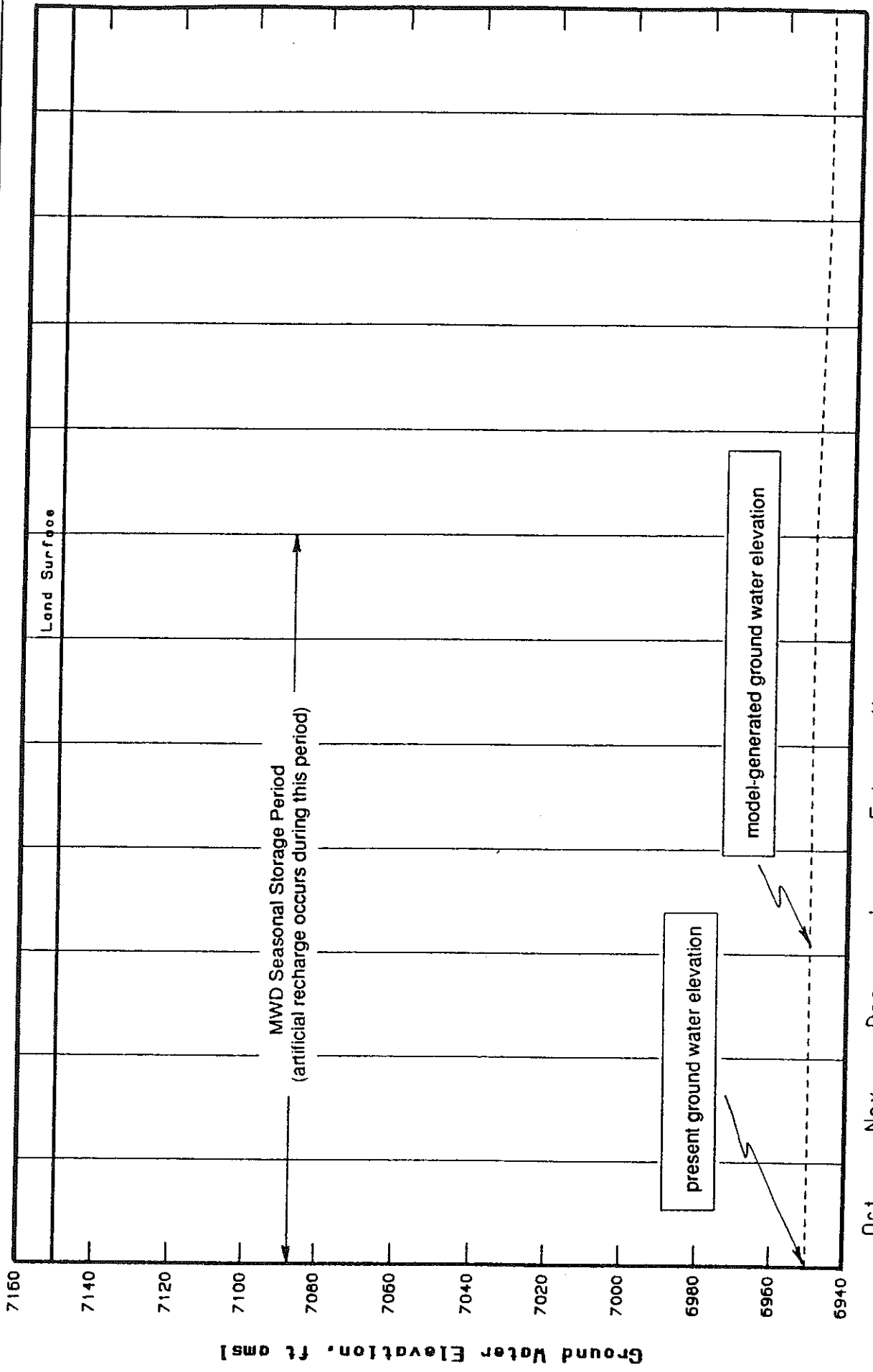
MIDDLE OF EXTRACTION FIELD



CITY OF BIG BEAR LAKE DWP - Sand Canyon Model

Hydrograph of Model Node [1,j]: 19,24

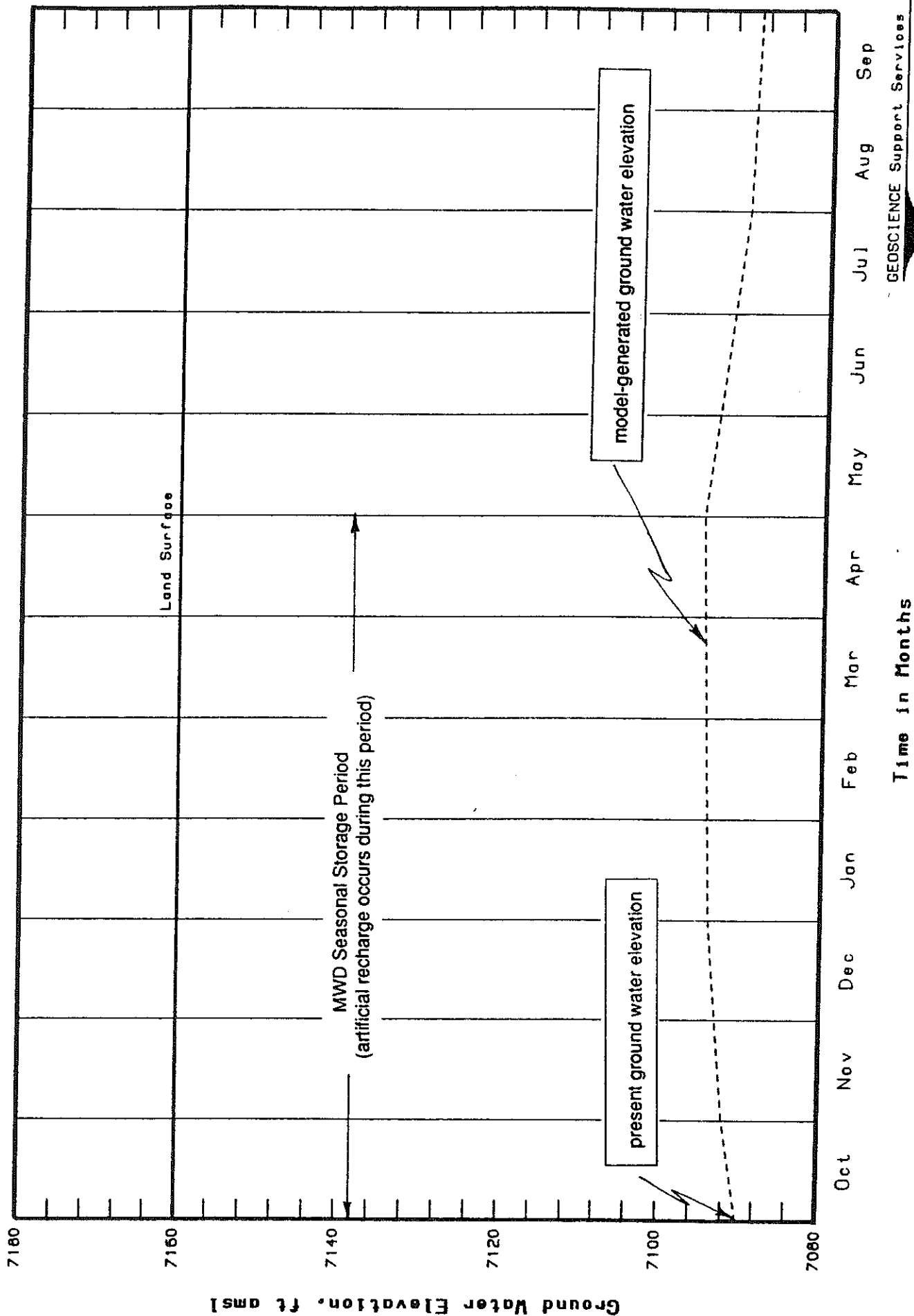
HALFWAY BETWEEN RECHARGE PONDS
AND EXTRACTION WELLS



CITY OF BIG BEAR LAKE DWP - Sand Canyon Model

Hydrograph of Model Node (1,j): 25.32

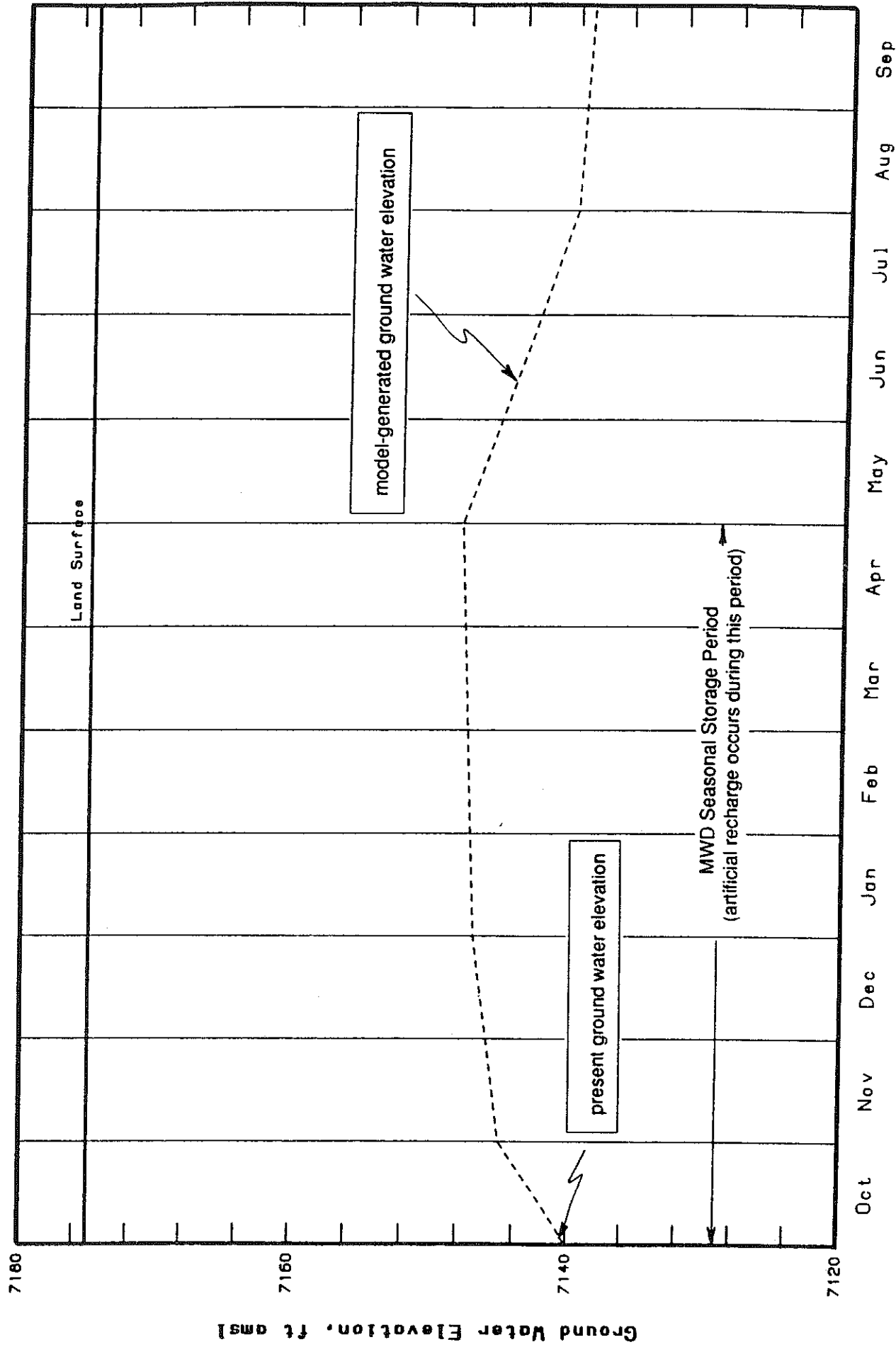
NEAR WELL TH-3



CITY OF BIG BEAR LAKE DWP - Sand Canyon Model

Hydrograph of Model Node (1,j): 28,35

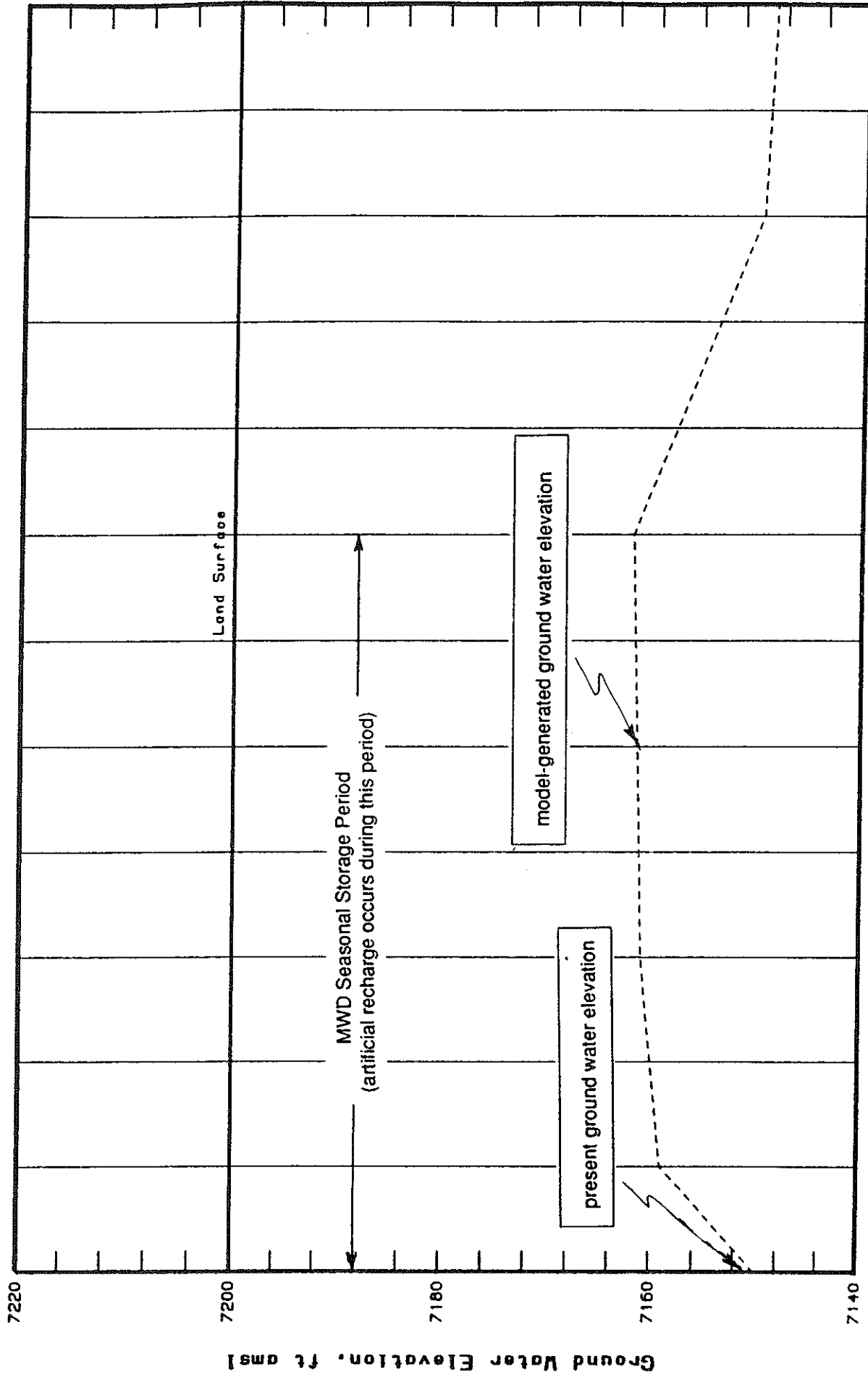
IMMEDIATELY WEST OF TETON RD.



CITY OF BIG BEAR LAKE DWP - Sand Canyon Model

Hydrograph of Model Node (1,j): 29.38

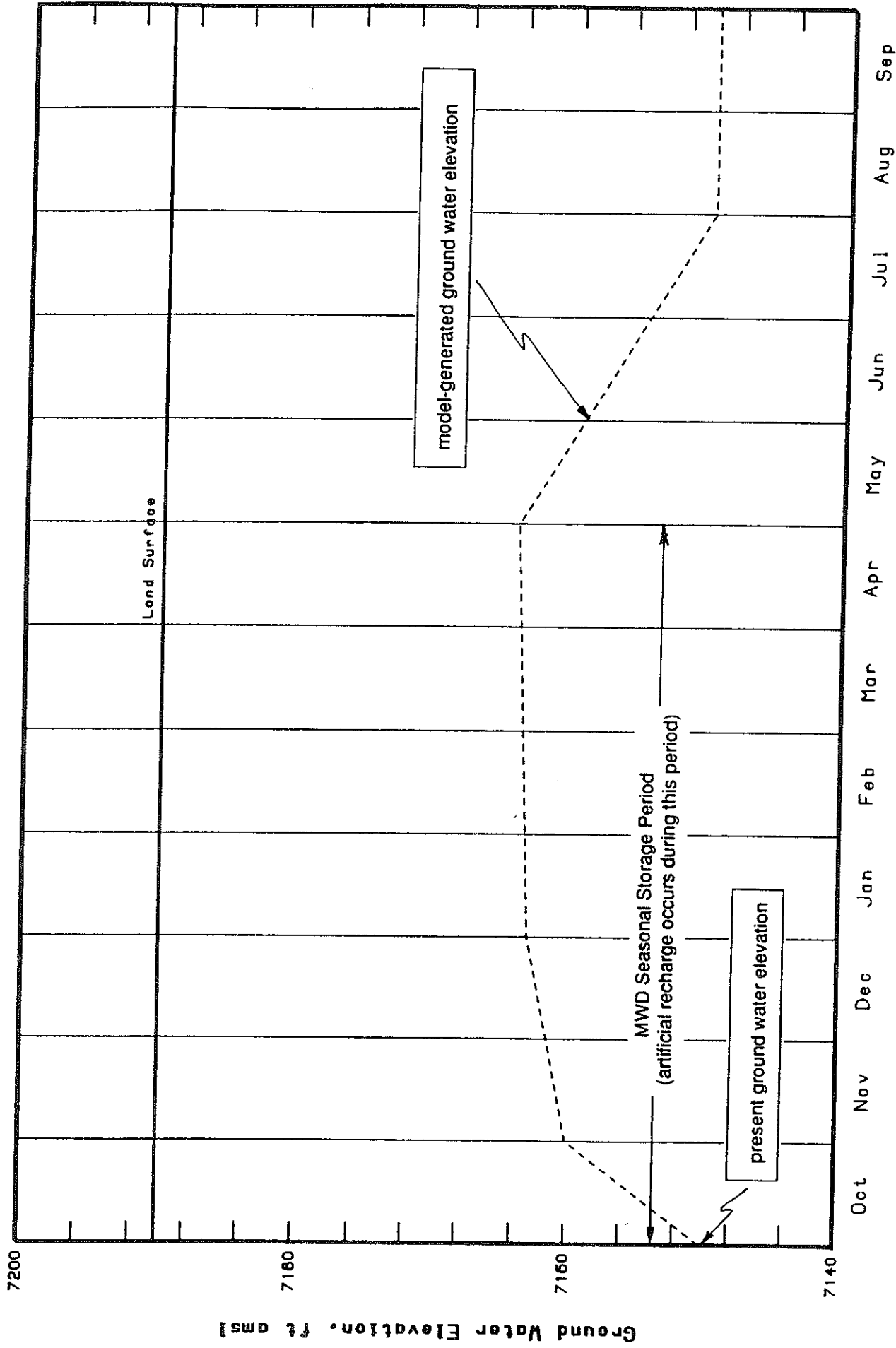
NEAR WELL TH - 6



Time in Months

Hydrograph of Model Node (1,j): 32.40

NEAR WELL TH-2

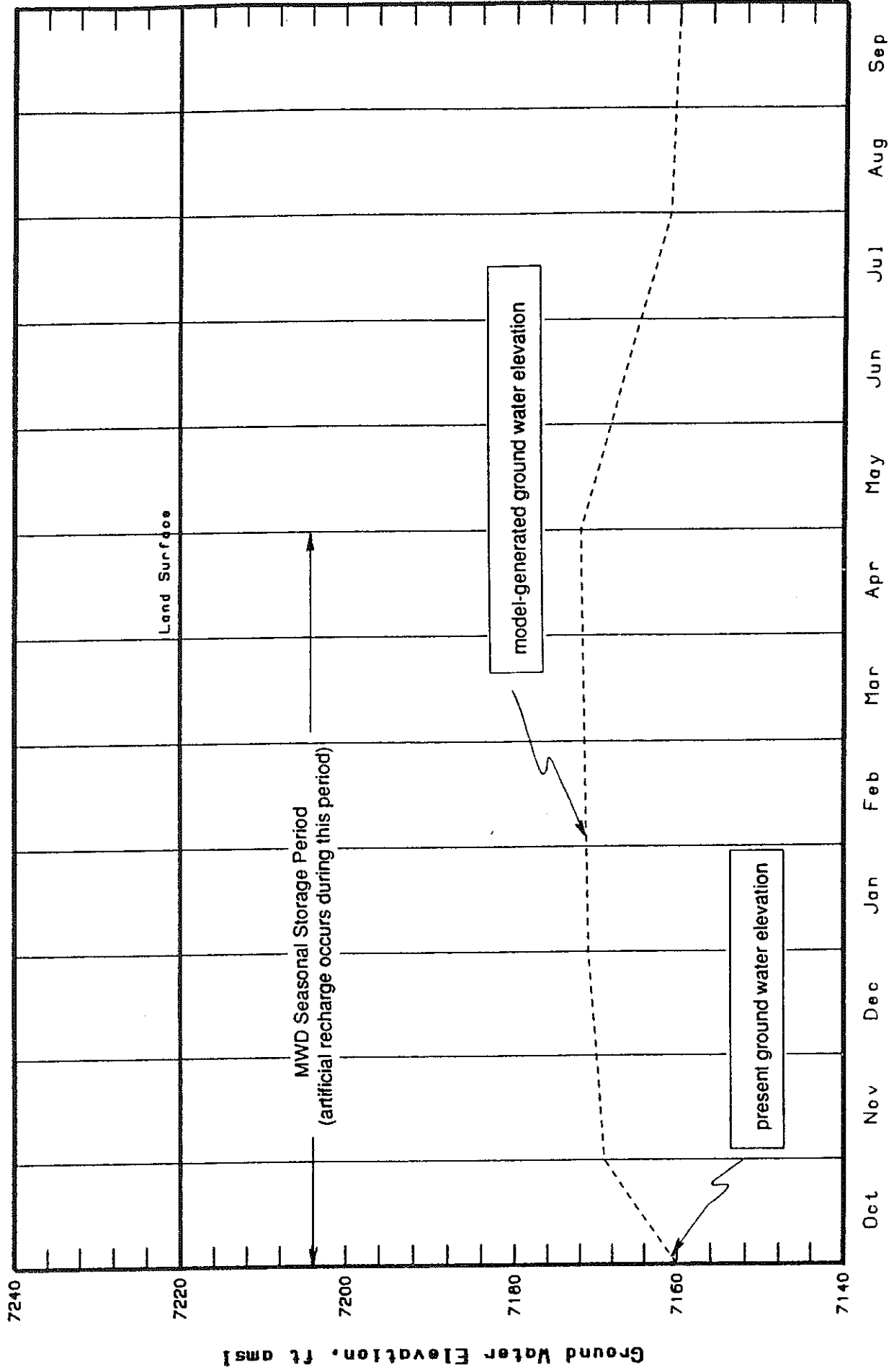


Time in Months

CITY OF BIG BEAR LAKE DWP - Sand Canyon Model

Hydrograph of Model Node (1,j): 34.45

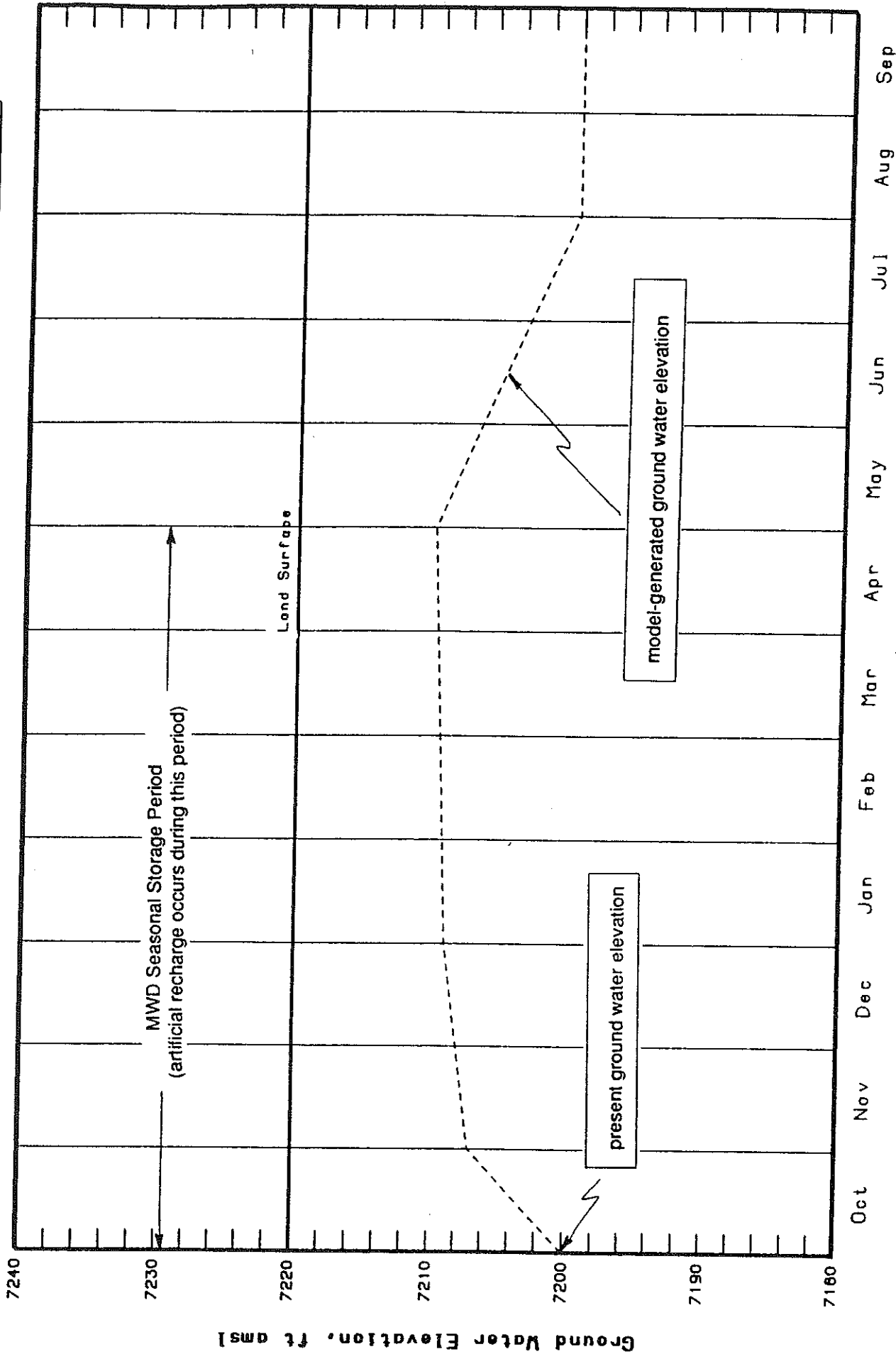
WEST OF WELL TH-1



CITY OF BIG BEAR LAKE DWP - Sand Canyon Model

Hydrograph of Model Node (1,j): 35.48

NEAR WELL TH-1



Time in Months

City of Big Bear Lake
Department of Water and Power

**Supplemental Report on the Proposed
Sand Canyon Artificial Recharge Project
with Recovery Wells Pumping 1,500 Acre-ft/yr**

April 1991

GEOSCIENCE Support Services Inc.
1164 North Padua Avenue, Suite 4
P.O. Box 220, Claremont, CA 91711
(714) 920-0707

April 5, 1991

Mr. Michael Perry
General Manager
City of Big Bear Lake
Department of Water and Power
41972 Garstin Drive
P.O. Box 1929
Big Bear Lake, CA 92315

re: Sand Canyon Artificial Recharge Project

Dear Michael:

This letter is a supplemental report on the proposed Sand Canyon artificial recharge project. The report summarizes changes requested by you and Mr. David Argo of Black and Veatch concerning extraction well recovery rates.

The sand canyon ground water model was re-run with a combined total extraction from the recovery wells of 1,500 acre-ft/yr. This complies with the 50% blend of recharged and natural waters required by DHS.

Results show that at the end of the seven-month recharge cycle, regional drawdowns in the vicinity of the well field (e.g. at TH-4) increase from approximately 6 ft (see Figure 6 in the original report) to 10 ft (Figure 6a - this report). In the 1,500 acre-ft/yr pumping scenario, the *zero drawdown contour* also shifts approximately 250 ft to the southeast reflecting the higher pumping rates.

At the end of the 12-month period, drawdowns increase from approximately 7 ft (see Figure 7 in the original report) to approximately 11 ft (Figure 7a - this report).

Sand Canyon Artificial Recharge Project - Revision

Examination of the key node hydrographs (Appendix D - this report) shows that the 1,500 acre-ft/yr pumping scenario is stable and reaches equilibrium conditions. Recharge to the well field is supplied by both artificial recharge in Sand Canyon and natural recharge from Sand and Bow canyons.

If you require further information or interpretation of these revisions please call at your convenience.

Sincerely,

A handwritten signature in black ink, appearing to read 'D Williams', with a long horizontal flourish extending to the right.

Dennis E. Williams, Ph.D.
President

DEW:mw

Revised Figures

6a and 7a

Figure 6a

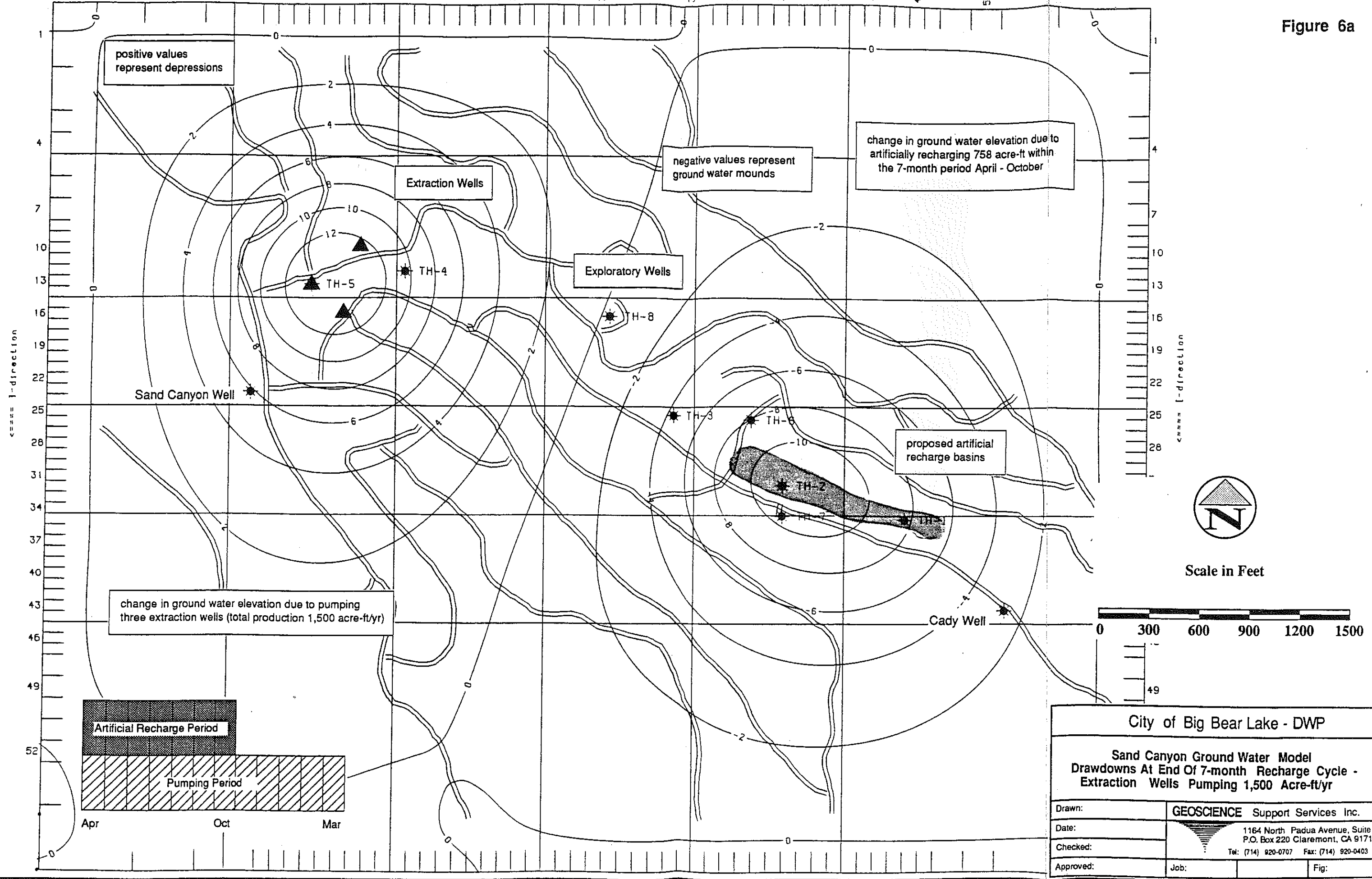
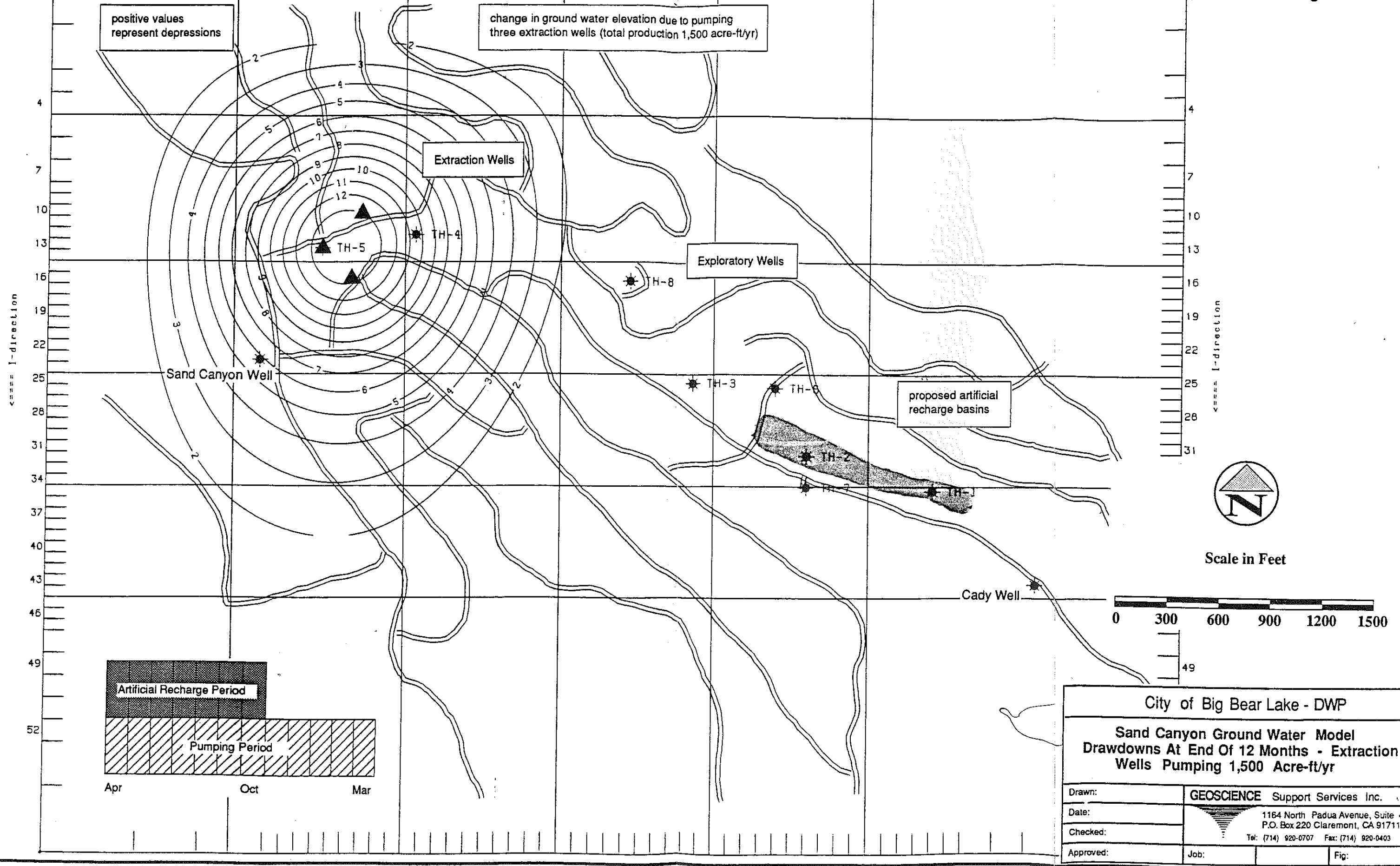


Figure 7a



Revised Table 6A

Table 6A - Summary of Sand Canyon Ground Water Model Pumping and Recharge

Pumping Nodes

Model Node (i,j)	Period	Amount [acre-ft/yr]
(10,11)	Apr-Mar	500
(13,8)	Apr-Mar	500
(16,10)	Apr-Mar	500
Total		1500 Acre-ft/yr*

Artificial Recharge Nodes

Mode Node (i,j)	Period	Amount [acre-ft/yr]
(29,37)	Apr-Oct	46.7
(30,37)	Apr-Oct	46.7
(30,38)	Apr-Oct	46.7
(30,39)	Apr-Oct	40.8
(31,38)	Apr-Oct	46.7
(31,39)	Apr-Oct	40.8
(31,40)	Apr-Oct	40.8
(32,40)	Apr-Oct	40.8
(32,41)	Apr-Oct	40.8
(32,42)	Apr-Oct	40.8
(33,42)	Apr-Oct	40.8
(33,43)	Apr-Oct	40.8
(34,44)	Apr-Oct	40.8
(34,45)	Apr-Oct	40.8
(34,46)	Apr-Oct	40.8
(35,47)	Apr-Oct	40.8
(35,48)	Apr-Oct	40.8
(36,49)	Apr-Oct	40.8
Total		758 Acre-ft/yr

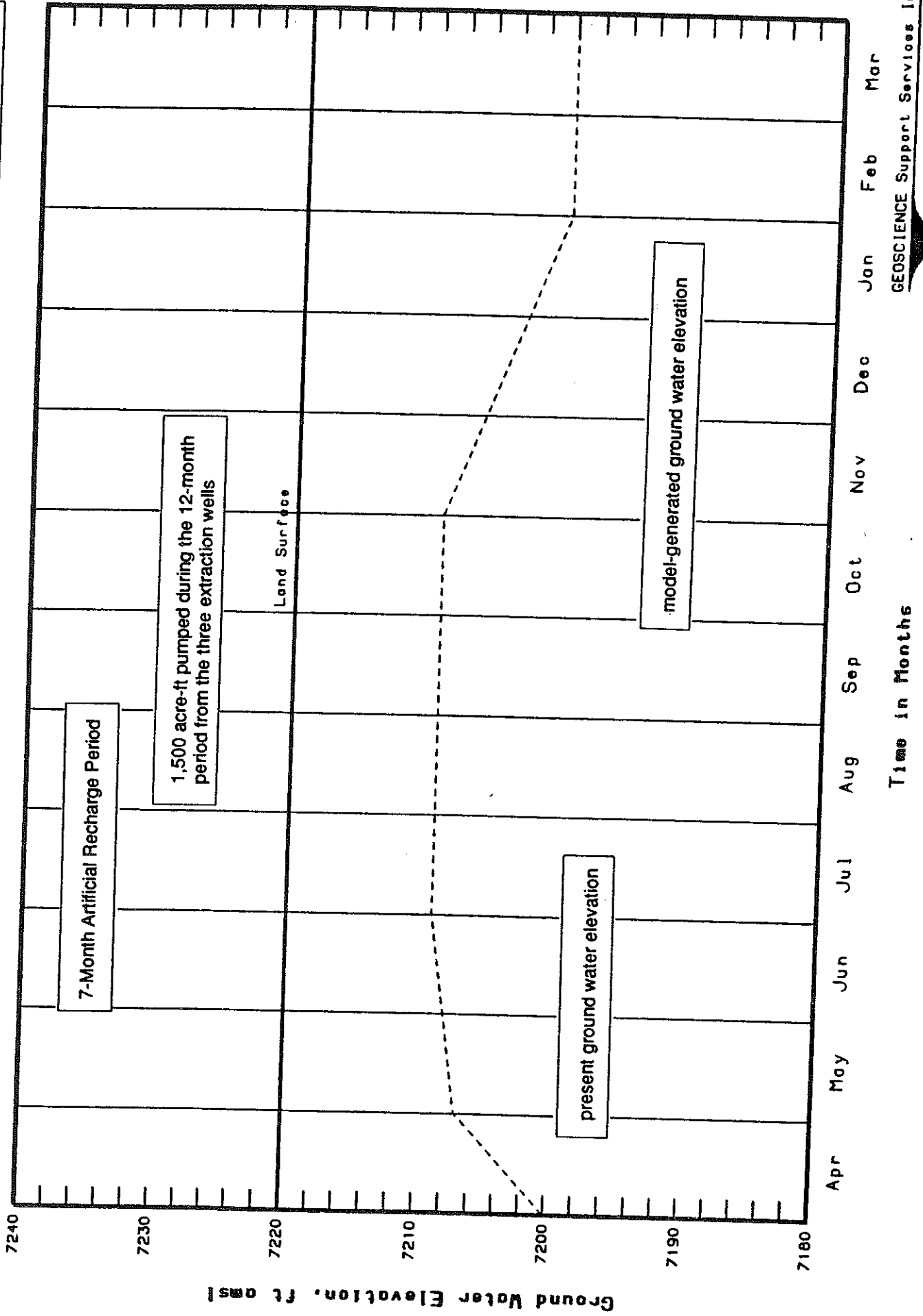
*Annual pumping exceeds annual recharge as the extraction wells also receive natural recharge from the Bow Canyon area.

Revised Appendix D

CITY OF BIG BEAR LAKE DWP - Sand Canyon Model

Hydrograph of Model Node (1,j): 35.48

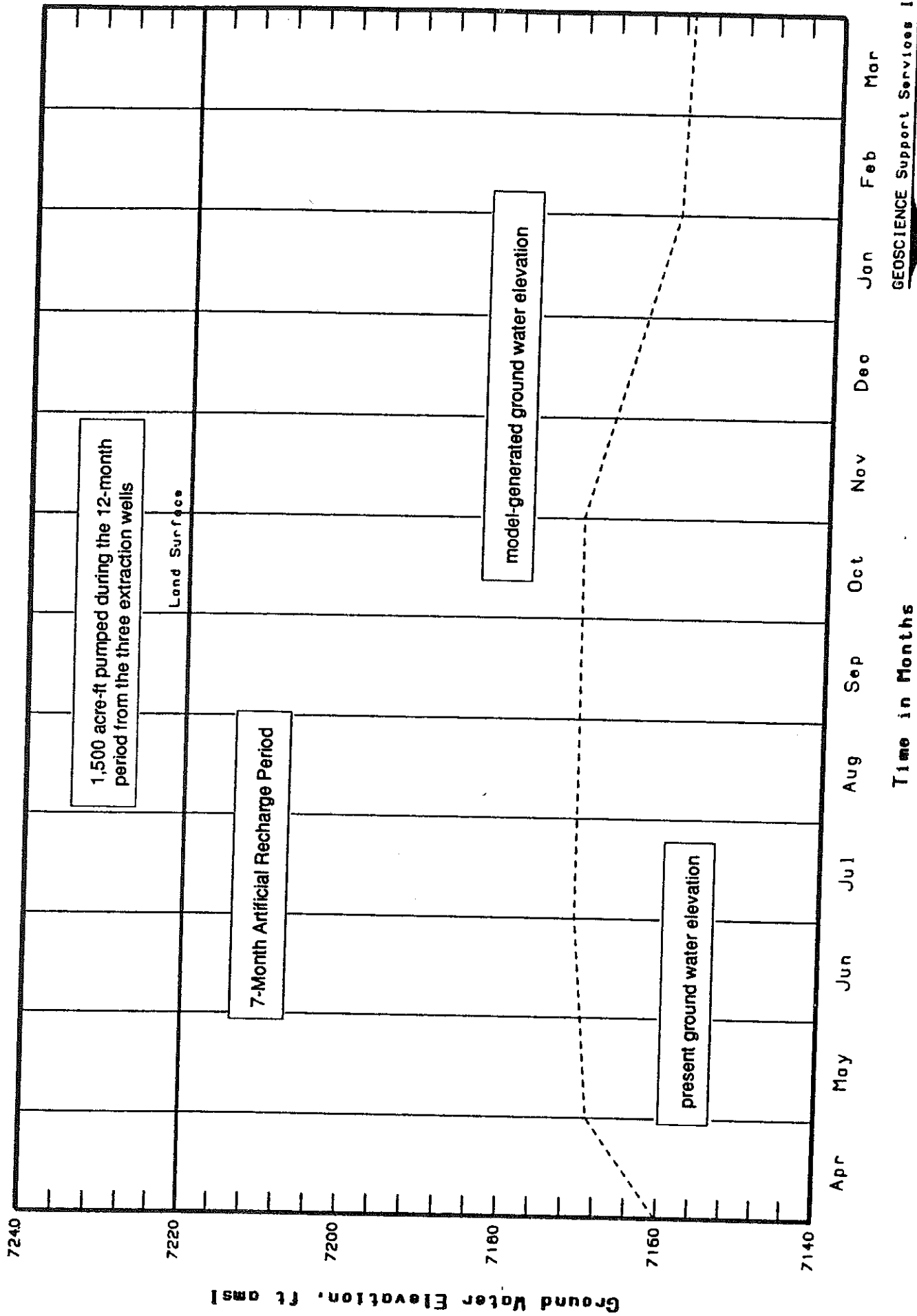
NEAR WELL TH-1



CITY OF BIG BEAR LAKE DWP - Sand Canyon Model

Hydrograph of Model Node (1.J): 34.45

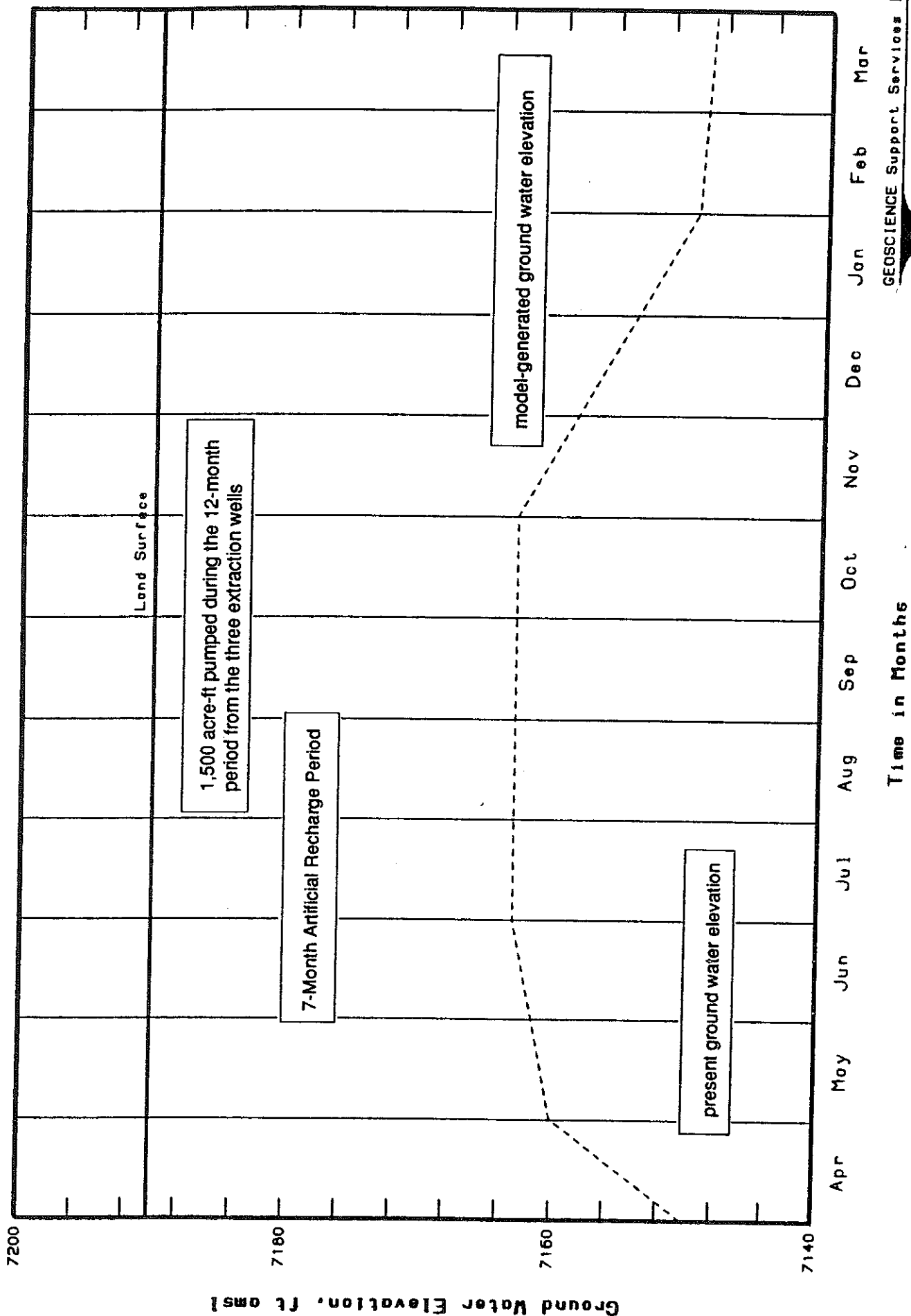
WEST OF WELL TH-1



CITY OF BIG BEAR LAKE DWP - Sand Canyon Model

Hydrograph of Model Node (1.j): 32.40

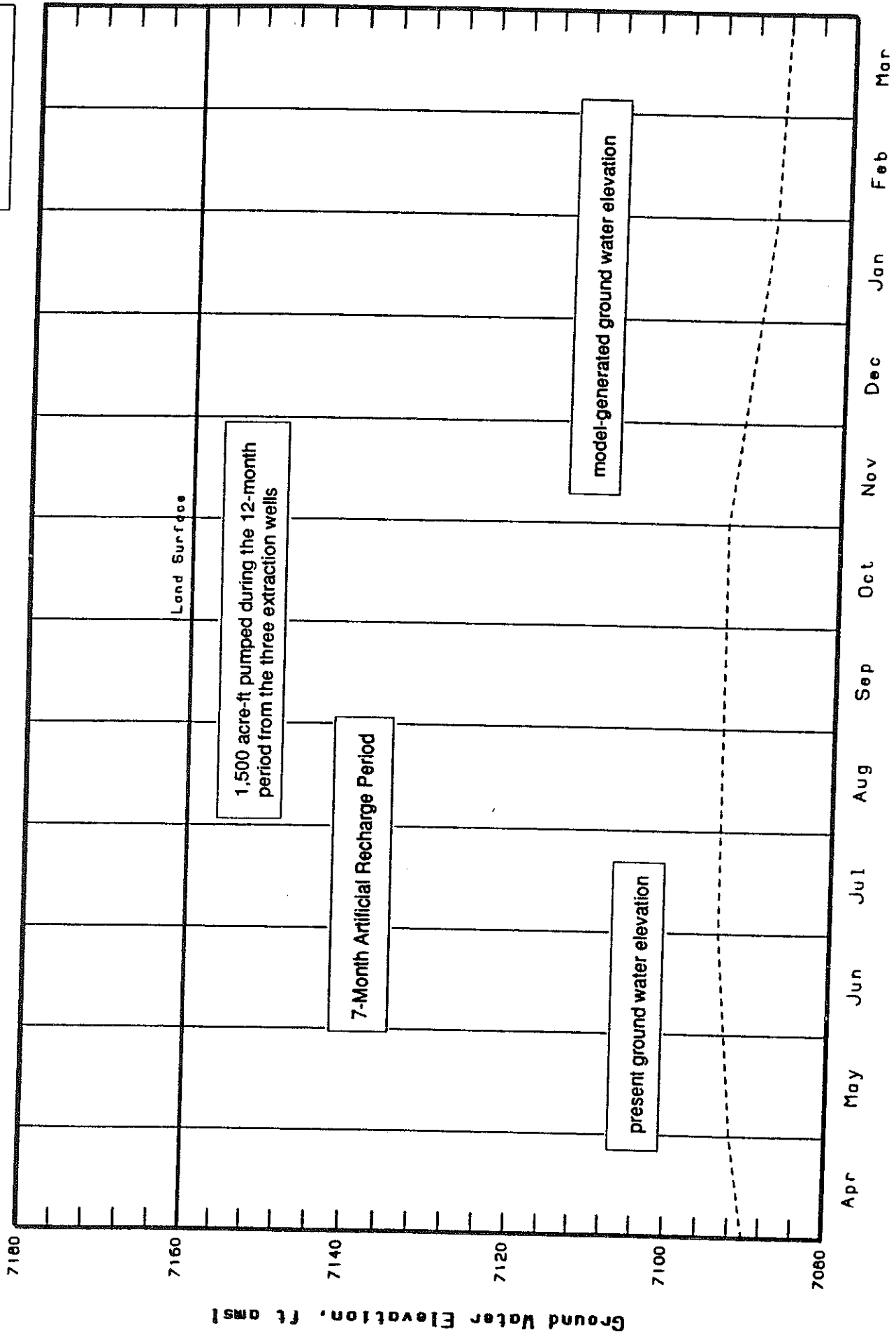
NEAR WELL TH-2



CITY OF BIG BEAR LAKE DWP - Sand Canyon Model

Hydrograph of Model Node (1.j): 25.32

NEAR WELL TH-3



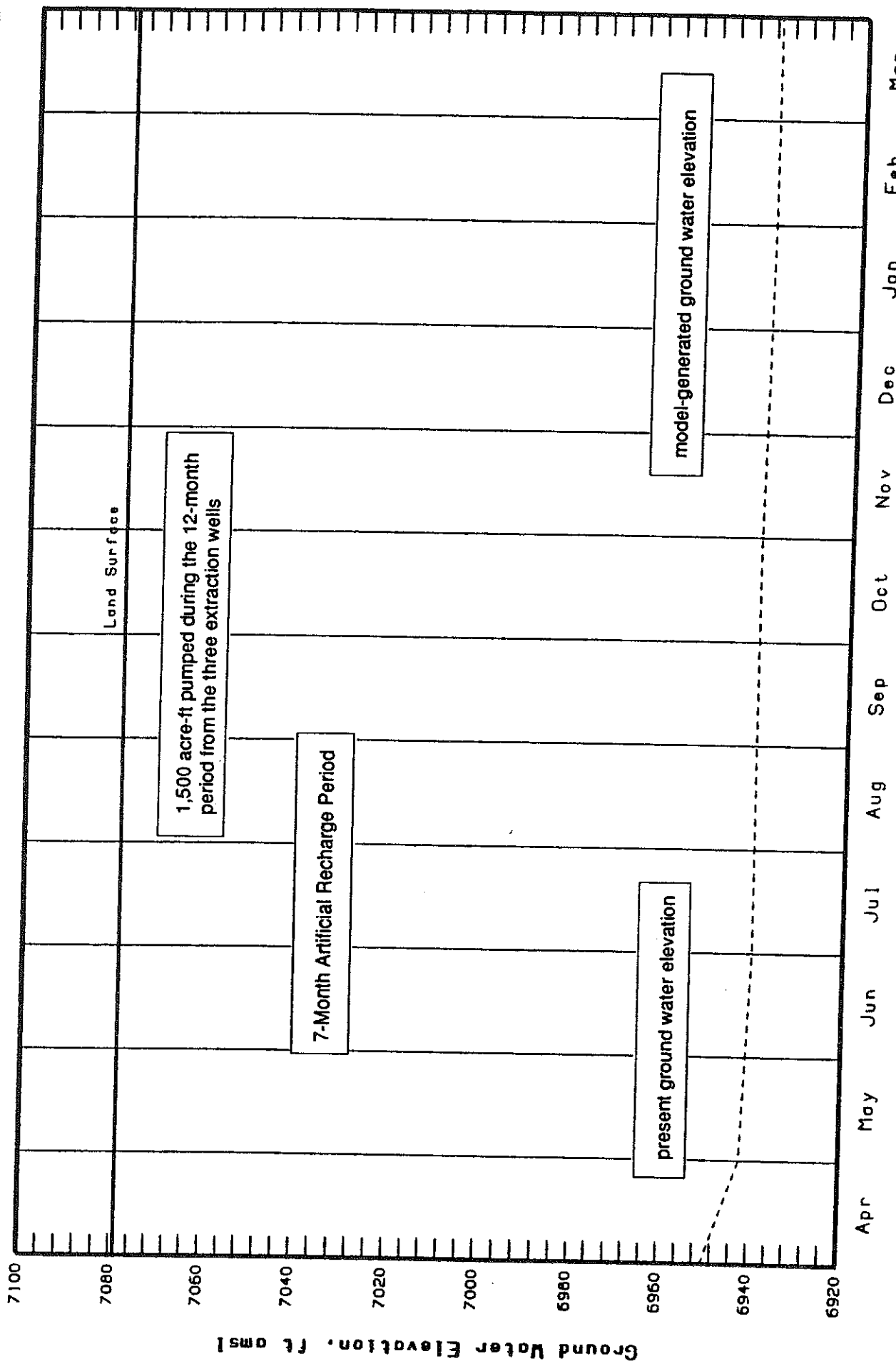
Time in Months

GEOSCIENCE Support Services Inc.

CITY OF BIG BEAR LAKE DWP - Sand Canyon Model

Hydrograph of Model Node (1.j): 12.14

NEAR WELL TH - 4



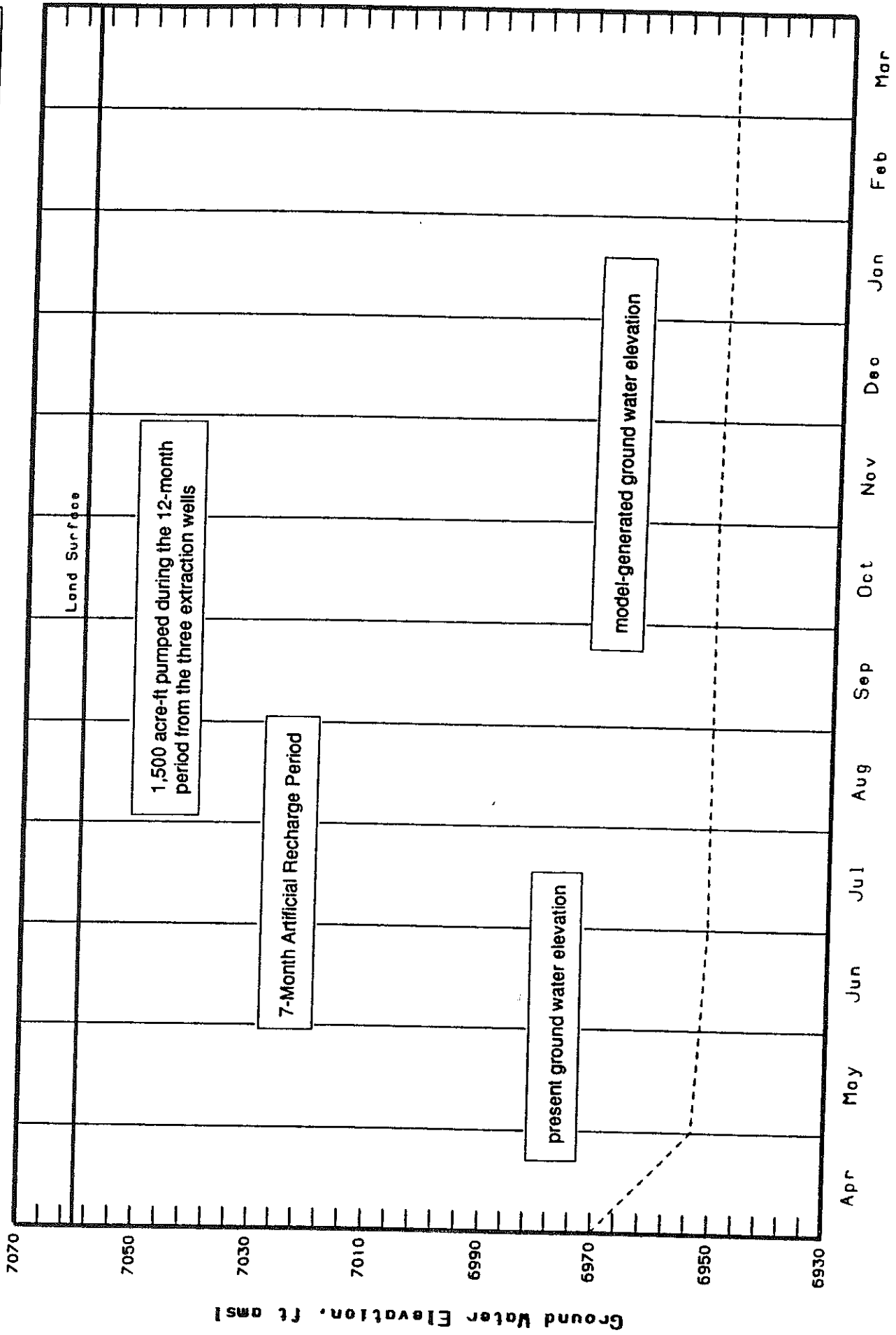
Time in Months

GEOSCIENCE Support Services Inc.

CITY OF BIG BEAR LAKE DWP - Sand Canyon Model

Hydrograph of Model Node (1,j): 13.8

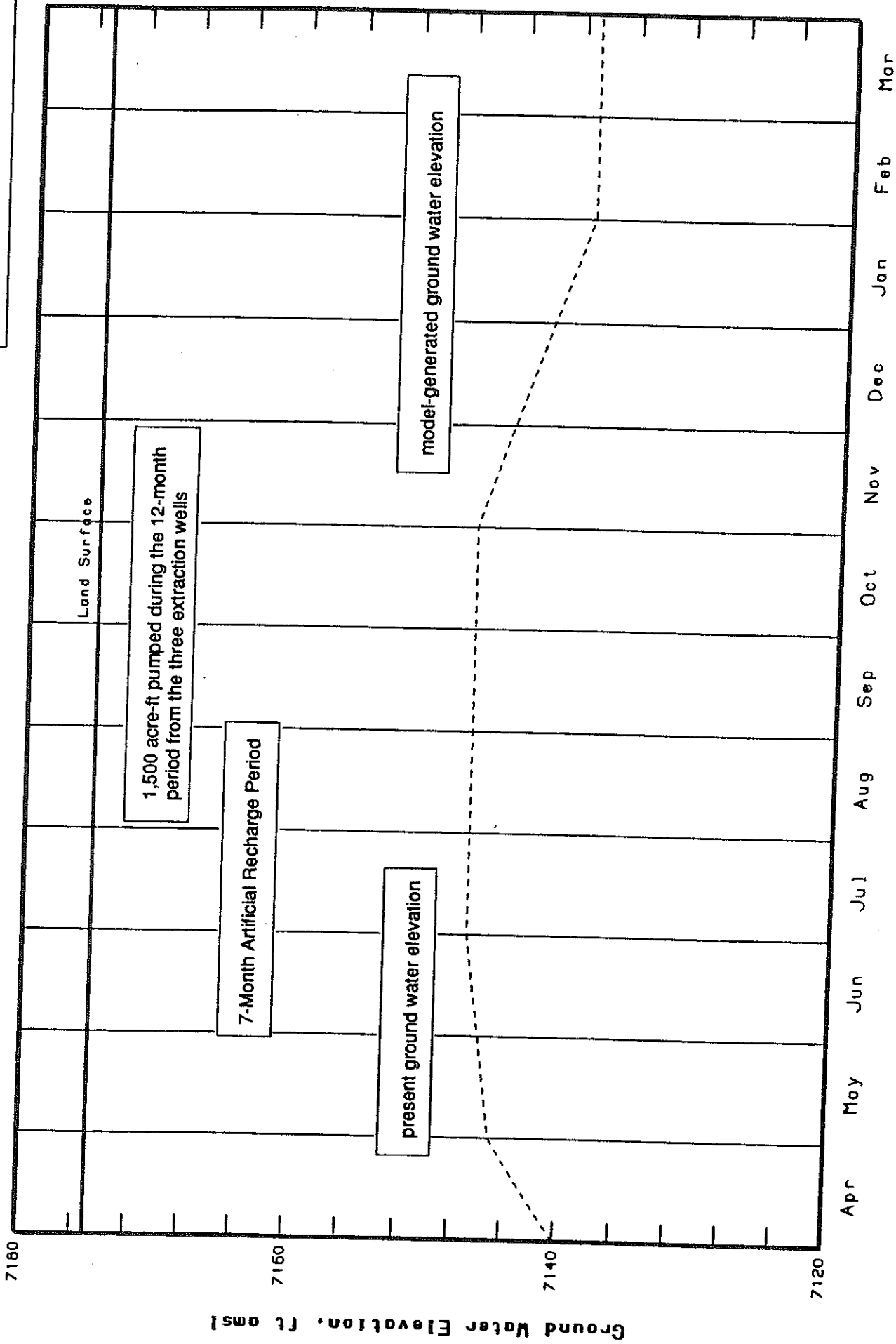
NEAR WELL TH - 5



CITY OF BIG BEAR LAKE DWP - Sand Canyon Model

Hydrograph of Model Node (1.j): 28,35

IMMEDIATELY WEST OF TETON RD.



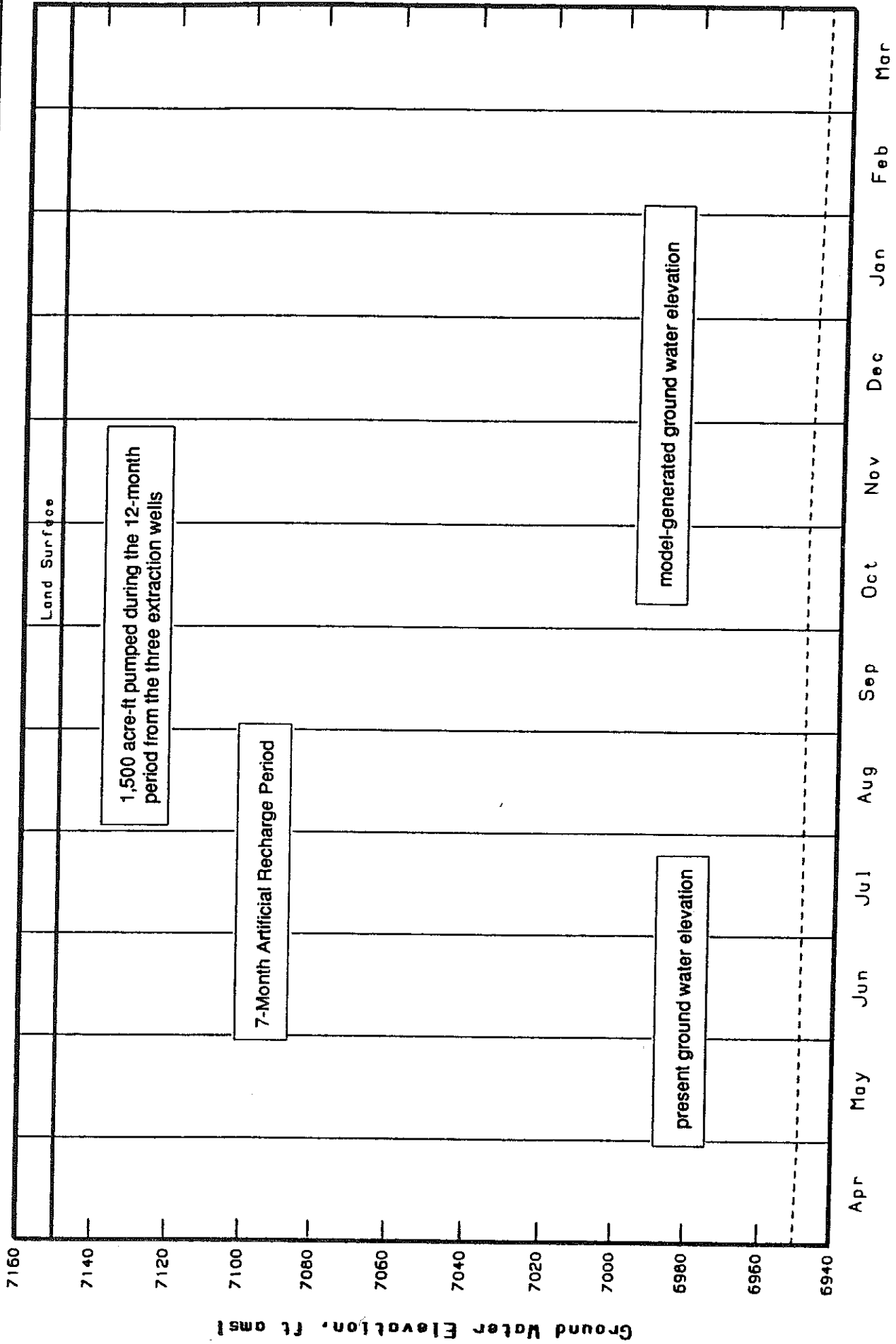
Time in Months

GEOSCIENCE Support Services Inc

CITY OF BIG BEAR LAKE DWP - Sand Canyon Model

Hydrograph of Model Node (1,j): 19.24

HALFWAY BETWEEN RECHARGE PONDS
AND EXTRACTION WELLS



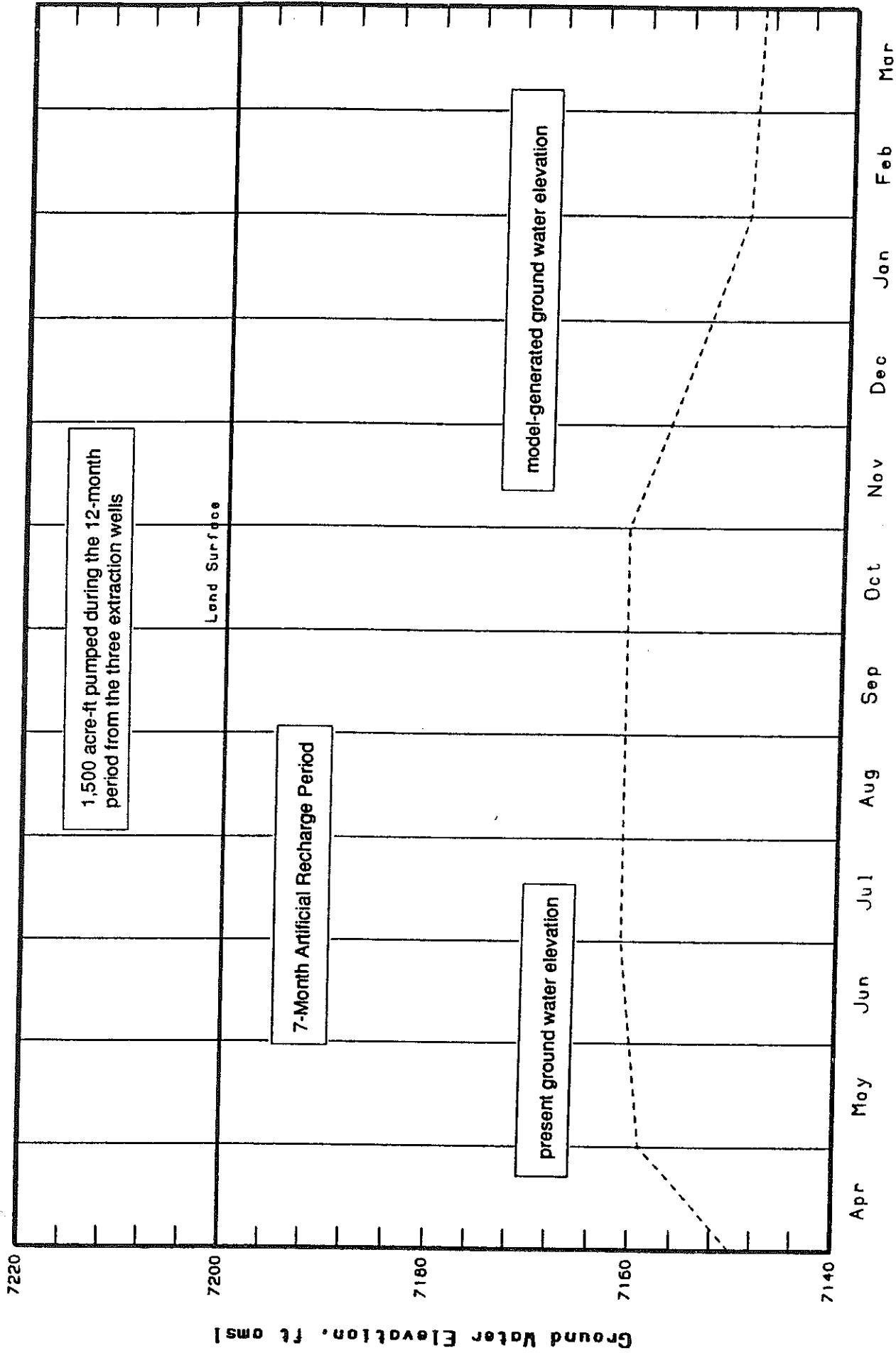
Time in Months

GEOSCIENCE Support Services Inc.

CITY OF BIG BEAR LAKE DWP - Sand Canyon Model

Hydrograph of Model Node (i,j): 29.38

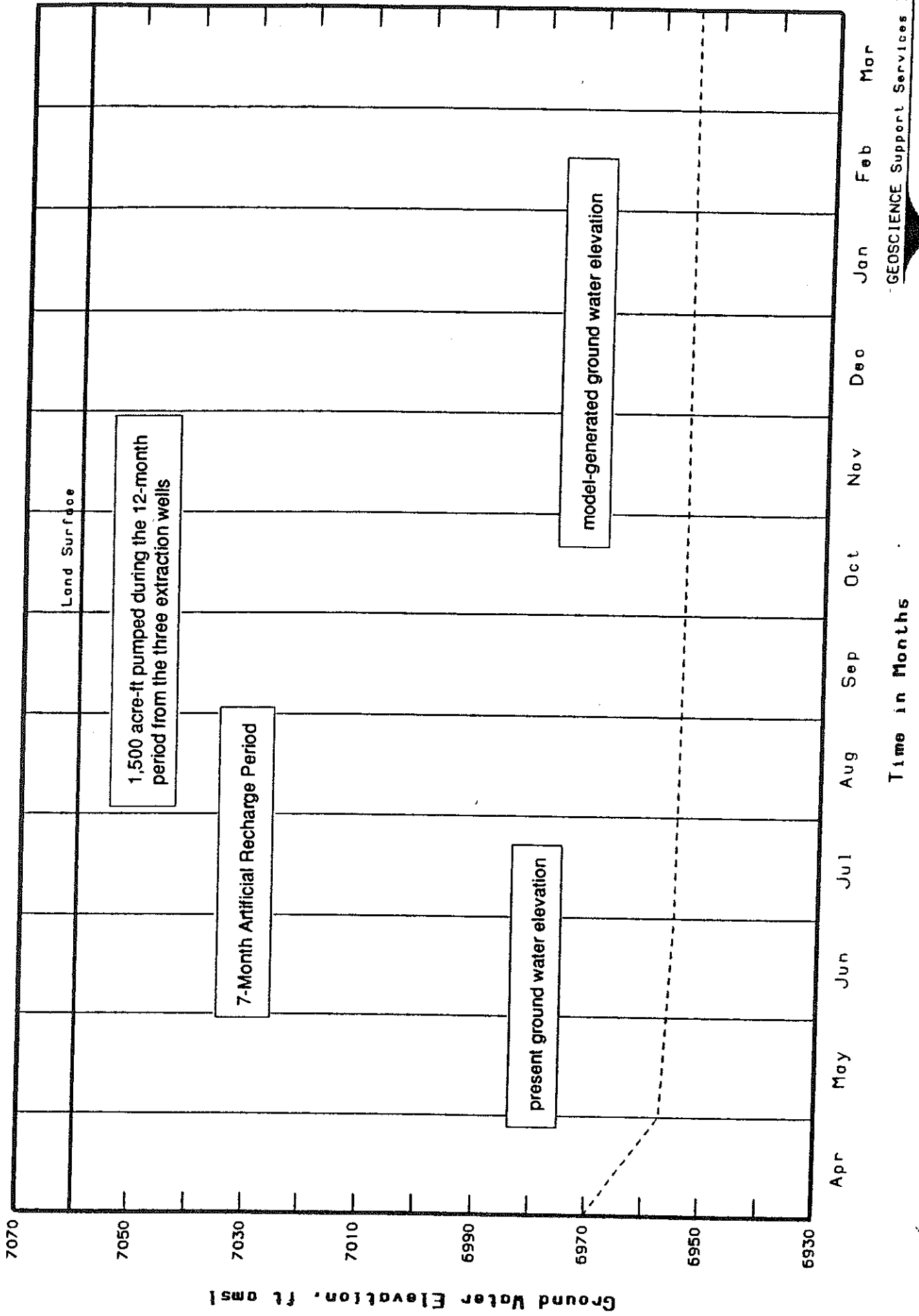
NEAR WELL TH - 6



CITY OF BIG BEAR LAKE DWP - Sand Canyon Model

Hydrograph of Model Node (i,j): 13,10

MIDDLE OF EXTRACTION FIELD



References

1. NBS/Lowry, "Current Wastewater Reuse Opportunities in Big Bear Valley Area," November 1989.
2. NBS/Lowry, "Status Report on the Phase II Reuse Study," April 1990.
3. Black & Veatch, "Preliminary Feasibility Study for Wastewater Reuse for the Department of Water and Power, City of Big Bear Lake," April 1990.
4. T. W. Dibblee, Jr., "Geologic Map of the San Geronio Mountain Quadrangle, San Bernardino and Riverside Counties, California, Map I-431 U.S. Geological Survey, Washington DC, 1964.
5. Masch-Denny, Masch-Denny Prediction Curves, Water Resources Research, Volume 2, Number 4, Fourth Quarter, 1966.
6. D. A. Morris and A. I. Johnson, Summary of Hydrologic and Physical Properties of Rock and Soil Materials as Analyzed by the Hydrologic Laboratories of the U.S. Geological Survey, 1948-1960, Geological Survey Water Supply Paper 1839-D, 1967.
7. W. H. Green and G. A. Ampt, Studies on Soil Physics. I. The Flow of Air and Water Through Soils, J. Agric. Sci. 4:1-24, 1911.
8. J. R. Philip, Advances in Hydrosience, V. T. Chow (ed.), Academic Press, Inc., New York, 1969.
9. David Keith Todd, Groundwater Hydrology, Second Edition, John Wiley and Sons, Inc., 1980.
10. The Roscoe Moss Company, Handbook of Groundwater Development, John Wiley and Sons, Inc., 1990.