Division of Geological & Geophysical Surveys

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ANALYSIS OF POTABLE WATER-SUPPLY OPTIONS GAMBELL, ALASKA

by

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in cooperation with
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Department of Environmental Conservation,
and
City of Gambell

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APPENDIX

ANALYSIS OF POTABLE WATER-SUPPLY OPTIONS FOR GAMBELL, ALASKA

by
James A. Munter[1] and Jerry Williams[2]

INTRODUCTION

The City of Gambell, located on the northwest tip of St. Lawrence Island in the Bering Sea, is planning a piped water system to serve the entire city of 500 to 600 residents. A limited piped-water system currently serves twelve residences. This system obtains fresh water from a shallow infiltration gallery during the summer and brackish water from a lake (Troutman Lake) during the winter. Although water from the lake is not potable and actively corrodes pipes, hot water heaters, and other fixtures, the city plans to use it as a winter source for the entire city because no other known sources are considered economically developable for year round use.
The Alaska Hydrologic Survey (AHS), under a letter of agreement with Chuck Eggener Consulting Engineers, through Alaska's Village Safe Water Program has agreed to evaluate potential potable water sources (if any) sufficient to meet the City of Gambell's water needs and recommend methods of developing the sources, including, if applicable, additional investigative techniques to further define the limits of fresh water and possible methods of capture.

These tasks were performed during May and June, 1992, and are reported on in this report. Also included in this report, as an appendix, are the results of a direct-current resistivity survey performed at Gambell June 18-20, 1992, by the coauthor.

The scope of this evaluation was limited to reviewing information assembled from various agency files, published reports, and local observations relayed by Chuck Eggener Consulting Engineers. Although an adequate potable water supply has been previously identified approximately 2 mi south of the City, the absence of electric power to the site and projected water line costs have caused it to be judged uneconomical to develop. An existing infiltration gallery used by the City during summer months was the focus of this investigation because the aquifer at the site could probably be tapped with a relatively simple and inexpensive gravity feed system to the City.

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GEOLOGIC SETTING

Gambell is situated on a gravel spit on the northwest tip of St. Lawrence Island. Troutman Lake, located immediately south of the City, is separated from the Bering Sea by a narrow gravel spit. The level of the lake is about 4 ft above sea level, and the lake is fed by Troutman Creek, a fresh water stream at its south end. Storm surges are reported to break over the spit periodically and cause the lake water to be brackish. The lake has no surface water outlet.

Sevuokuk Mountain lies about 1 mi east of the City and the lake, rising to an elevation of 614 ft above sea level. The mountain is comprised predominantly of quartz monzonite, a granitic rock type. Permafrost is discontinuous throughout the area, and is commonly found at depths of 7-10 ft (RZA, Inc, 1985). Annual precipitation at Gambell is about 16 inches (Phil Johnson Engineering, 1972a).

GROUND-WATER OCCURRENCE

Both fresh and brackish ground water has been found by several wells drilled in Gambell (Waller, 1959; RZA, Inc., 1985). Waller (1959) suggested that Troutman Lake probably discharges via ground water to the north. Shallow ground water beneath Gambell does not appear to be continuous because of the presence of shallow permafrost in some areas.

Although no wells are known to be drilled into the quartz monzonite of Sevuokuk Mountain, the rocks are reported to have well-developed vertical joints and would probably support yields of up to about 10 gallons per minute (gpm).

The present infiltration gallery is located about 2000 ft from the City of Gambell at the base of Sevuokuk Mountain at an elevation of about 90 ft. Although design drawings of the structure are available, no as-built diagrams have been found and the current size, depth, and structure of the gallery are uncertain. The gallery was probably constructed during the late 1970's. Peak historic production from the gallery was during September, 1991, when 712,000 gallons (an average of 16.5 gpm) of water were reportedly produced.

Three wells drilled at the gallery can be used to characterize subsurface conditions. Two of the wells penetrated silty surficial soils overlying a gravel aquifer up to 7 ft thick. The base of the aquifer is ten feet deep in one well and fourteen ft deep in the other well. The aquifer is underlain by frozen interbedded sands, silts, and gravels up to about 78 ft thick. The frozen sediments are underlain by a sand and gravel aquifer that yields brackish water. The shallow aquifer is confined by overlying soils, with a potentiometric surface at the land surface. Two of the three test wells had reported yields of 5-10 gpm. Reports from local residents indicate that ground-water seepages are observable near the infiltration gallery and elsewhere along the base of Sevuokuk Mountain, even during winter months.

Numerous monitoring wells have been drilled at Gambell to investigate possible ground-water contamination (RZA, Inc., 1985). Three wells drilled about 2000 ft northeast of the infiltration gallery penetrated 12 ft of saturated "fine gravelly medium sand" overlying colluvial rock fragments at a depth of 16.5 ft. Although not tested for yield, these permeable sediments could potentially be a year-round source of water.

Ott Water Engineers (1985) conducted water supply investigations near Troutman Creek located about 2 mi south of Gambell. They discovered a potable water source capable of yielding 75 gpm from an aquifer at a depth of 21-24 ft. As a result of the low elevation of this aquifer, a pumping station would be required to move the water from this site to Gambell through a water main. Further testing of this aquifer during April, 1986, (CRW Engineering Group, 1986; Appendix C) showed that the static water level had declined 17 ft during the previous six months and that the probable sustainable yield was 40 to 50 gpm.

WATER DEMAND

Limited records from the city of Gambell show that twelve homes hooked up to the current water source use an average of 122 gallons per day per home. Total near-future water demand is projected to reach approximately 16,000 gallons per day (11 gallons per minute), assuming: 1) consumption of 140 gallons per day per home, 2) hookup of an additional 67 homes, and 3) consumption of approximately 4500 gallons per day for other municipal uses.

WATER-SUPPLY OPTIONS

Near-term potable water-supply options open to the City of Gambell appear to be:

1. Truck water from Troutman Creek on a regular or as-needed basis;

2. Desalinate Troutman Lake water through reverse osmosis or some other suitable technology;

3. Attempt to construct shallow wells or infiltration galleries beneath the City to tap the shallow aquifer;

4. Attempt to rehabilitate the existing infiltration gallery and water main to the City to increase yield and provide year-round service;

5. Attempt to locate and develop additional sites for infiltration gallery development along the base of Sevuokuk Mountain north or south of the existing gallery.

Phil Johnson Engineering (1972b; 1972c) evaluated potential groundwater sources beneath Gambell and concluded that a fresh water aquifer located east of the current (1972) village well provided a good prospect for further exploration. Subsequent work by RZA Inc. (1985) in this area revealed the presence of ice-rich permafrost at depths of 8-11 beneath a few feet of saturated sands and gravels. Drilling of these holes was conducted during August, 1985. Much of this water probably freezes during the winter.

CRW Engineering Group (1986, Appendix B) also evaluated this aquifer and noted that previous drilling attempts were not successful. Nevertheless, this area still merits attention as a possible ground water source because of the possible presence of a perennially thawed aquifer containing potable water. This fresh water would be locally recharged precipitation and water discharging from the slopes of Sevuokuk Mountain, possibly mixed with water from Troutman Lake. Water source development in this area could be affected by local sources of contamination, if any.
Electrical resistivity or shallow seismic refraction surveying would probably be the most effective means of evaluating the shallow aquifer. Fresh water in this area, at least seasonally, could be obtained through shallow drilled or dug wells, drive points, or infiltration galleries.

Another potential long-term, low cost, source of potable water for the City is option 4 above. If option 4 is successful, additional water might be obtainable through option 5. The existing infiltration gallery appears to occupy the most favorable basin near Gambell for attempting development of a year-round potable water source.

Examination of the infiltration gallery option includes a basin analysis of potential annual water availability, an evaluation of methods to tap the aquifer, and a discussion of the probable size and configuration of the aquifer.

Both 1:1200 and 1:2400 scale topographic maps with contour intervals of 2 ft and 5 ft, respectively, are available for the area around the infiltration gallery. These maps indicate that the current infiltration gallery occupies a subtle basin-like feature near the base of Sevuokuk Mountain. The maximum size of the basin supplying the infiltration gallery is about 70 acres. As a result of limited plant activity in the area, permeable soils, and high relative humidity much of the year, it is reasonable to assume that annual recharge to the ground-water system, could total about 1 ft per year. Although Ott Water Engineers (1985) used 4 in. per year for their water budget analysis, they misquoted Feulner (1980) in supporting that figure. For St. Paul Island, Feulner (1980) stated that "losses of moisture through evaporation and transpiration are probably small, and most of the water falling as precipitation probably penetrates to the water table."

Using 1 ft per year, calculated recharge to the basin is 70 acre-ft per year, or an average of about 40 gpm. Of this amount, some is probably lost to deeper flow systems through fractures in the granitic rocks, some would likely bypass an infiltration gallery or well, and the rest is potentially available for capture. Initially, it is estimated that about half of the total ground water could be captured with an infiltration gallery. This amount, 20 gpm, compares favorably to the projected average demand of 11 gpm. Seasonal fluctuations in actual water availability are likely, however, suggesting that flows from this basin may need to be supplemented with water from other sources during winter months.

Considering available well logs for the area of the infiltration gallery and local land slopes and rock outcrop patterns, the area of land underlain by the target aquifer is probably no larger than about 7 acres. This aquifer is probably not tapped efficiently by the existing infiltration gallery as evidenced by the observations of water levels at the land surface in test wells and seeps near the gallery.

The simplest long-term potable water-supply development option for Gambell would be to construct a gravity-flow system that operates year round. Although the year-round operation of such a system cannot be assured, existing evidence suggests that the aquifer at the extraction site is not seasonally frozen, making it feasible to investigate. A gravity-flow system would yield the most water if aquifer drawdowns could be maximized. This could be done by constructing an infiltration well finished near the lowest point of the aquifer with a water main connection at the well bottom leading to the city storage tanks. Unfortunately, the location of the lowest point of the aquifer is not known. To solve this problem, a field exploration program could be initiated. Geophysical techniques such as electrical resistivity mapping or profiling or seismic refraction surveying could be used to delineate aquifer boundaries and determine low-elevation areas suitable for tapping. Further test drilling could also be done to define the limits of the aquifer.

Alternatively, the location of the lowest point could be assumed to be close to test well 2, where the bottom of the aquifer is known to exist at a depth of 14 ft. Given the difficulty of excavating below 14 ft in saturated granular materials, the latter alternative may be the most viable one.

SUGGESTIONS FOR AQUIFER DEVELOPMENT

The need for laterals from the central part of the infiltration well is questionable. The primary limitation to water availability at this site is more likely to be the small size and climatic setting of the basin, rather than the size of the intake structure.

The aquifer bail-down test data from the test wells indicate that the aquifer is sufficiently permeable to act as a natural drain of the ground-water system if sufficient means can be made to lower water levels. Furthermore, physical disturbance through test pits or lateral installation has the potential to disrupt and impair the aquifer.

Development of the aquifer should include installation of suitable means to control and measure discharge from the water collection system. This would provide useful data for managing future growth in water demand and reduce or eliminate wasteful discharges from the aquifer. In the event that development of the basin is successful, provision should be included in system design to construct additional infiltration wells or galleries that tap adjacent basins or slopes along the mountain front.

Summer flows from the basin could perhaps be augmented by strategic placement of snow fencing to enhance drifting in the basin above the collection structure. The aquifer should be kept as full of water as possible during early fall to maximize water yield during the winter low-flow period.

Finally, water developed from shallow depths from the base of Sevuokuk Mountain will be of short residence time in the ground, and will be vulnerable to contamination from surface activities that may occur on the mountain. Evaluation of risks associated with land-use activities in this area should be included in aquifer development planning.

CONCLUSIONS

A reasonable prospect for year-round potable water-supply development exists within 2000 ft of the City of Gambell at the site of an existing infiltration gallery. Potential warm-season flows over 20 gpm are potentially more than double projected average demand of 11 gpm for a piped-water system for the City of Gambell.

The major problem associated with developing the aquifer for year round use is that flows are not likely to meet City demands during winter months. An example of strong seasonal influence on ground-water in this area is provided by a well near lower Troutman Creek that showed 17 ft of water level decline between October, 1985 and April, 1986. At the site of the infiltration gallery, sustained winter flows are not likely to exceed about 5 gpm. This estimate is based on the reported hydrogeology of the basin, an annualized water budget and typical seasonal climatic variabilities for the region.

A less promising target for further exploration is the shallow aquifer located between the old village well and the base of Sevuokuk Mountain. The aquifer is susceptible to seasonal freezing, contamination, salt-water intrusion, and low yield. Despite these potential problems, the aquifer has not been thoroughly evaluated by field investigations, and may be capable of providing useful quantities of potable water through shallow wells or galleries year-round.

Flow from the aquifer beneath the existing infiltration gallery can be supplemented by use of alternate potable water sources described previously in this report or by mixing potable water with nonpotable brackish water from Troutman Lake. Even if brackish water must be used exclusively for part of the year, corrosion of pipes and fixtures would be lessened by partial use of fresh water.

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APPENDIX A

Resistivity Survey for Ground Water
Village of Gambell, St. Lawrence Island, Alaska

RESISTIVITY SURVEY FOR GROUND WATER

VILLAGE OF GAMBELL, ST. LAWRENCE ISLAND, ALASKA

A direct-current resistivity survey was conducted at 14 locations in Gambell, Alaska. The purpose of the survey was to locate a year-round source of fresh water. Soundings were taken using both Schlumberger and Wenner array configurations at all of the following locations except for location no 9. See Figure 1 for sounding locations.

Sounding No.	Approximate Sounding Location
1, 2, 8	In the vicinity of the existing PHS Infiltration Gallery and VSW emergency gallery.
3, 4	In the watershed south of the existing gallery watershed.
5, 6	In the watershed north of the existing gallery watershed.
10, 11	A gravel area at the base of Sevuokok Mountain in between archaeological sites Ayveghyaget and Mayughaq.
12, 13	North of the Gambell High School on the crest and trough of a relict beach line.
7	In the vicinity of the elementary school well.
9, 14	North of Subdivision A.

Data were reduced in the field to evaluate their quality and provide a rough idea of the subsurface. Modeling of the data was completed in Anchorage using the resistivity modeling program RESIX Plus, published in 1988 by Interplex Limited of Golden, Colorado. RESIX Plus is a forward and inverse modeling program for interpreting resistivity sounding data in terms of a layered earth. Forward modeling calculates a synthetic curve with up to ten layers using linear filters. Direct inversion allows estimation of the layered model and a Ridge regression provides a fit to the curve. Inverse modeling provides a best fit model in a least squares sense through iterative Ridge regressions to adjust the parameters of the starting model. Parameters of the layered model (depth, thickness and resistivity) can be fixed where physical data are available for control. Equivalence analysis allows generation of equivalent or alternative models which fit the data nearly as well as the best fit model and determines the allowable range of each model parameter. The model was not able to resolve the data within the parameters of the model for the Wenner array configurations at locations 13 and 14. Raw data sheets containing apparent resistivities are included for those locations in lieu of model outputs.

The range of a typical apparent resistivities for the materials encountered in this investigation are as follows:

Frozen sediment - $3*10^4$ to $3*10^8$ ohm feet

Brackish sediment - 1 to 3,000 ohm feet

Wet to saturated sediment - 1,000 to $3*10^4$ ohm feet

Wet organics and fine sediment - 300 to 3,000 ohm feet

Dry gravel - 10^4 ohm feet

Saturated rock - $3*10^3$ to $3*10^6$ ohm feet

The wet saturated sediments are interpreted to consist of mostly sand and gravel with some layers of fine grained material. An interpreted lithologic profile was sketched for each array and is shown with the model outputs.

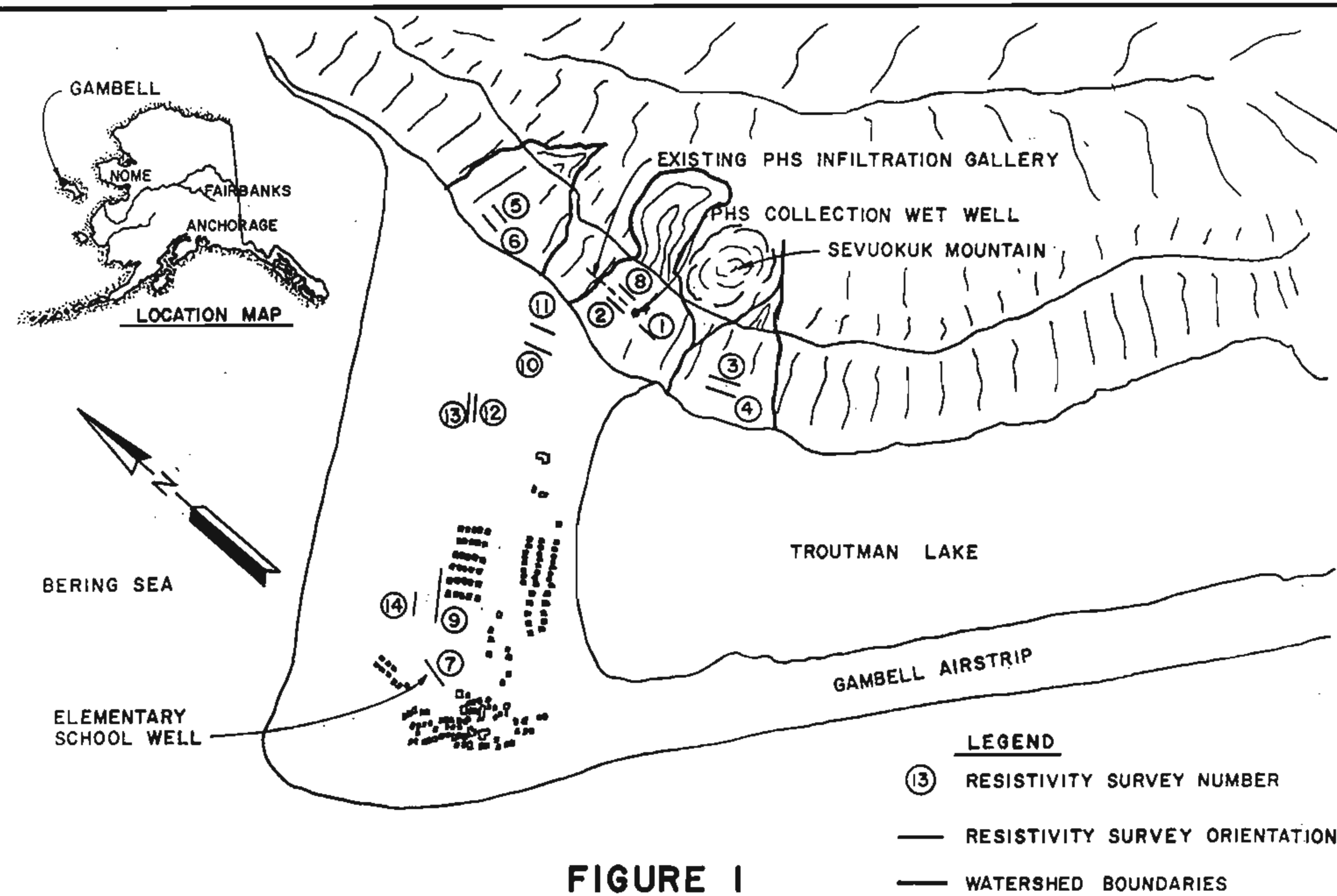
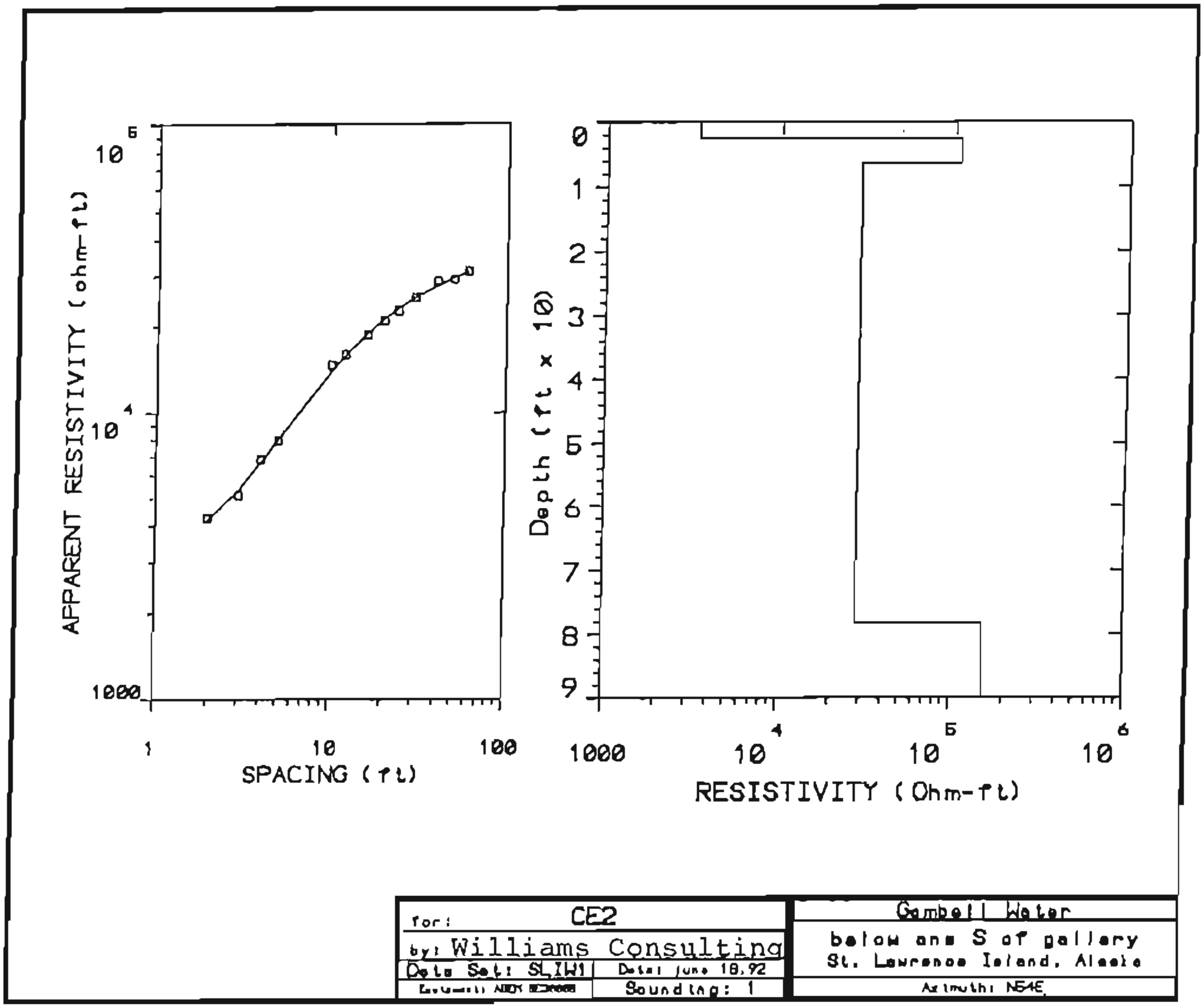


FIGURE I

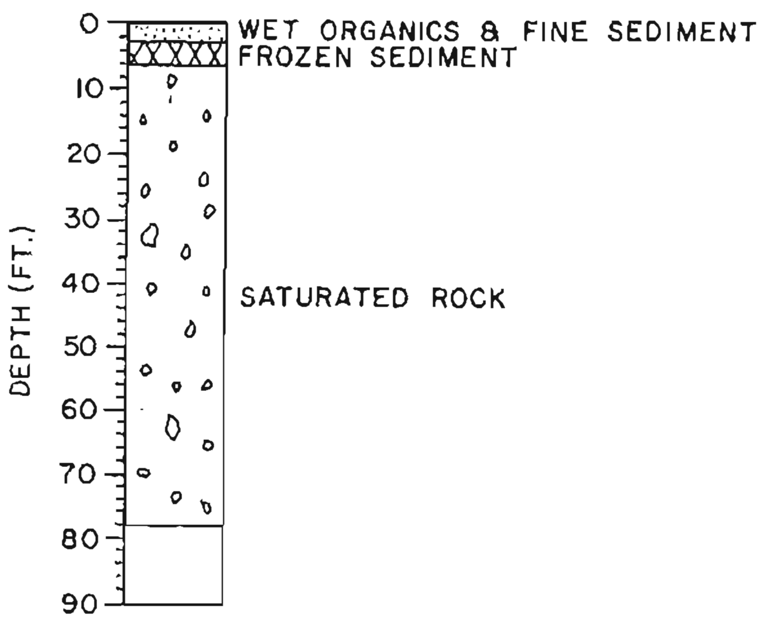
GAMBELL RESISTIVITY SURVEY LOCATIONS

SCALE: 1" ≅ 1575'

NOTE: BASE MAP IS 7-19-80 AERIAL PHOTO

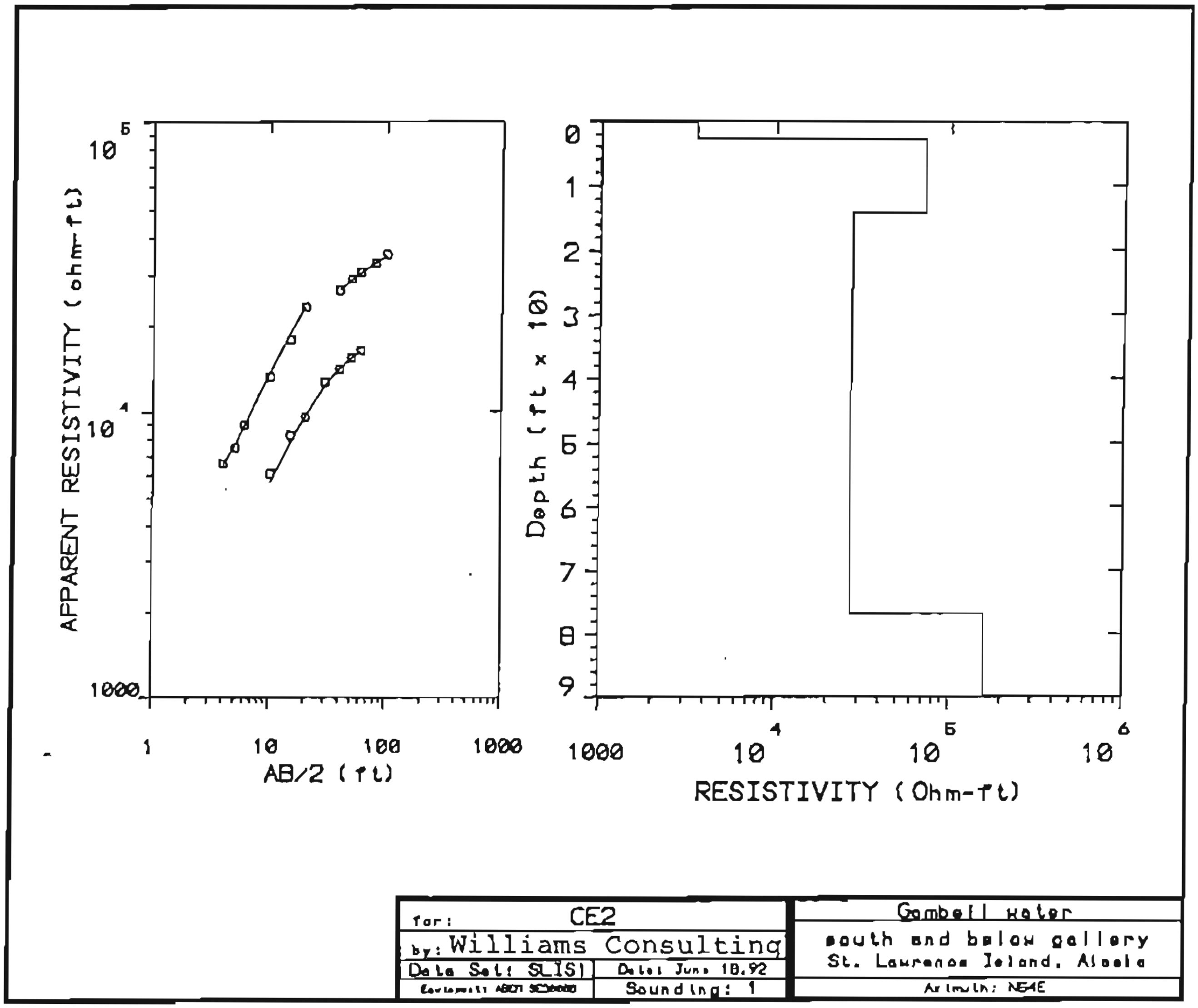


APPARENT RESISTIVITY (ohm-ft)
SPACING (ft)
Depth (ft x 10)
RESISTIVITY (Ohm-ft)
for: CE2
by: Williams Consulting
Data Set: SLIW1
Date: june 18,92
Sounding: 1
Gambell Water
below one S of gallery
St. Lawrence Island, Alaska
Azimuth: N54E



WET ORGANICS & FINE SEDIMENT
FROZEN SEDIMENT
SATURATED ROCK
DEPTH (FT.)

SOUNDING I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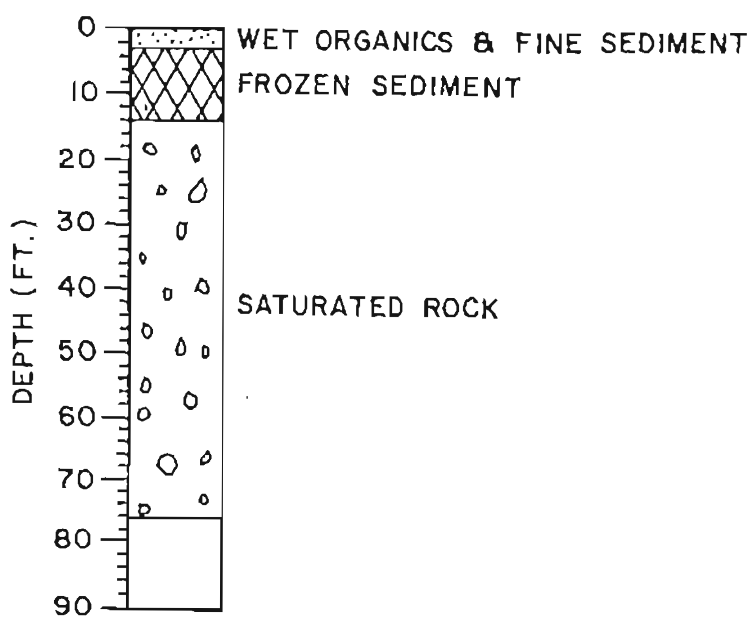
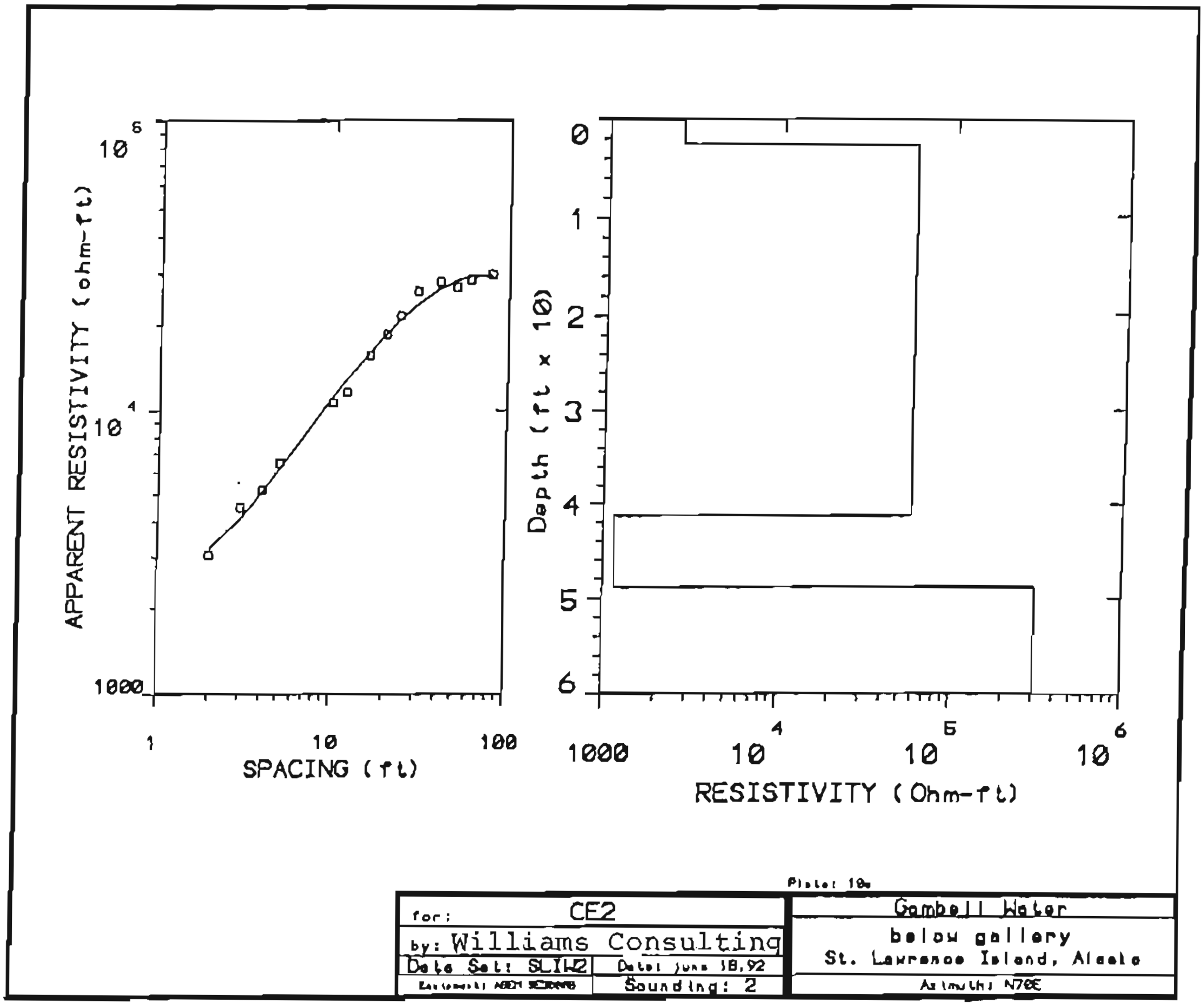
AB/2 (ft)
Depth (ft x 10)
RESISTIVITY (Ohm-ft)
for: CE2
by: Williams Consulting
Data Set: SL1S1
Date: June 18.92
Sounding: 1
Gambell water
south and below gallery
St. Lawrence Island, Alaska


DEPTH (FT.)
WET ORGANICS & FINE SEDIMENT
FROZEN SEDIMENT
SATURATED ROCK

SOUNDING 1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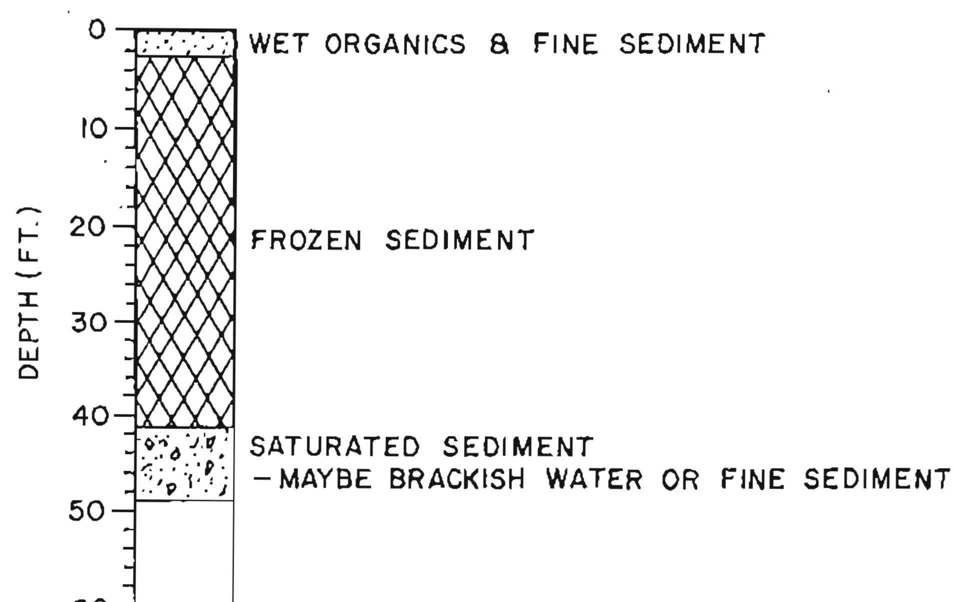
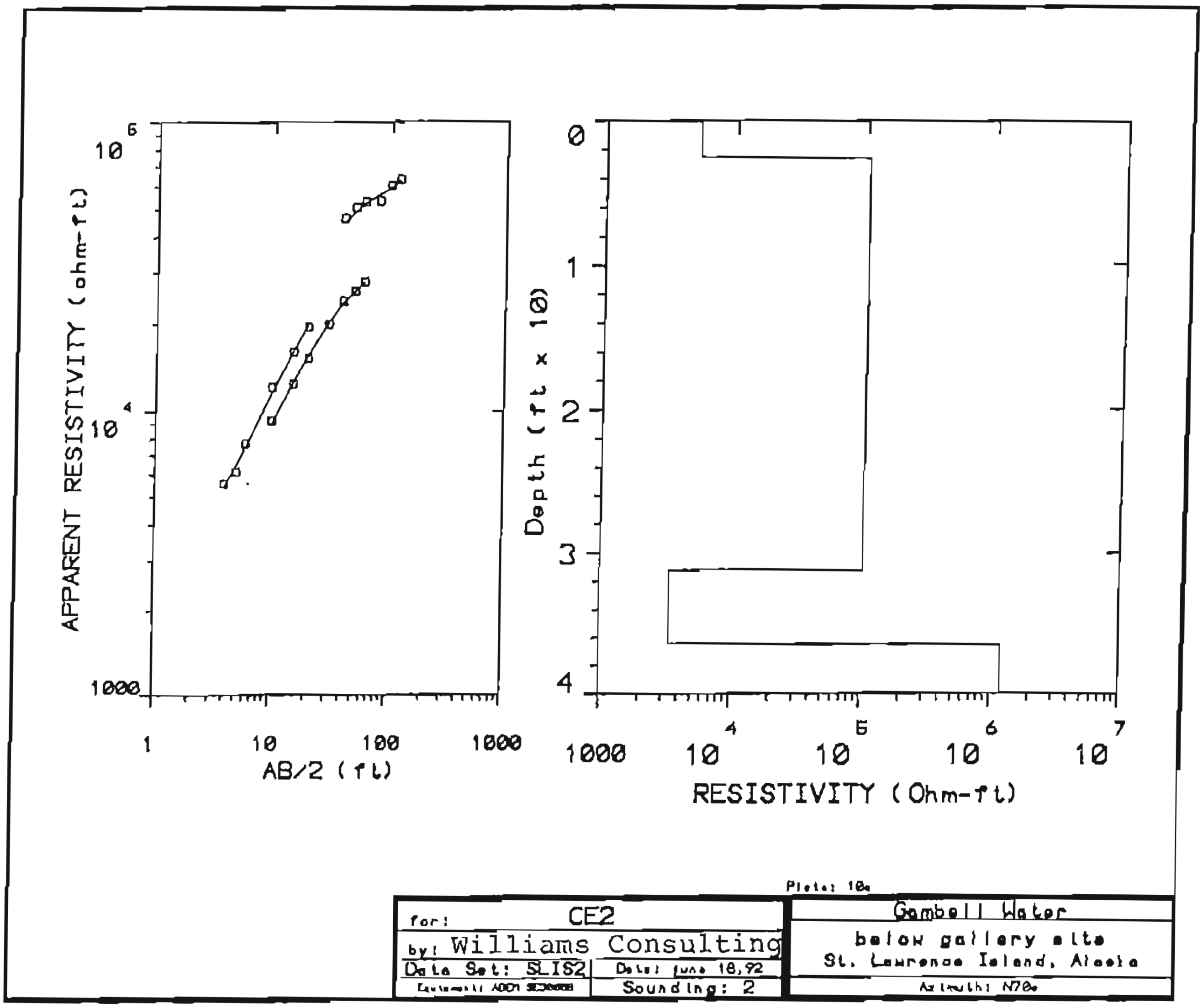
SPACING (ft)
Depth (ft x 10)
RESISTIVITY (Ohm-ft)
for: CE2
by: Williams Consulting
Data Set: SLIW2
Date: june 18,92
Sounding: 2
Gambell Water
below gallery
St. Lawrence Island, Alaska
Azimuth: N70E


DEPTH (FT.)
WET ORGANICS & FINE SEDIMENT
FROZEN SEDIMENT
SATURATED SEDIMENT
- MAYBE BRACKISH WATER OR FINE SEDIMENT

SOUNDING 2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AB/2 (ft)
Depth (ft x 10)
RESISTIVITY (Ohm-ft)
for: CE2
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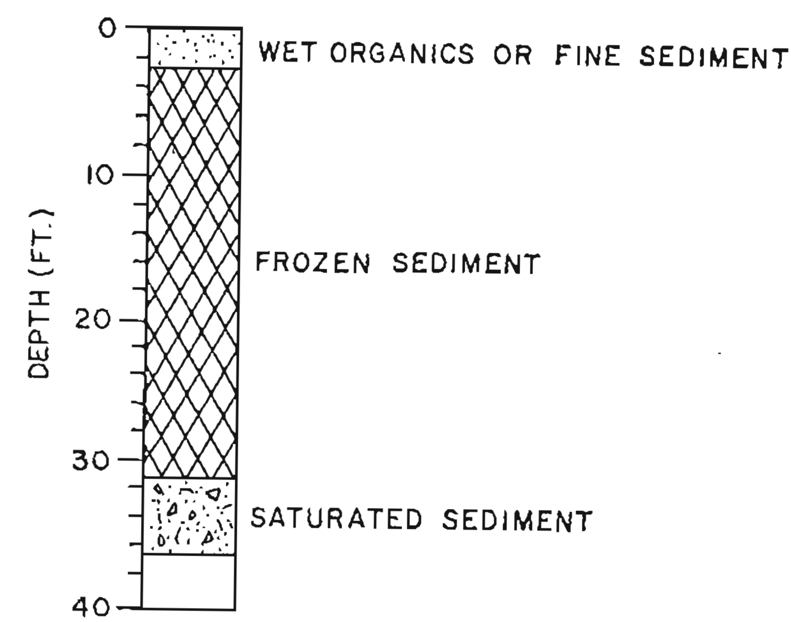
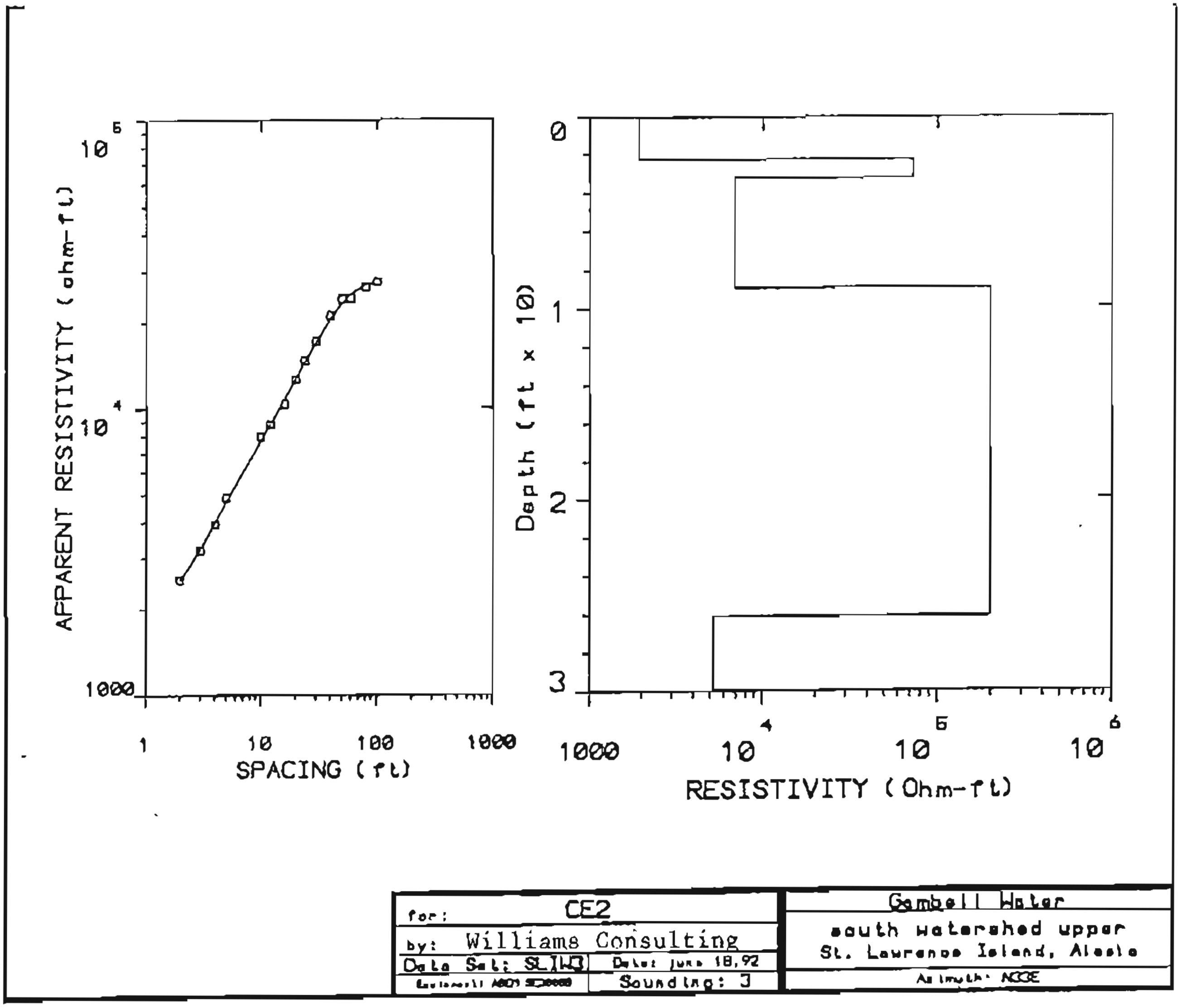
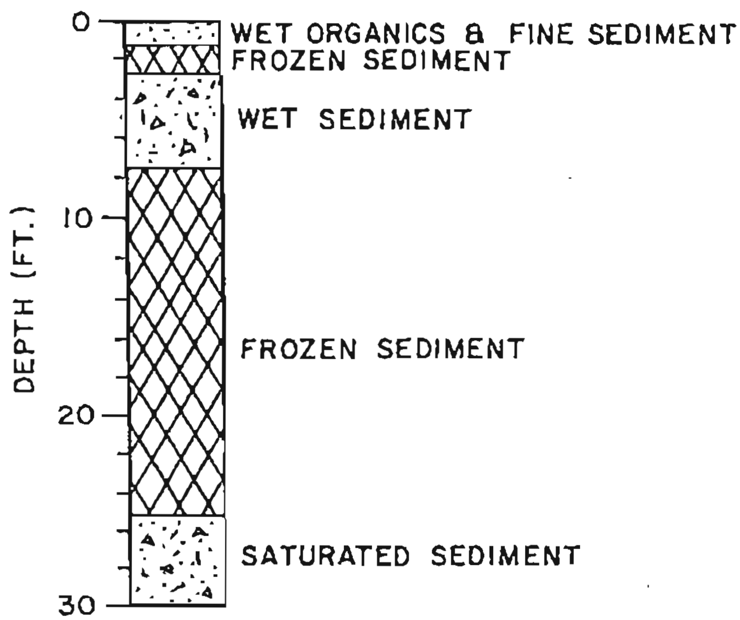
Date: June 18,92
Sounding: 2
Gambell Water
below gallery site
St. Lawrence Island, Alaska
Azimuth: N70e

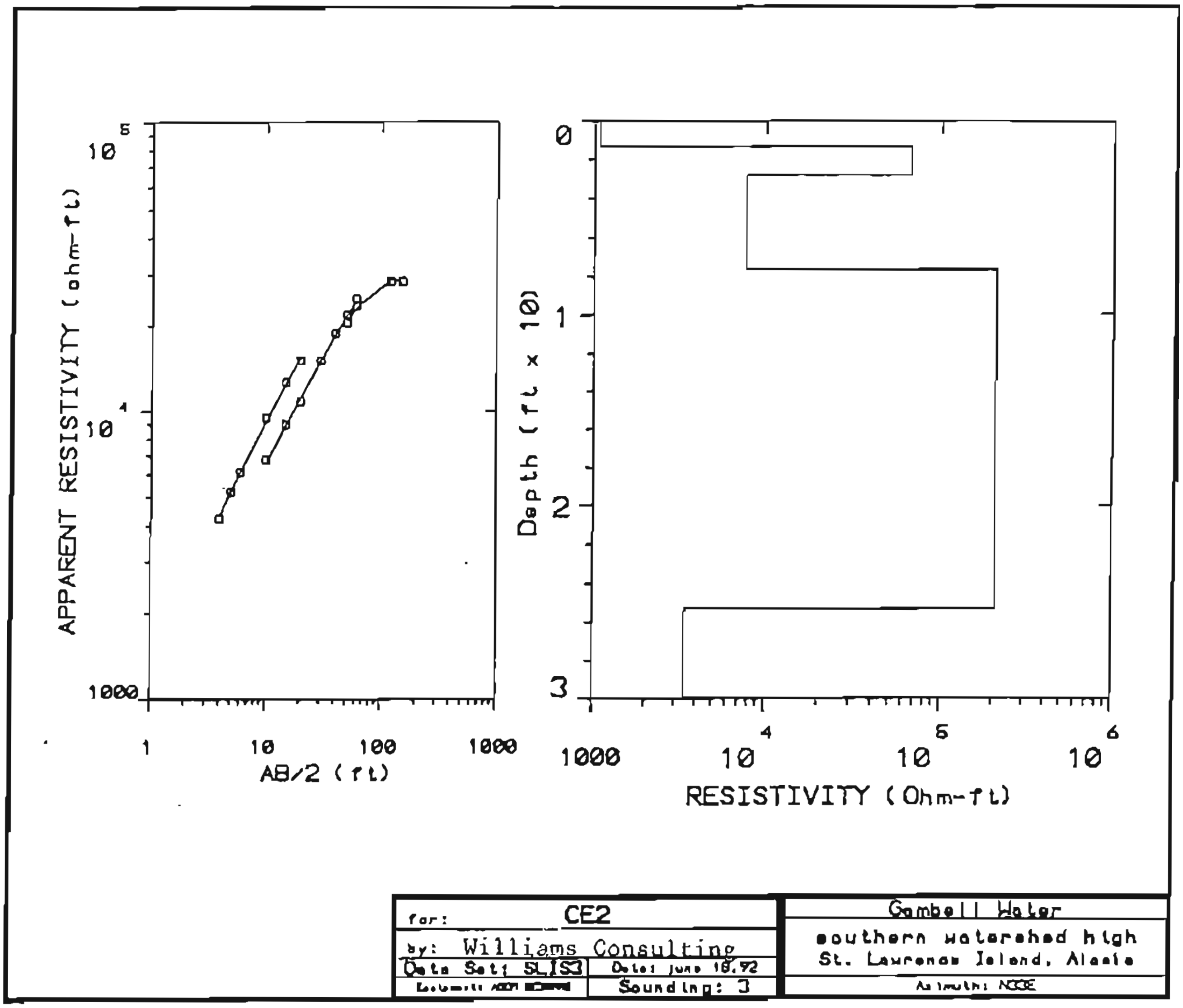

DEPTH (FT.)
WET ORGANICS OR FINE SEDIMENT
FROZEN SEDIMENT
SATURATED SEDIMENT

SOUNDING 2

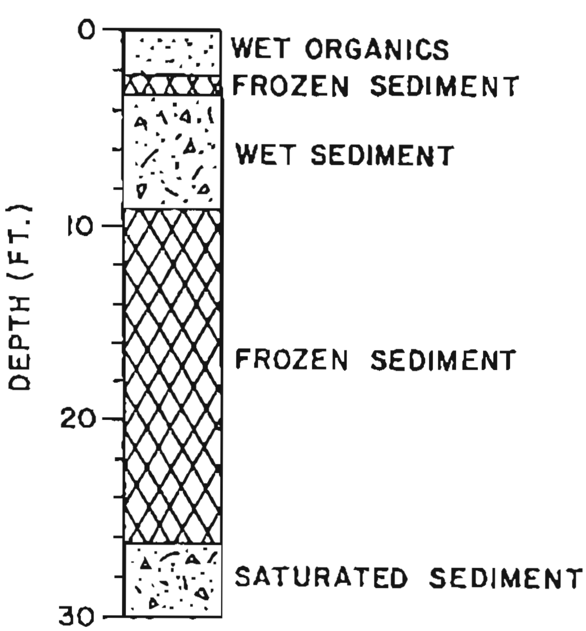

APPARENT RESISTIVITY (ohm-ft)
SPACING (ft)
1000
1
10
100
1000
Depth (ft x 10)
0
1
2
3
RESISTIVITY (Ohm-ft)
for: CE2
by: Williams Consulting
Data Set: SL1W3
Date: June 18,92
Sounding: 3
Gambell Water
south watershed upper
St. Lawrence Island, Alaska


DEPTH (FT.)
0
10
20
30
WET ORGANICS & FINE SEDIMENT
FROZEN SEDIMENT
WET SEDIMENT
FROZEN SEDIMENT
SATURATED SEDIMENT

SOUNDING 3

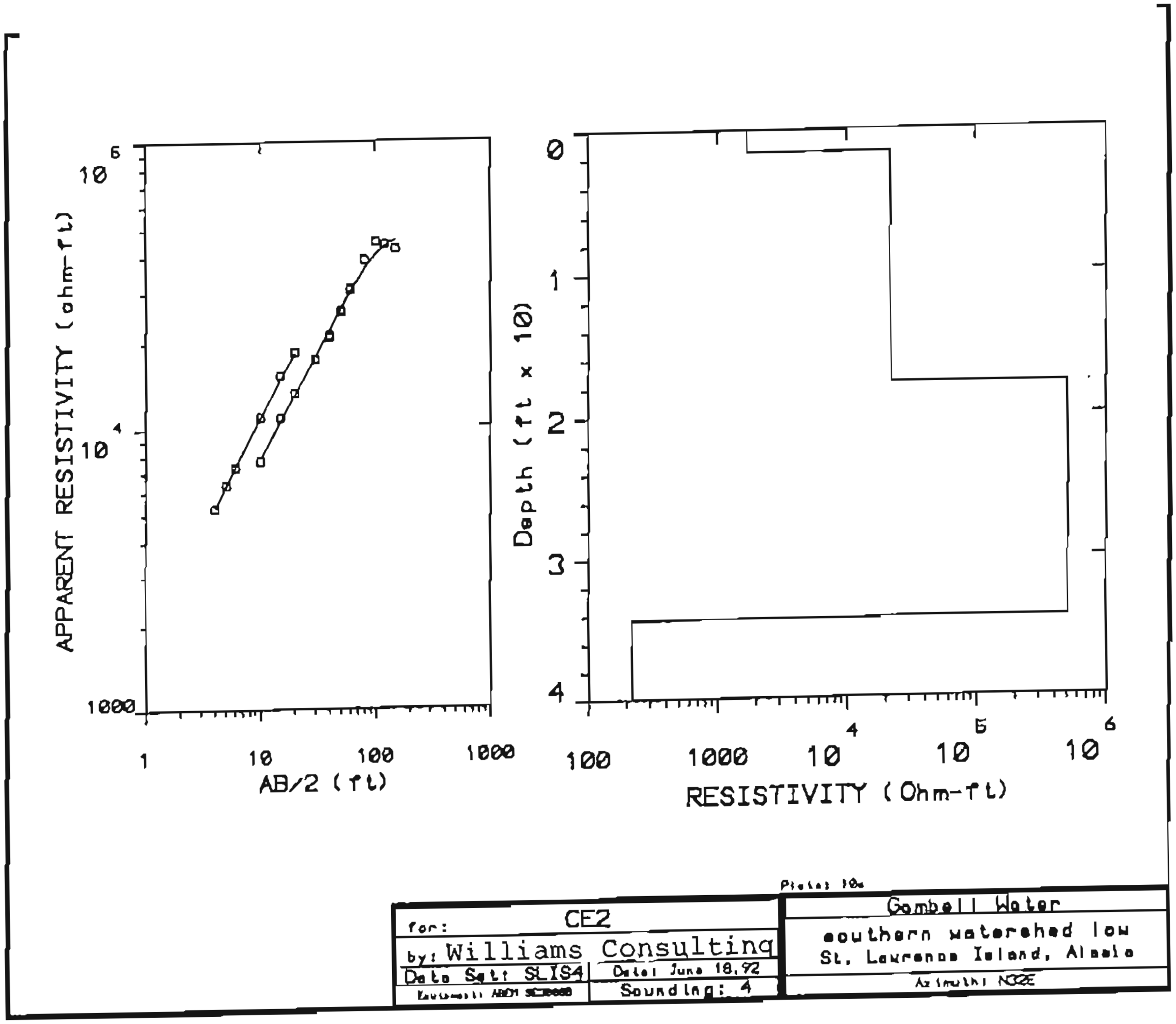


APPARENT RESISTIVITY (ohm-ft)
10^5
10^4
1000
1
10
100
1000
AB/2 (ft)
Depth (ft x 10)
0
1
2
3
1000
10^4
10^5
10^6
RESISTIVITY (Ohm-ft)
for: CE2
by: Williams Consulting
Data Set: SLIS3
Date: june 18,92
Sounding: 3
Gambell Water
southern watershed high
St. Lawrence Island, Alaska
Azimuth: N00E



0
10
20
30
DEPTH (FT.)
WET ORGANICS
FROZEN SEDIMENT
WET SEDIMENT
FROZEN SEDIMENT
SATURATED SEDIMENT

SOUNDING 3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AB/2 (ft)
Depth (ft x 10)
RESISTIVITY (Ohm-ft)
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by: Williams Consulting
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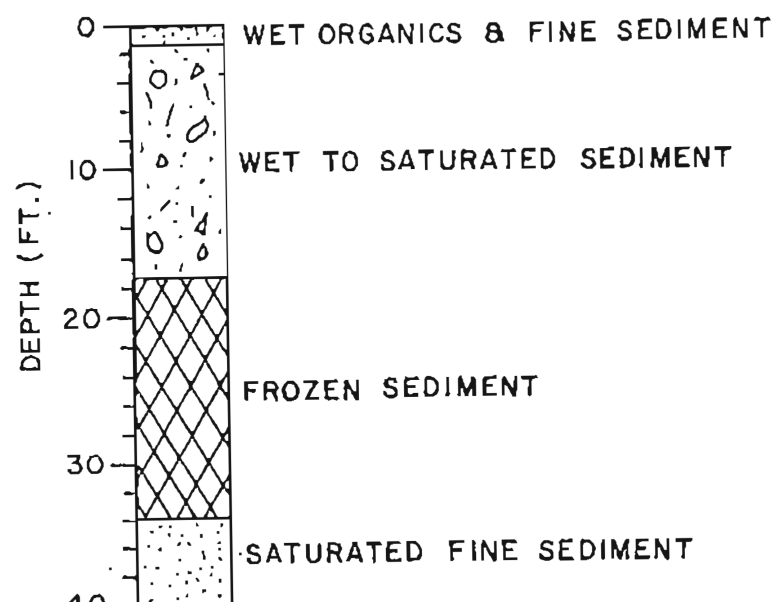
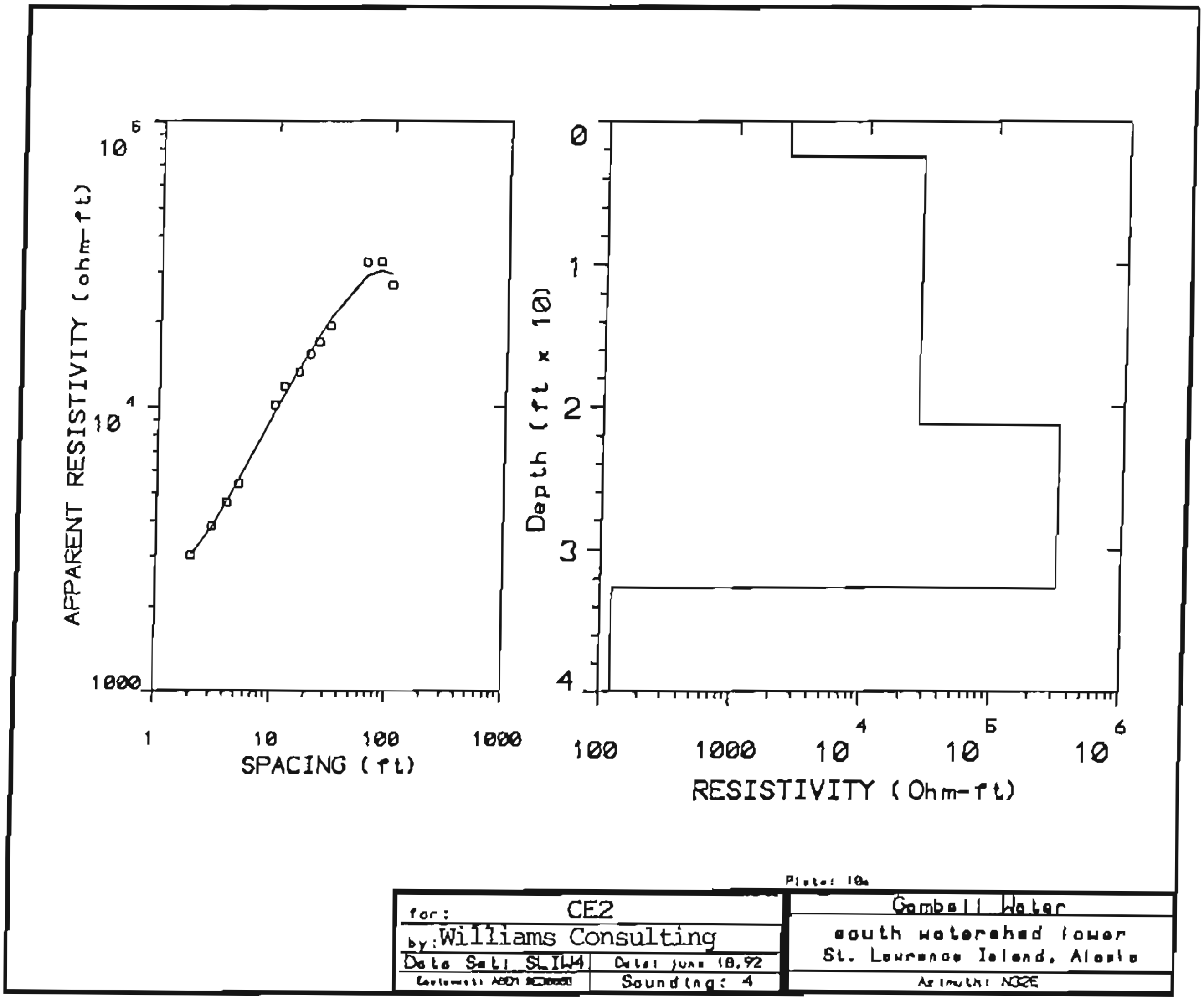
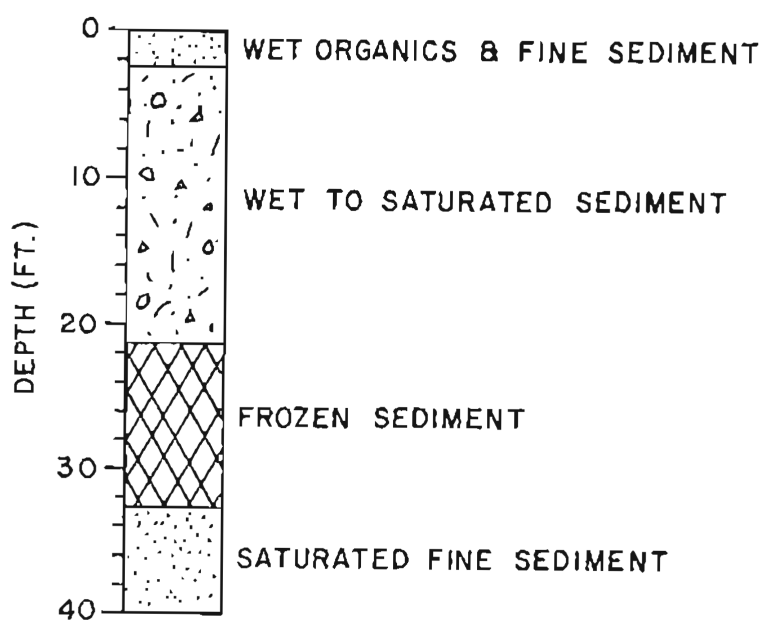
Sounding: 4
Gambell Water
southern watershed low
St. Lawrence Island, Alaska


DEPTH (FT.)
WET ORGANICS & FINE SEDIMENT
WET TO SATURATED SEDIMENT
FROZEN SEDIMENT
SATURATED FINE SEDIMENT

SOUNDING 4

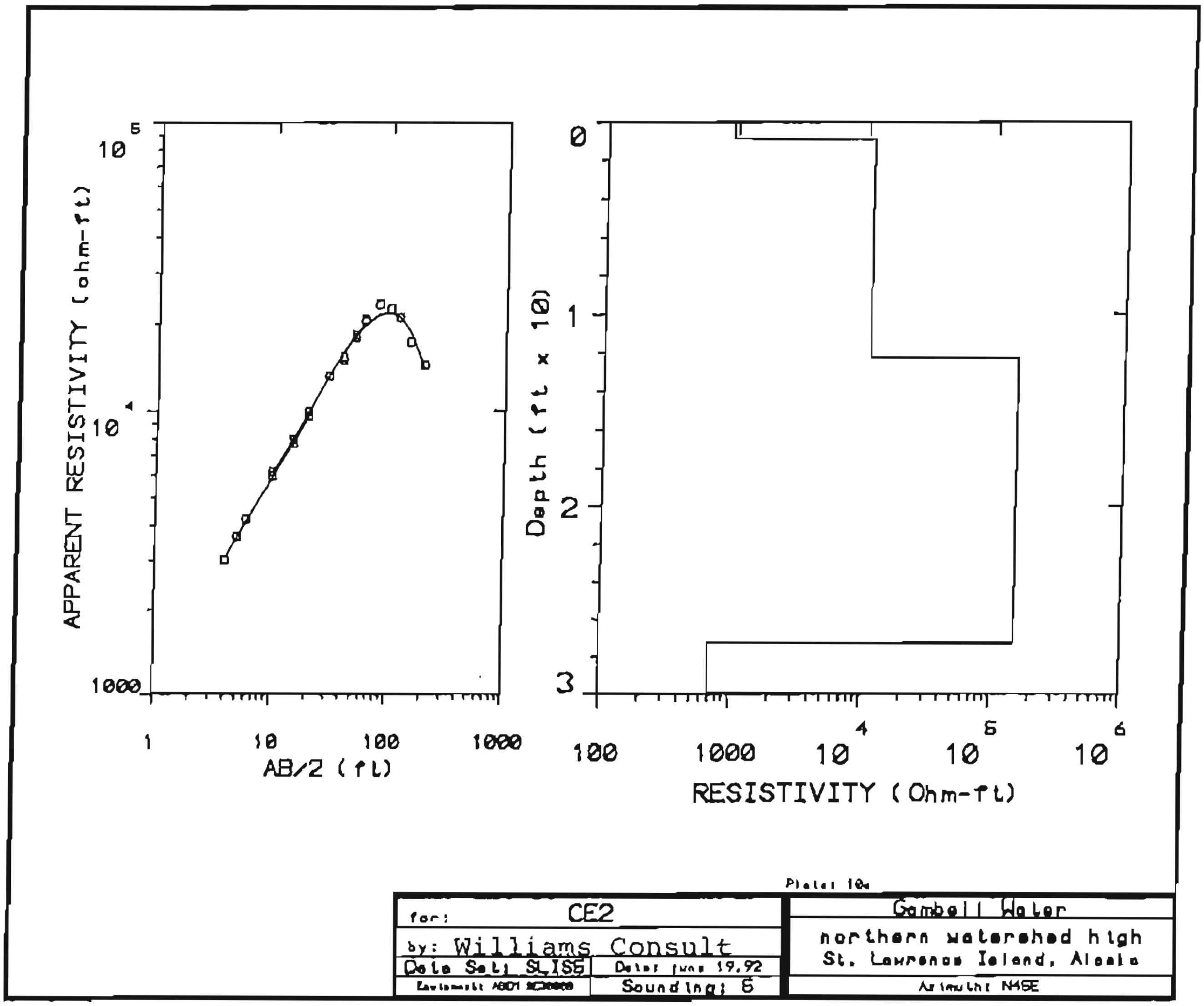


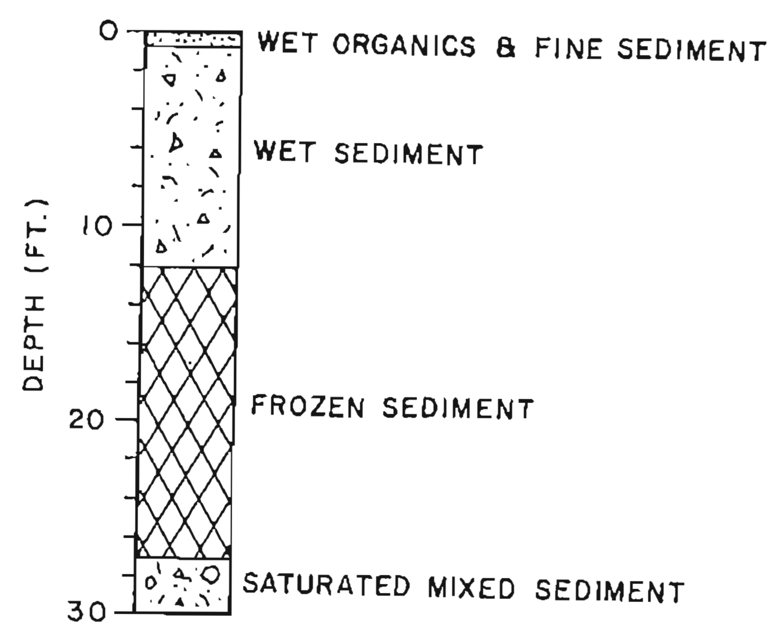
APPARENT RESISTIVITY (ohm-ft)
10^5
10^4
1000
1
10
100
1000
SPACING (ft)
Depth (ft x 10)
0
1
2
3
4
100
1000
10^4
10^5
10^6
RESISTIVITY (Ohm-ft)
Plate: 10a
for: CE2
by: Williams Consulting
Data Set: SLIW4
Date: June 18,92
Sounding: 4
Gambell Water
south watershed tower
St. Lawrence Island, Alaska
Azimuth: N32E



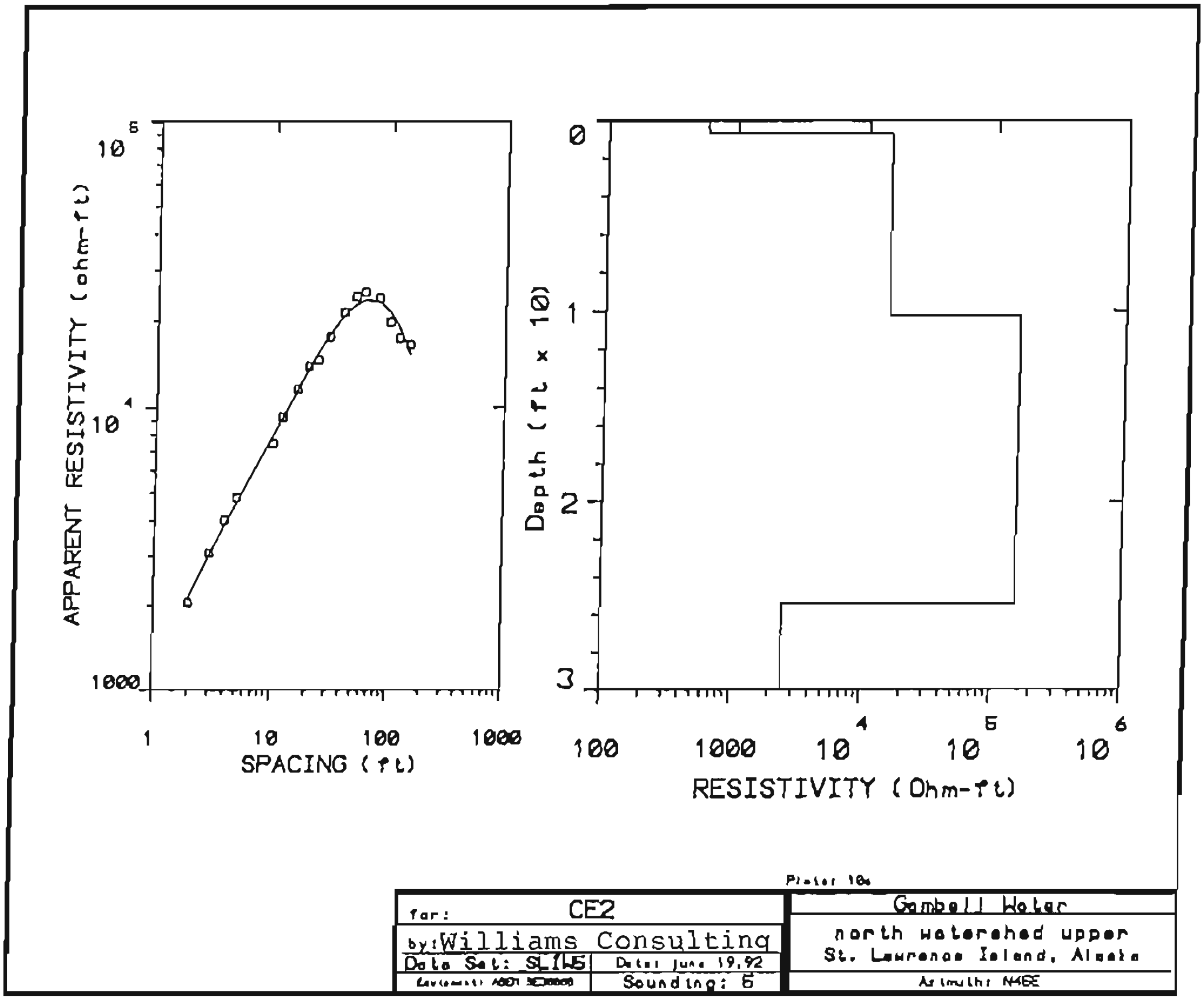
DEPTH (FT.)
0
10
20
30
40
WET ORGANICS & FINE SEDIMENT
WET TO SATURATED SEDIMENT
FROZEN SEDIMENT
SATURATED FINE SEDIMENT

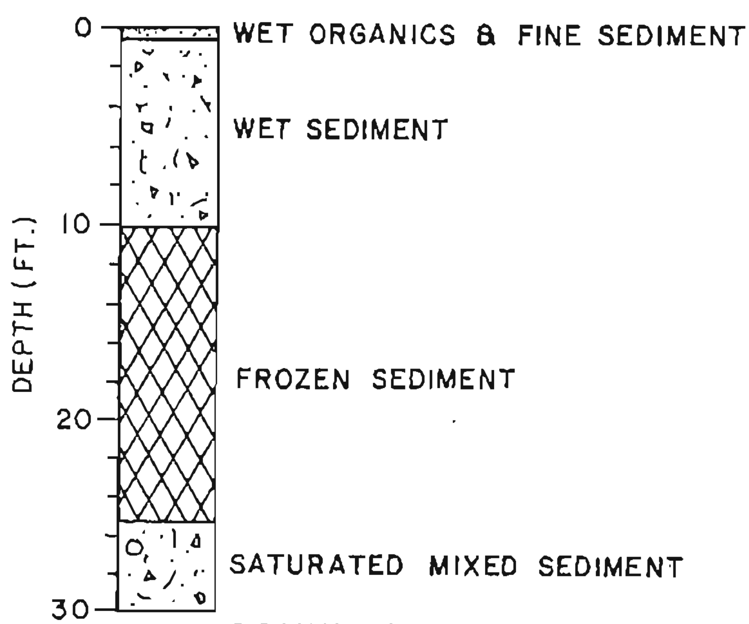
SOUNDING 4


APPARENT RESISTIVITY (ohm-ft)
AB/2 (ft)
Depth (ft x 10)
RESISTIVITY (Ohm-ft)
Plate: 10a
for: CE2
by: Williams Consult
Data Set: SLIS5
Date: june 19,92
Sounding: 5
Gambell Water
northern watershed high
St. Lawrence Island, Alaska
Azimuth: N45E

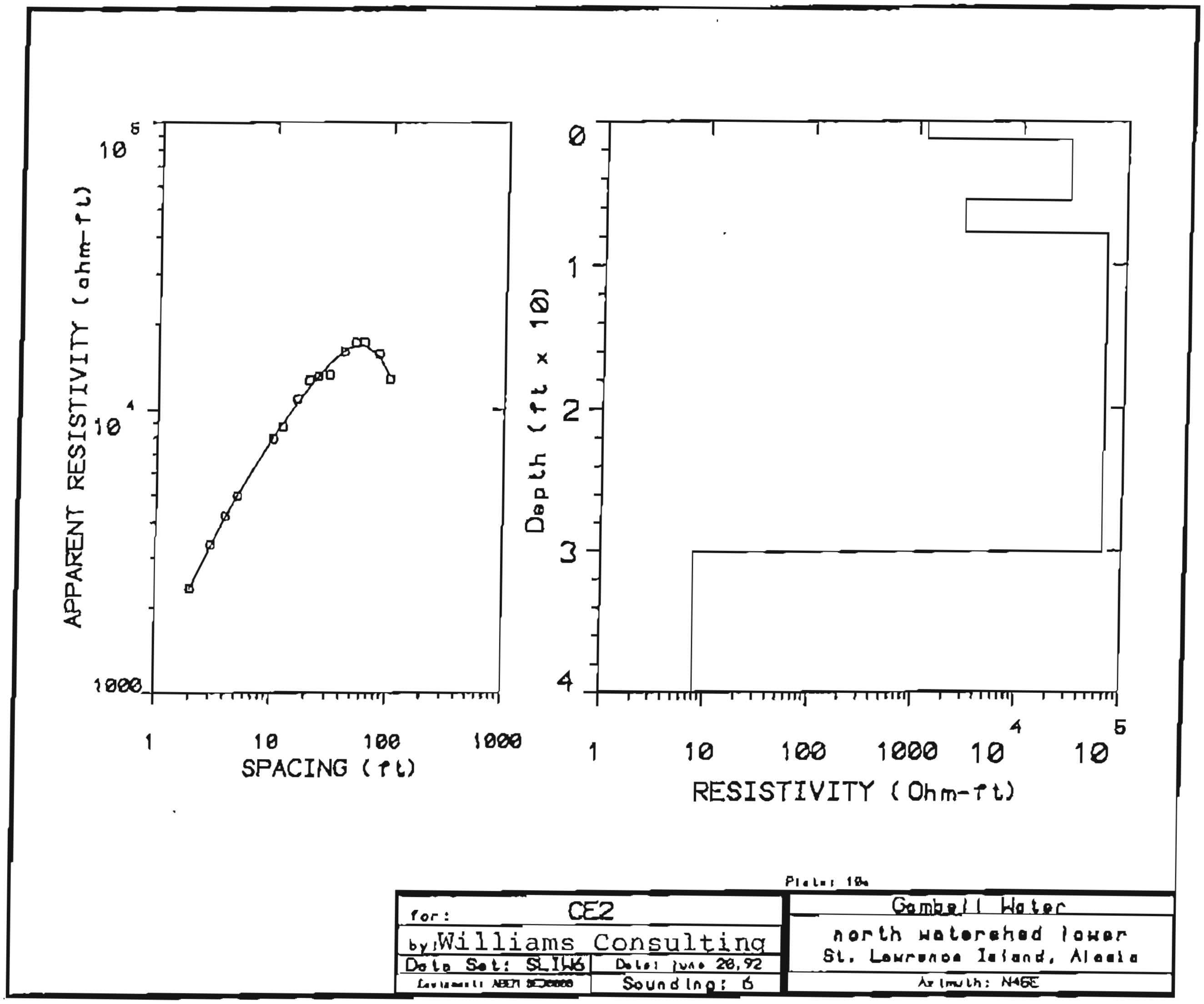

DEPTH (FT.)
WET ORGANICS & FINE SEDIMENT
WET SEDIMENT
FROZEN SEDIMENT
SATURATED MIXED SEDIMENT

SOUNDING 5

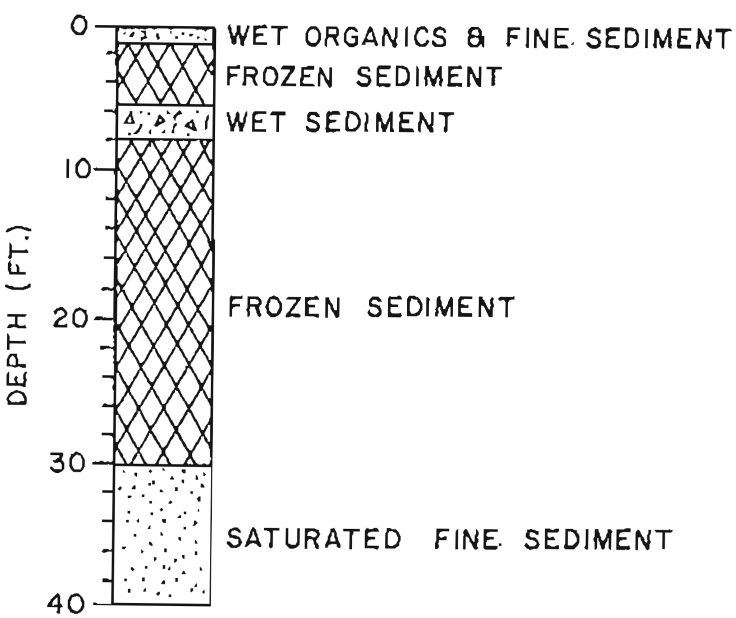

APPARENT RESISTIVITY (ohm-ft)
SPACING (ft)
Depth (ft x 10)
RESISTIVITY (Ohm-ft)
for: CE2
by: Williams Consulting
Data Set: SLIW5
Date: June 19,92
Sounding: 5
Gambell Water
north watershed upper
St. Lawrence Island, Alaska
Azimuth: N45E


WET ORGANICS & FINE SEDIMENT
WET SEDIMENT
FROZEN SEDIMENT
SATURATED MIXED SEDIMENT
DEPTH (FT.)

SOUNDING 5

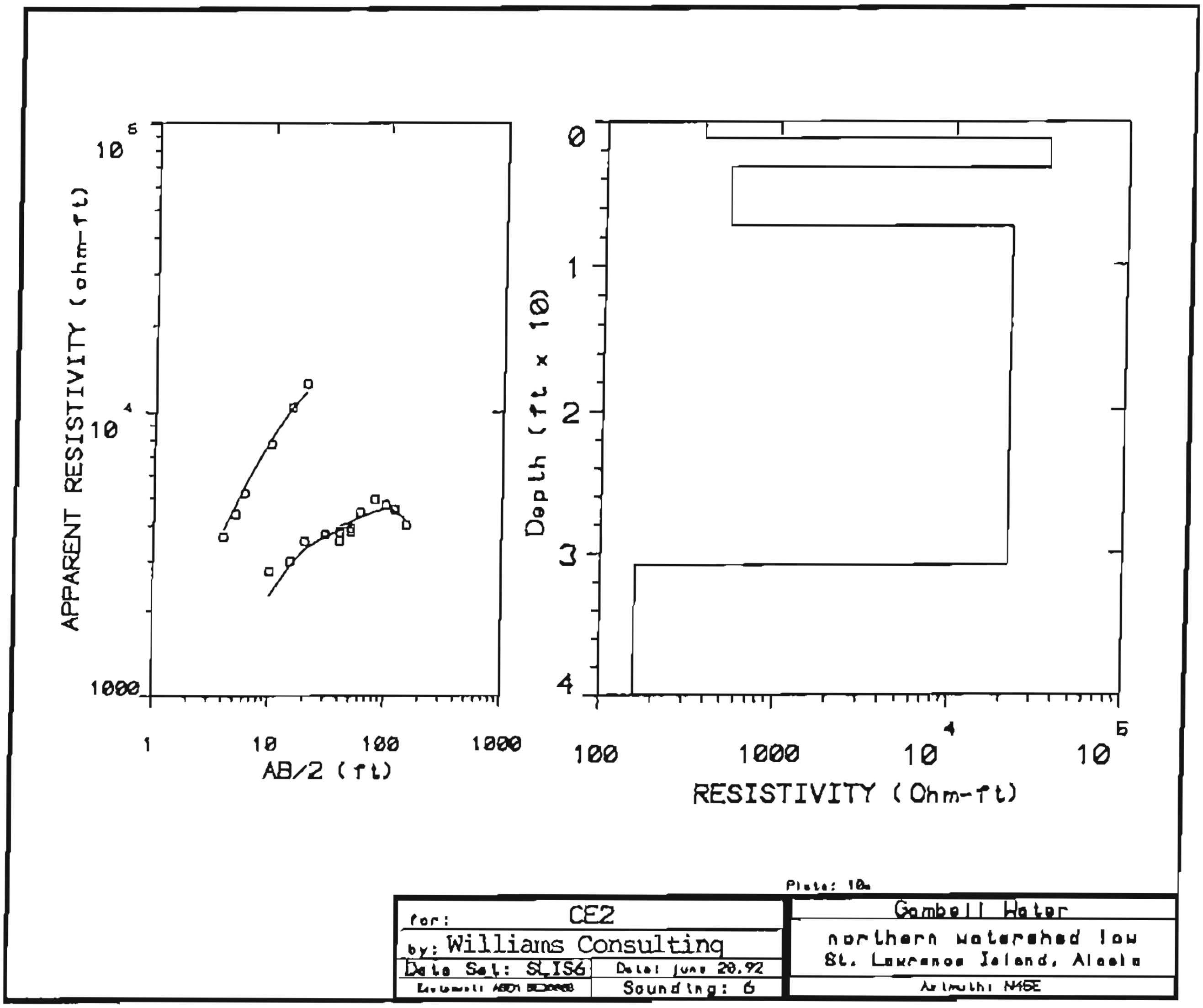


APPARENT RESISTIVITY (ohm-ft)
SPACING (ft)
Depth (ft x 10)
RESISTIVITY (Ohm-ft)
for: CE2
by: Williams Consulting
Data Set: SLIW6
Date: June 28,92
Sounding: 6
Gambell Water
north watershed lower
St. Lawrence Island, Alaska
Azimuth: N45E

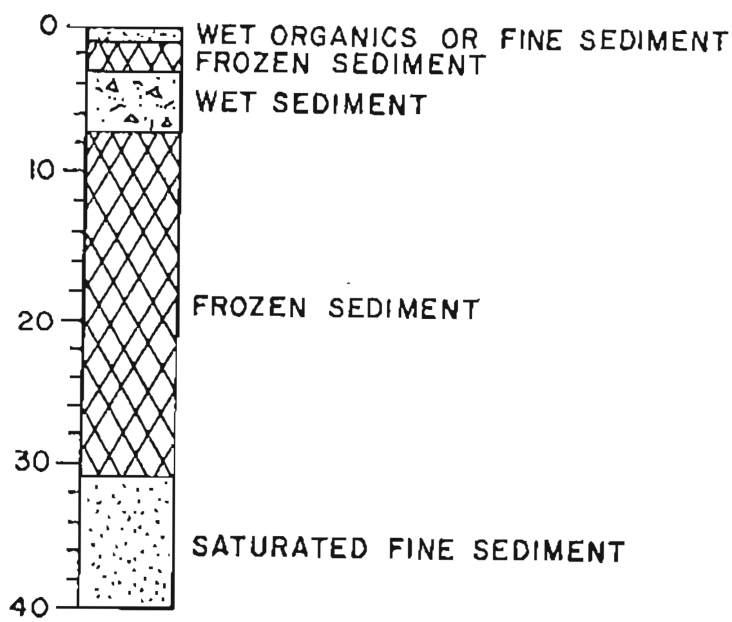


DEPTH (FT.)
WET ORGANICS & FINE SEDIMENT
FROZEN SEDIMENT
WET SEDIMENT
FROZEN SEDIMENT
SATURATED FINE SEDIMENT

SOUNDING 6

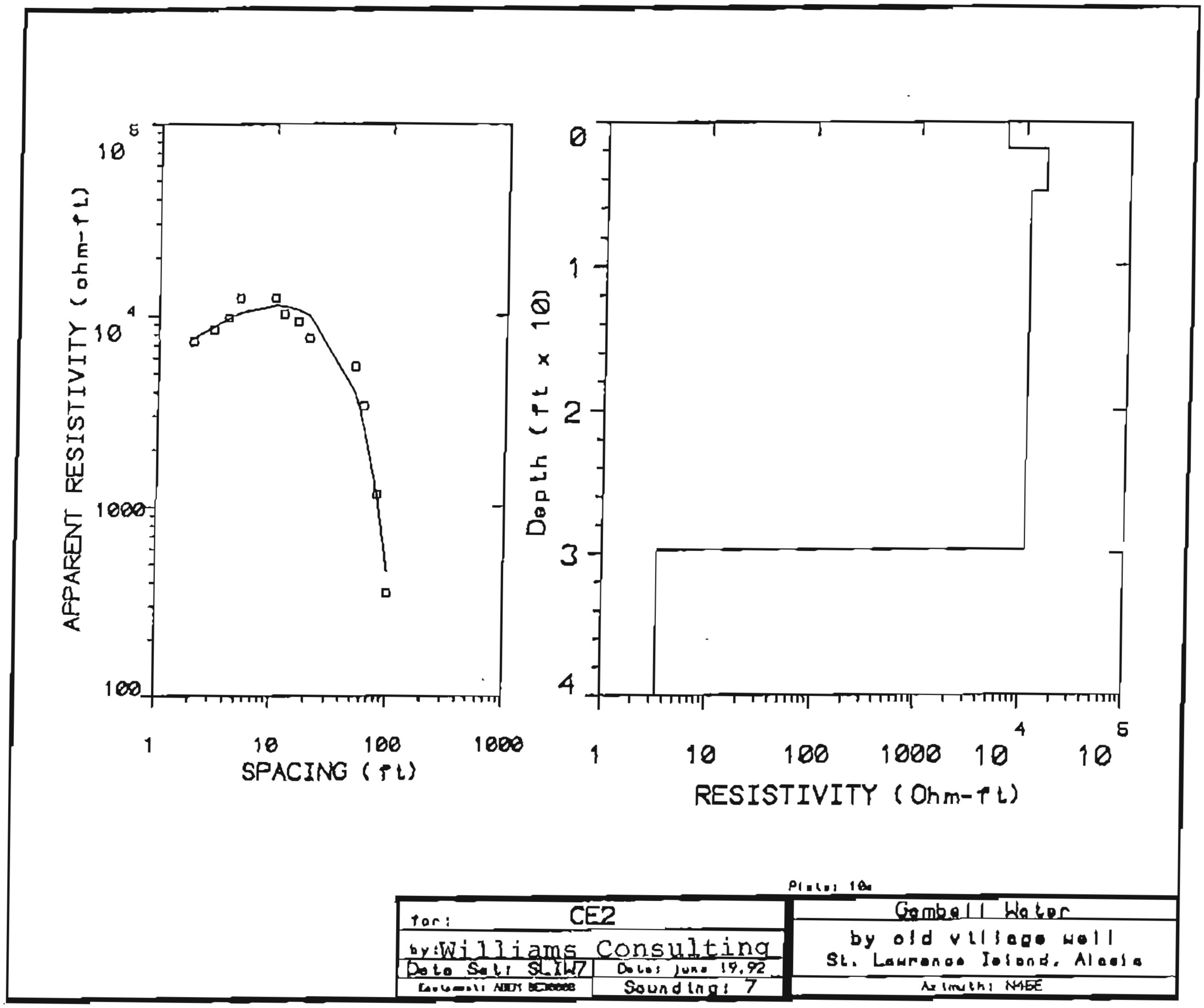


APPARENT RESISTIVITY (ohm-ft)
1000
AB/2 (ft)
1
10
100
1000
Depth (ft x 10)
0
1
2
3
4
RESISTIVITY (Ohm-ft)
100
1000
Plate: 10a
for: CE2
by: Williams Consulting
Data Set: SLIS6
Date: june 20.92
Sounding: 6
Gambell Water
northern watershed low
St. Lawrence Island, Alaska
Azimuth: N45E

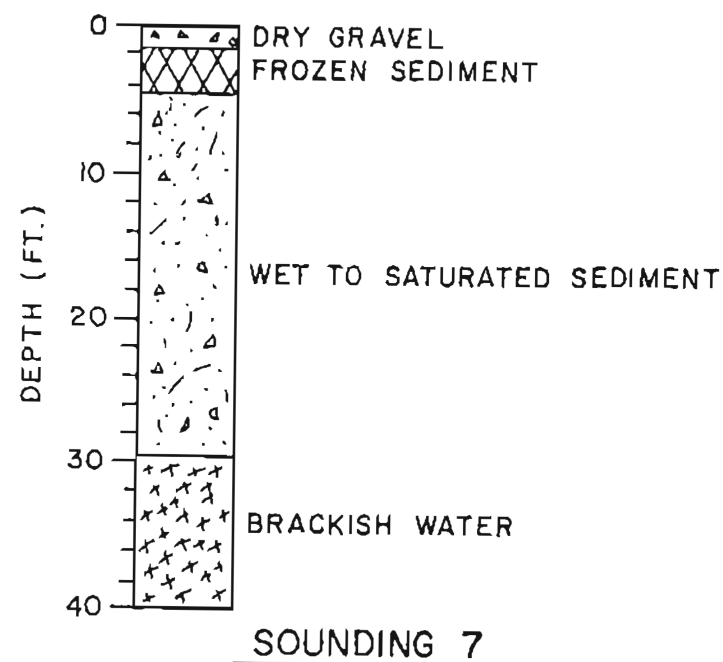


WET ORGANICS OR FINE SEDIMENT
FROZEN SEDIMENT
WET SEDIMENT
FROZEN SEDIMENT
SATURATED FINE SEDIMENT
DEPTH (FT.)
0
10
20
30
40

SOUNDING 6

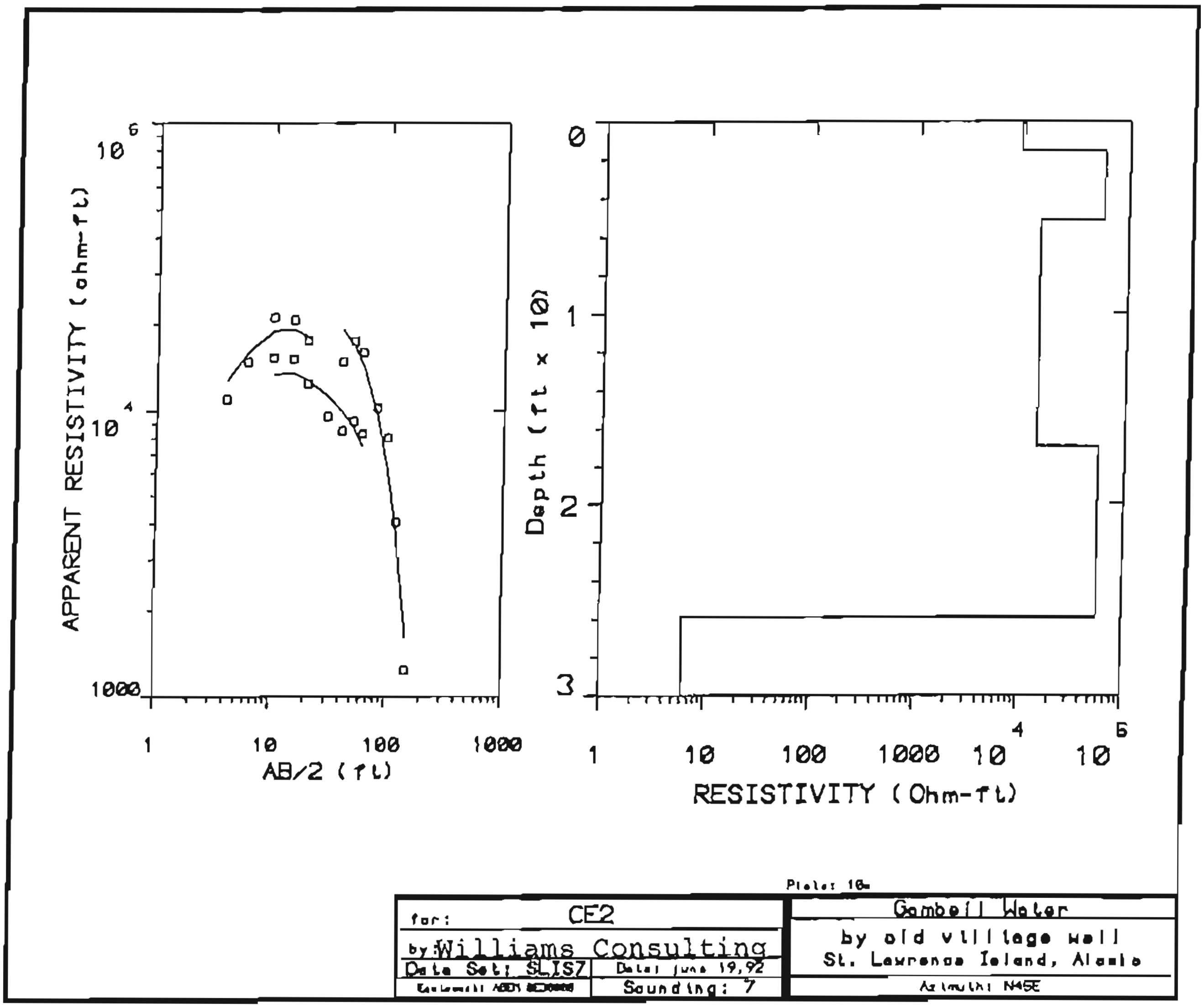


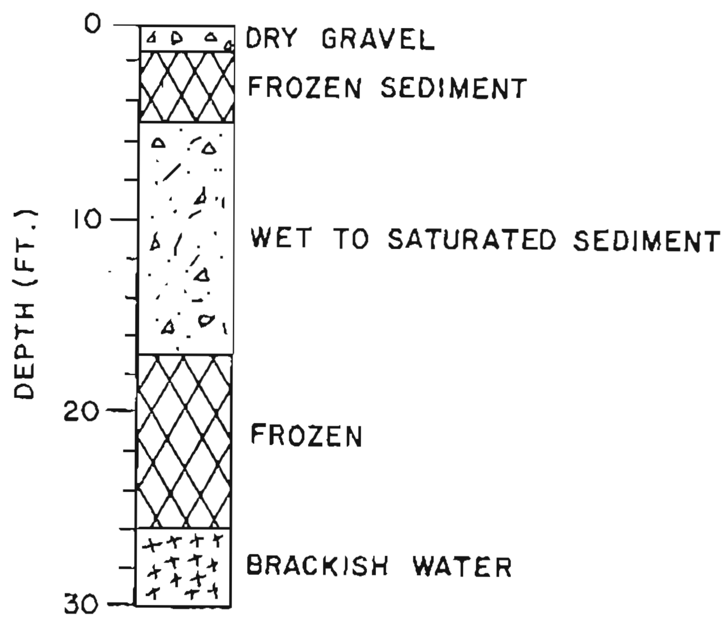
APPARENT RESISTIVITY (ohm-ft)
SPACING (ft)
Depth (ft x 10)
RESISTIVITY (Ohm-ft)
Plate: 10a
for: CE2
by: Williams Consulting
Data Set: SLIW7
Date: June 19,92
Sounding: 7
Gambell Water
by old village well
St. Lawrence Island, Alaska
Azimuth: N45E



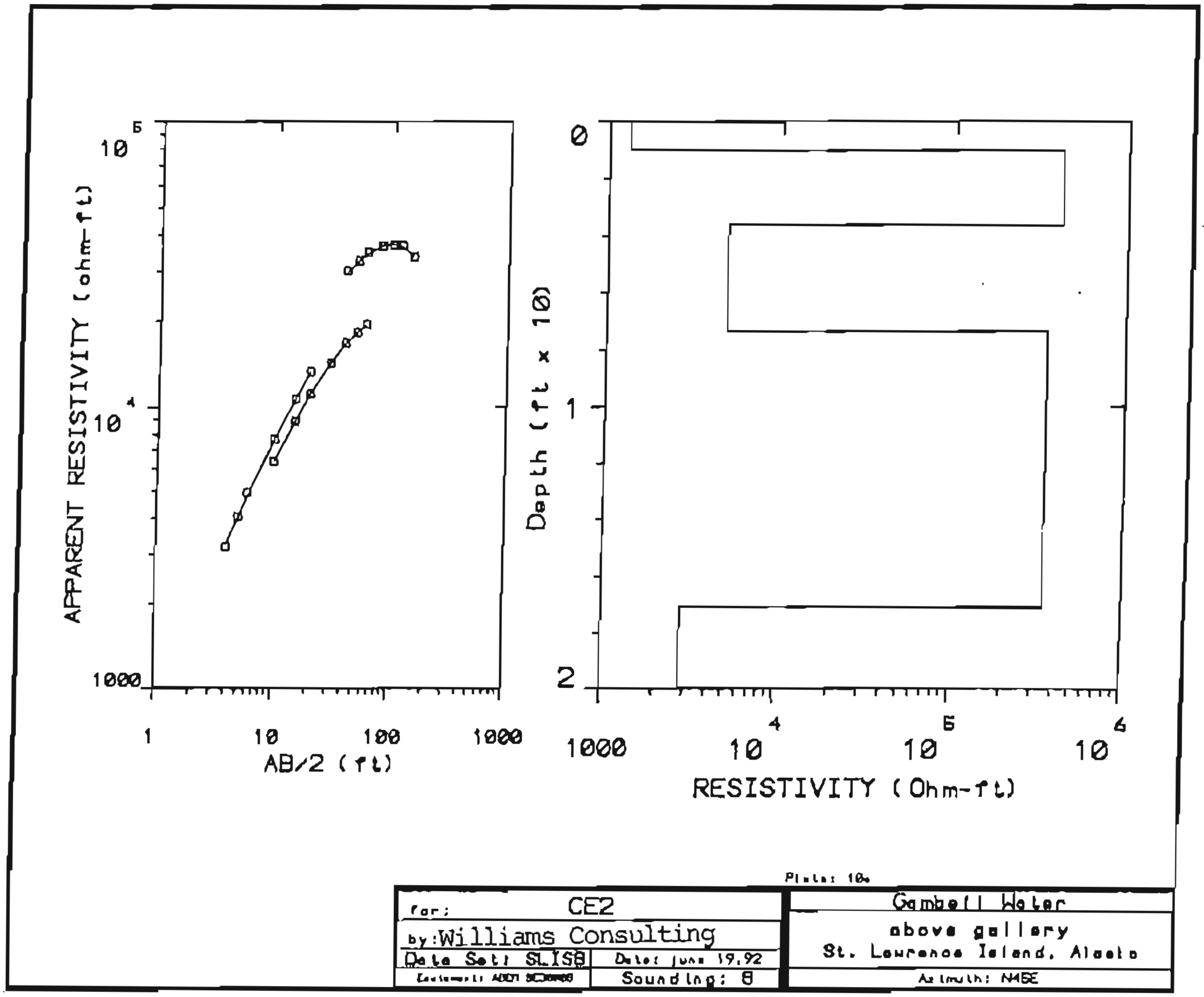
DEPTH (FT.)
DRY GRAVEL
FROZEN SEDIMENT
WET TO SATURATED SEDIMENT
BRACKISH WATER

SOUNDING 7

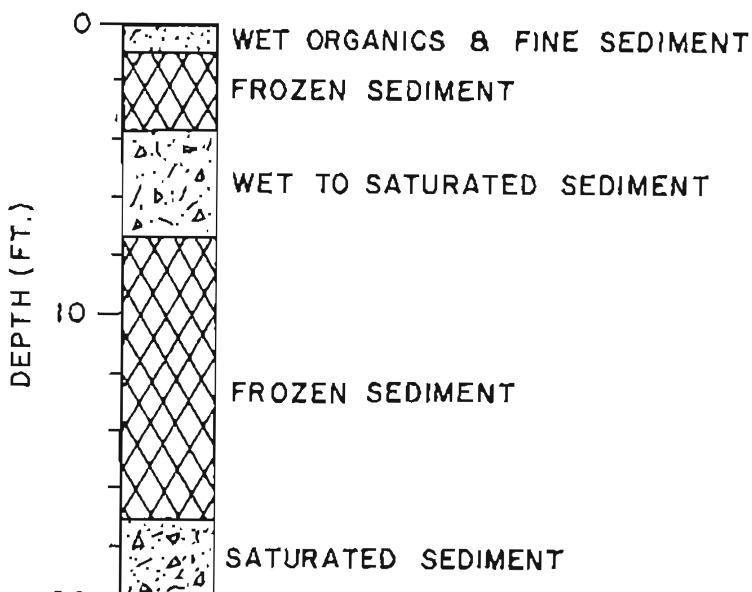

APPARENT RESISTIVITY (ohm-ft)
AB/2 (ft)
Depth (ft x 10)
RESISTIVITY (Ohm-ft)
for: CE2
by: Williams Consulting
Data Set: SLIS7
Date: june 19,92
Sounding: 7
Gambell Water
by old village well
St. Lawrence Island, Alaska
Azimuth: N45E


DEPTH (FT.)
DRY GRAVEL
FROZEN SEDIMENT
WET TO SATURATED SEDIMENT
FROZEN
BRACKISH WATER

SOUNDING 7

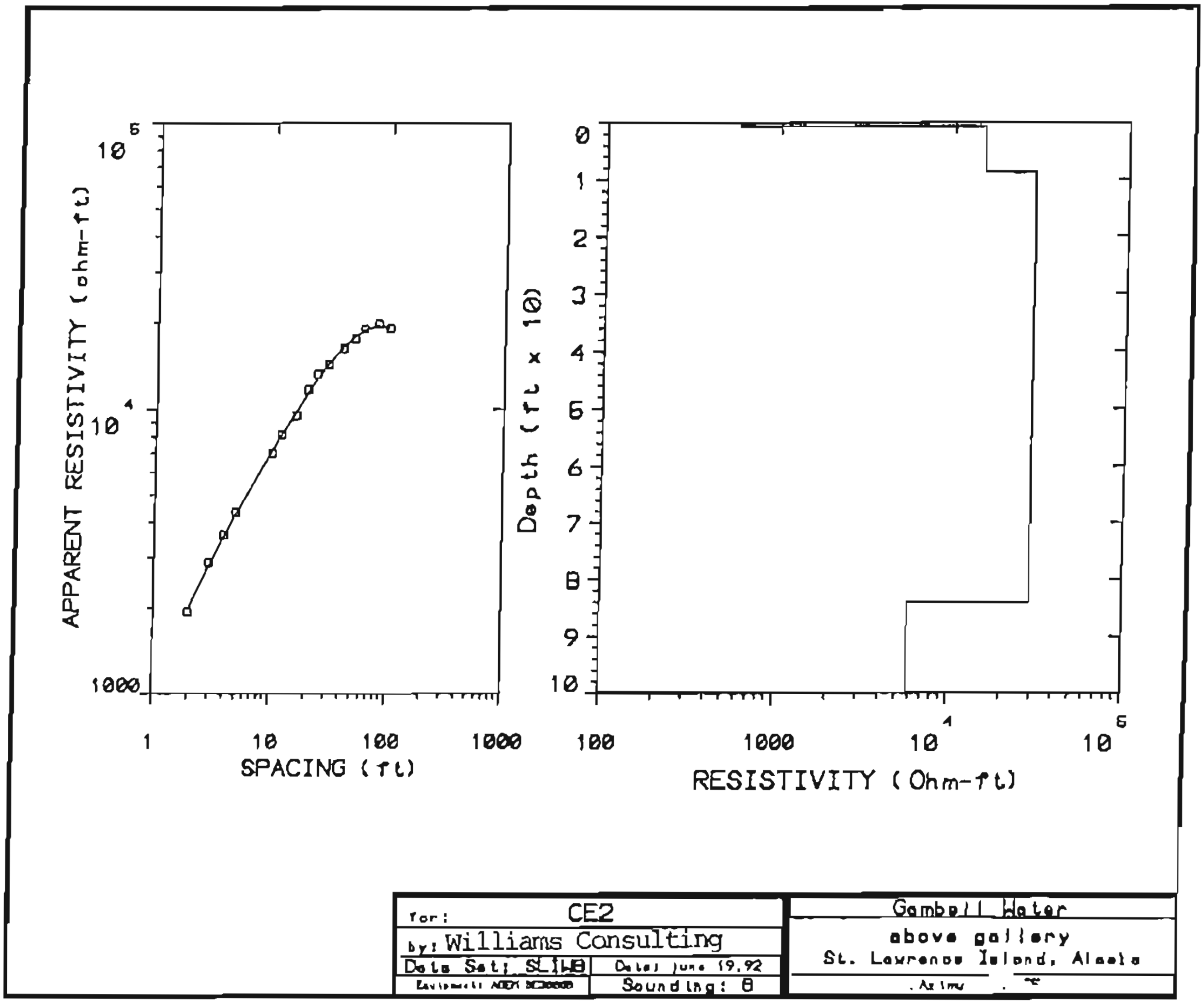


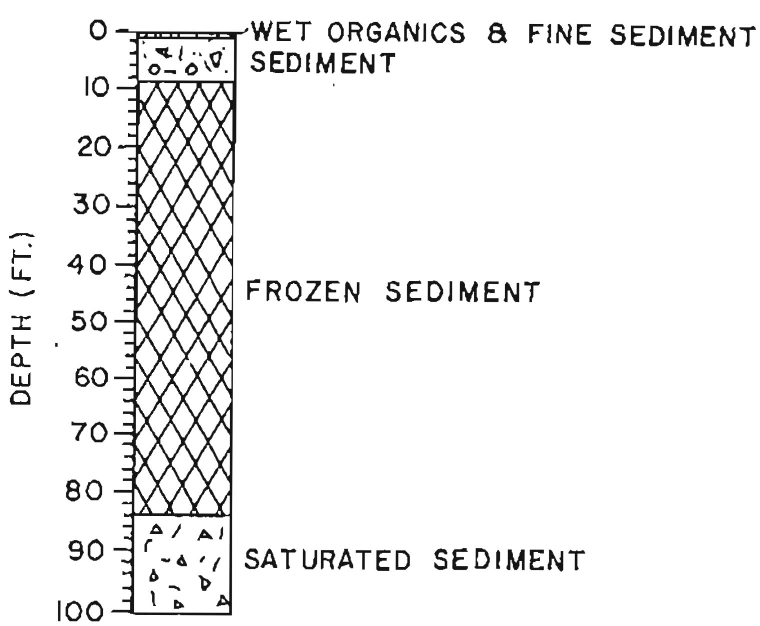
APPARENT RESISTIVITY (ohm-ft)
AB/2 (ft)
Depth (ft x 10)
RESISTIVITY (Ohm-ft)
Plate: 10
For: CE2
by: Williams Consulting
Data Set: SLIS8
Date: June 19,92
Sounding: 8
Gambell Water
above gallery
St. Lawrence Island, Alaska
Azimuth: N45E



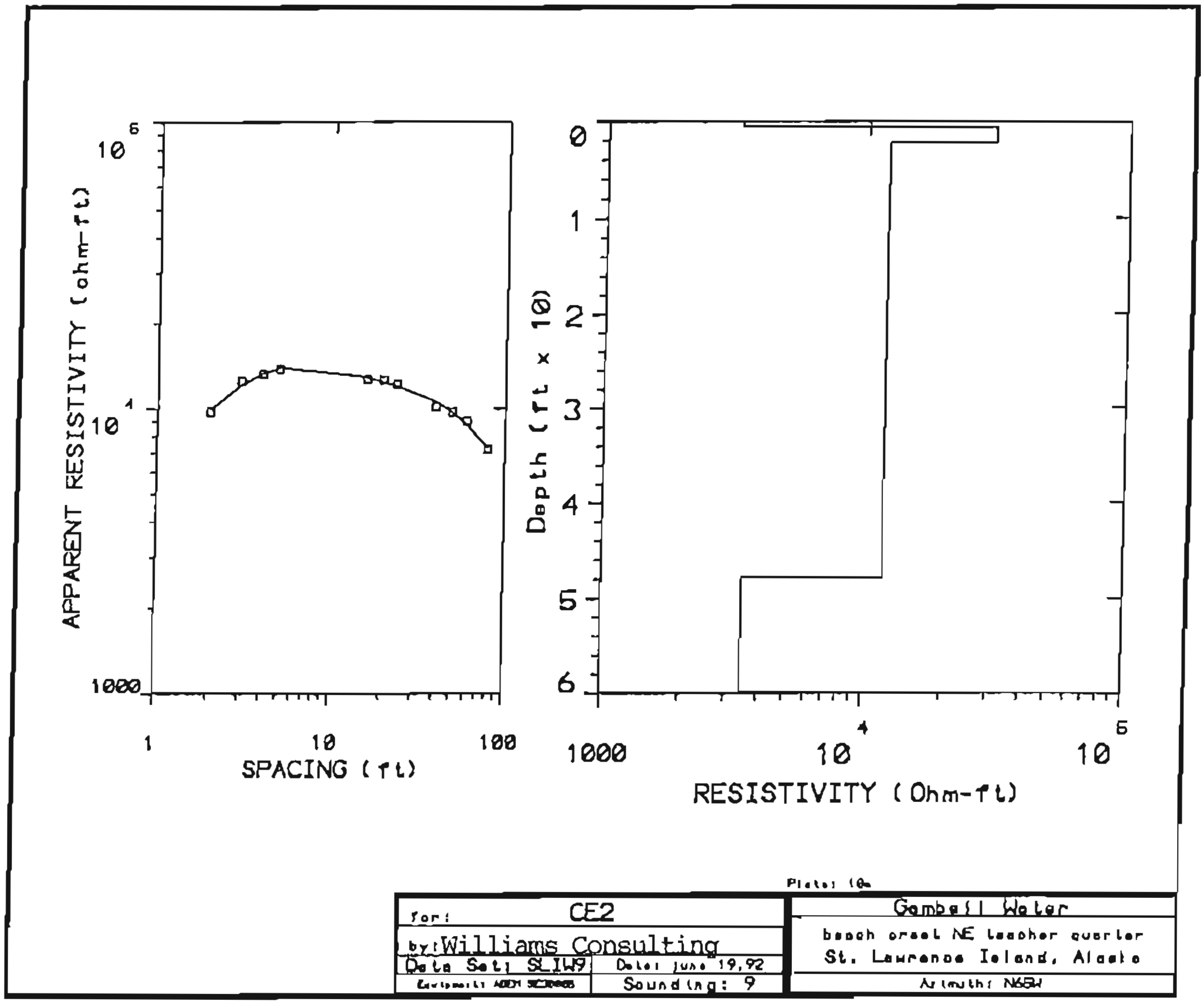
WET ORGANICS & FINE SEDIMENT
FROZEN SEDIMENT
WET TO SATURATED SEDIMENT
FROZEN SEDIMENT
SATURATED SEDIMENT
DEPTH (FT.)
0
10
20

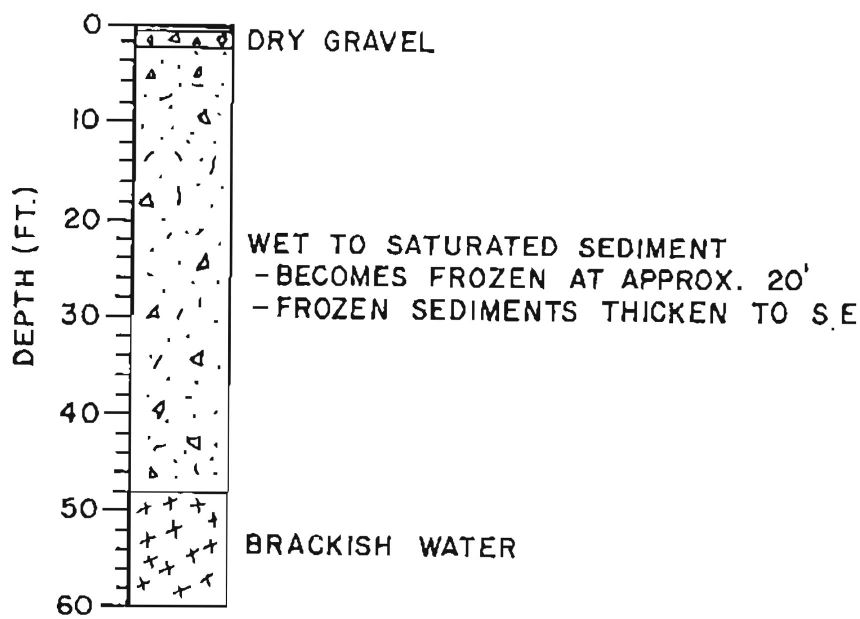
SOUNDING 8


APPARENT RESISTIVITY (ohm-ft)
SPACING (ft)
Depth (ft x 10)
RESISTIVITY (Ohm-ft)
For: CE2
by: Williams Consulting
Data Set: SL1WB
Date: June 19,92
Sounding: 8
Gambell Water
above gallery
St. Lawrence Island, Alaska

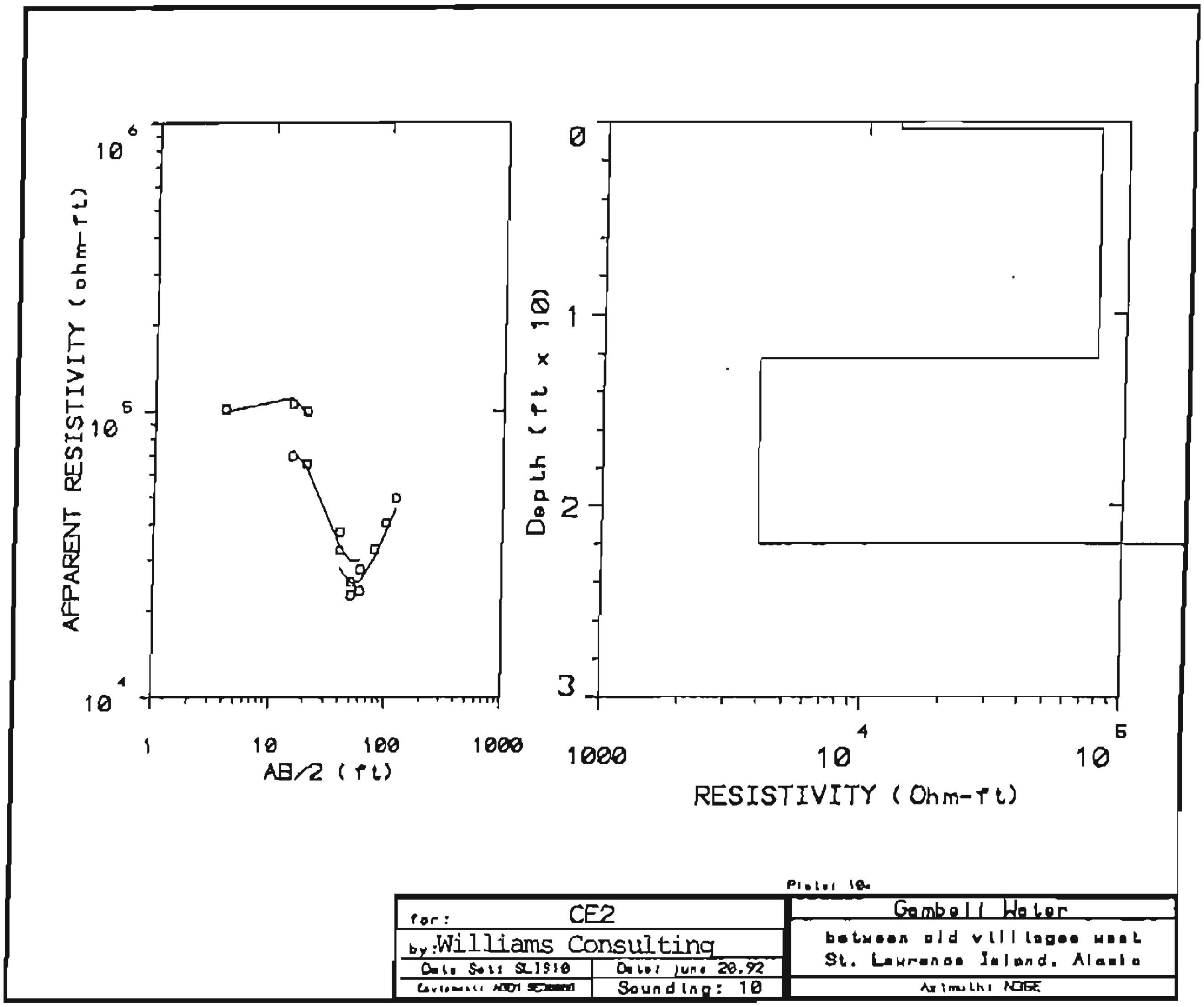

WET ORGANICS & FINE SEDIMENT
SEDIMENT
FROZEN SEDIMENT
SATURATED SEDIMENT
DEPTH (FT.)

SOUNDING 8

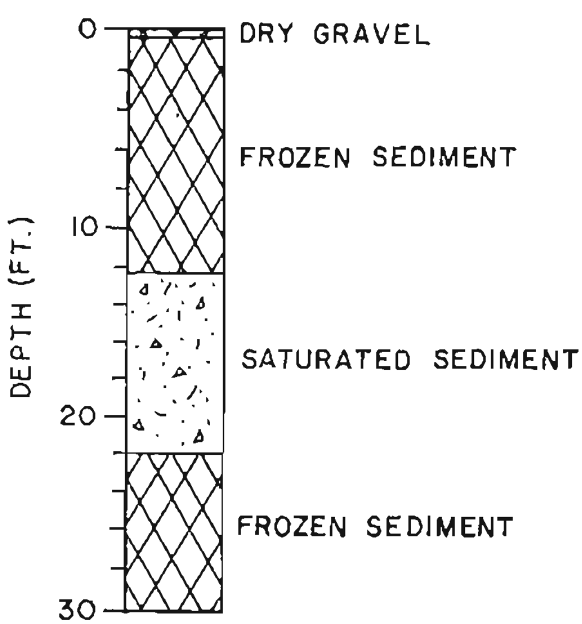

APPARENT RESISTIVITY (ohm-ft)
SPACING (ft)
Depth (ft x 10)
RESISTIVITY (Ohm-ft)
For: CE2
by: Williams Consulting
Data Set: SLIW9
Date: june 19,92
Sounding: 9
Gambell Water
beach area NE teacher quarter
St. Lawrence Island, Alaska
Azimuth: N65W


DEPTH (FT.)
DRY GRAVEL
WET TO SATURATED SEDIMENT
-BECOMES FROZEN AT APPROX. 20'
-FROZEN SEDIMENTS THICKEN TO S.E
BRACKISH WATER

SOUNDING 9

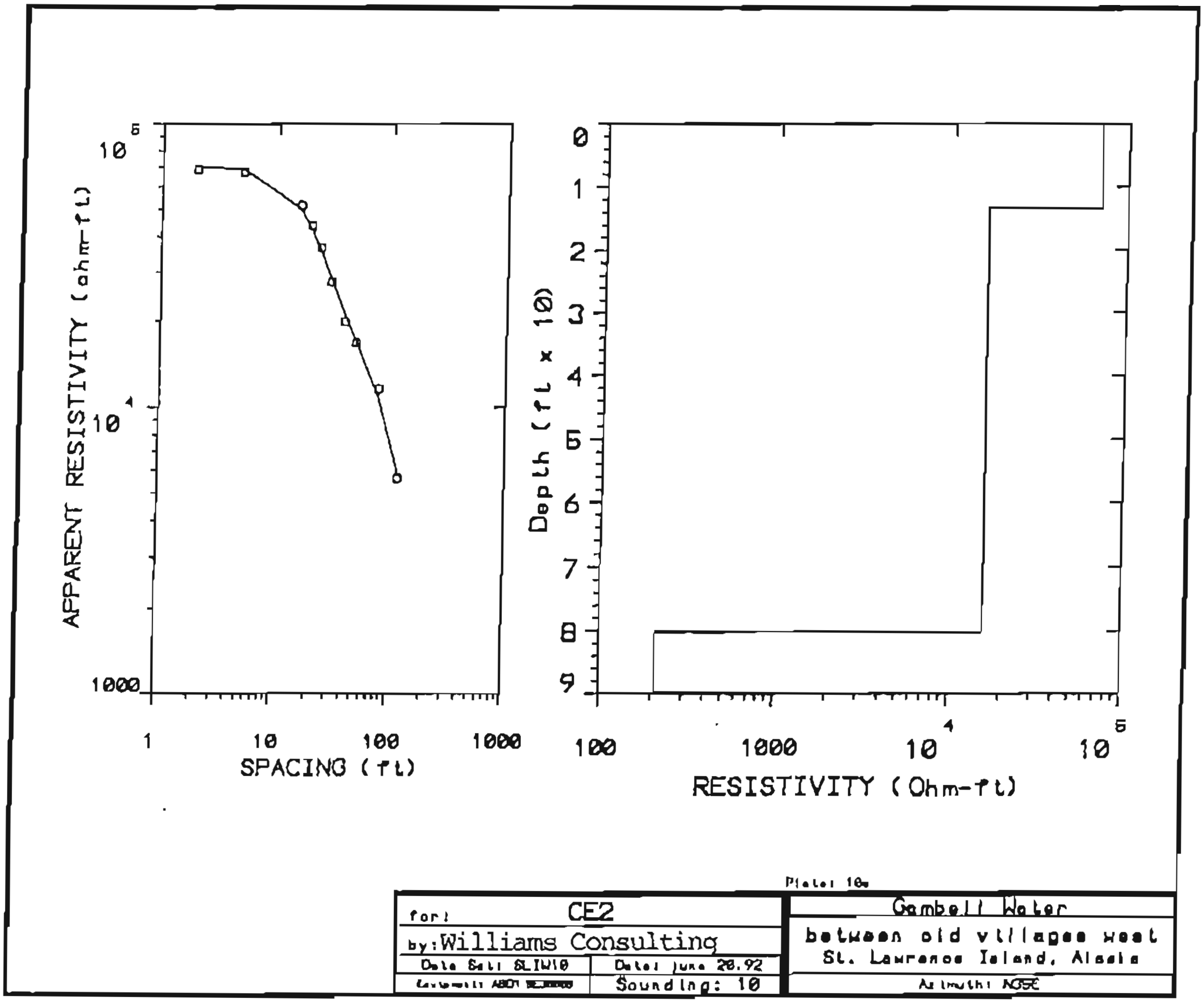


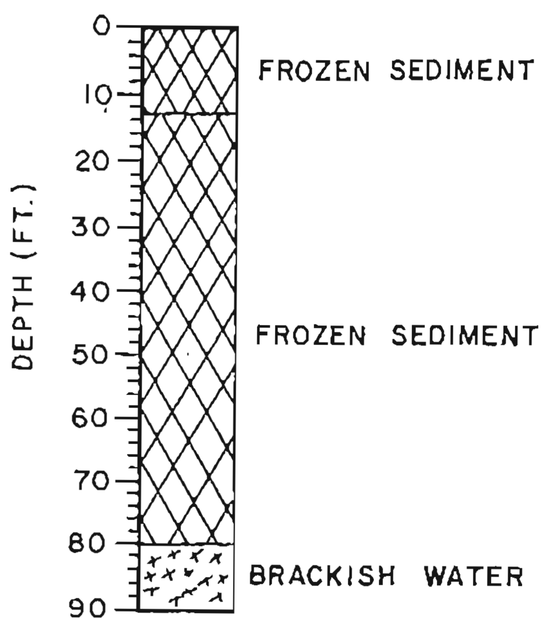
APPARENT RESISTIVITY (ohm-ft)
AB/2 (ft)
Depth (ft x 10)
RESISTIVITY (Ohm-ft)
for: CE2
by: Williams Consulting
Sounding: 10
Gambell Water
St. Lawrence Island, Alaska



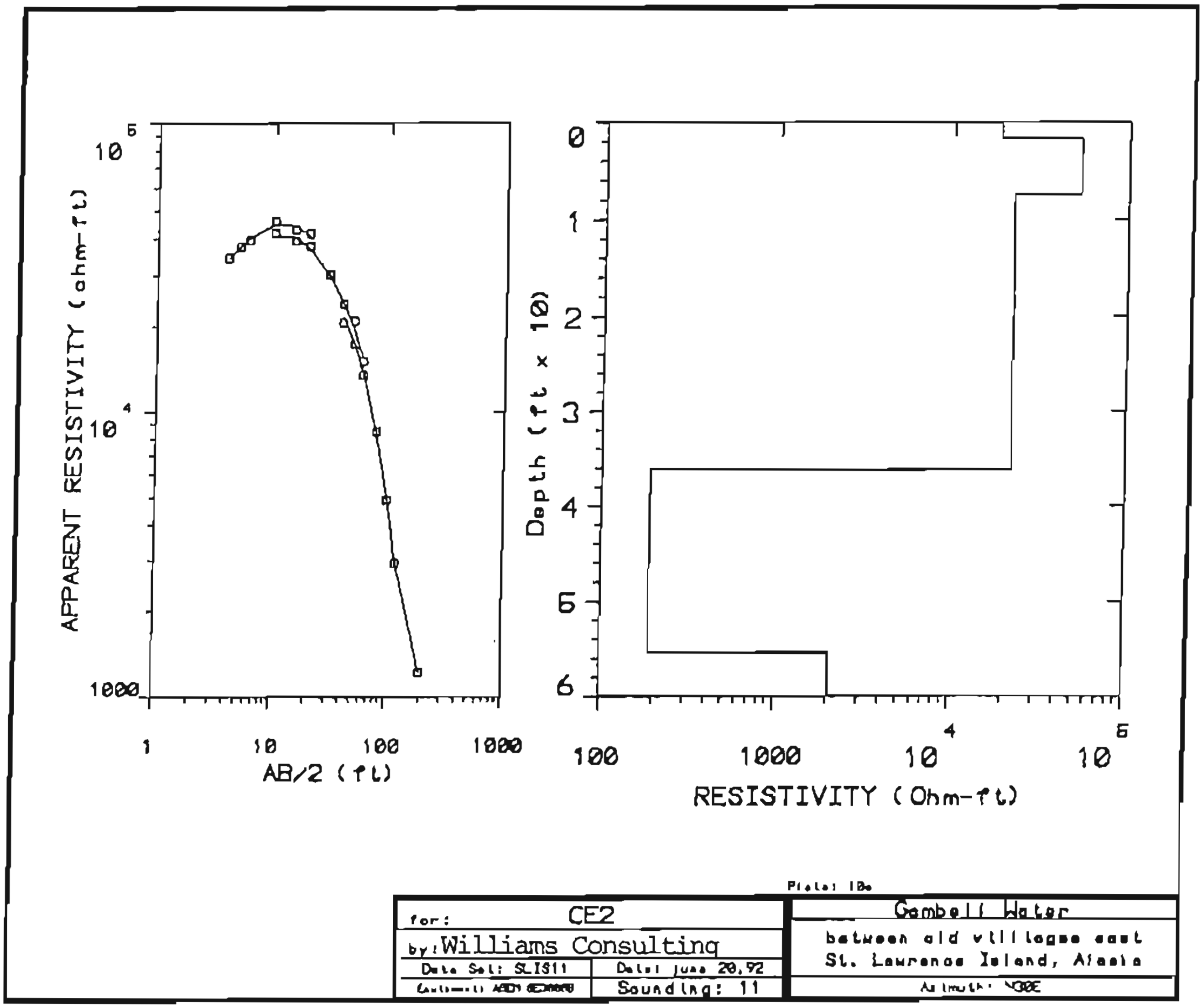
DRY GRAVEL
FROZEN SEDIMENT
SATURATED SEDIMENT
FROZEN SEDIMENT
DEPTH (FT.)

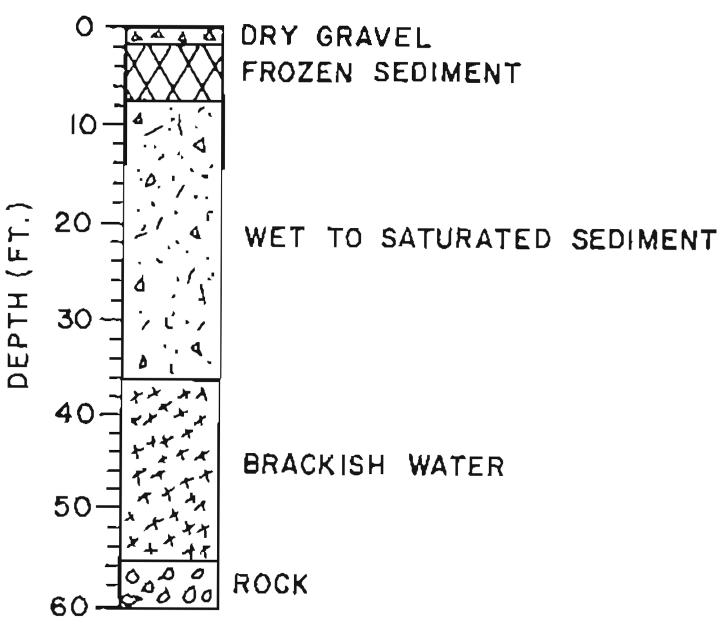
SOUNDING 10


APPARENT RESISTIVITY (ohm-ft)
SPACING (ft)
Depth (ft x 10)
RESISTIVITY (Ohm-ft)
Plate: 10a
for: CE2
by: Williams Consulting
Data Set: SLIW10
Date: June 28.92
Sounding: 10
Gambell Water
between old villages west
St. Lawrence Island, Alaska
Azimuth: N35E


DEPTH (FT.)
FROZEN SEDIMENT
FROZEN SEDIMENT
BRACKISH WATER

SOUNDING 10


APPARENT RESISTIVITY (ohm-ft)
1000
AB/2 (ft)
1
10
100
1000
Depth (ft x 10)
0
1
2
3
4
5
6
100
1000
RESISTIVITY (Ohm-ft)
Plate: 10e
for: CE2
by: Williams Consulting
Date Set: SLIS11
Date: June 20,92
Sounding: 11
Gambell Water
between old villages east
St. Lawrence Island, Alaska
Azimuth: N30E


0
10
20
30
40
50
60
DEPTH (FT.)
DRY GRAVEL
FROZEN SEDIMENT
WET TO SATURATED SEDIMENT
BRACKISH WATER
ROCK

SOUNDING 11

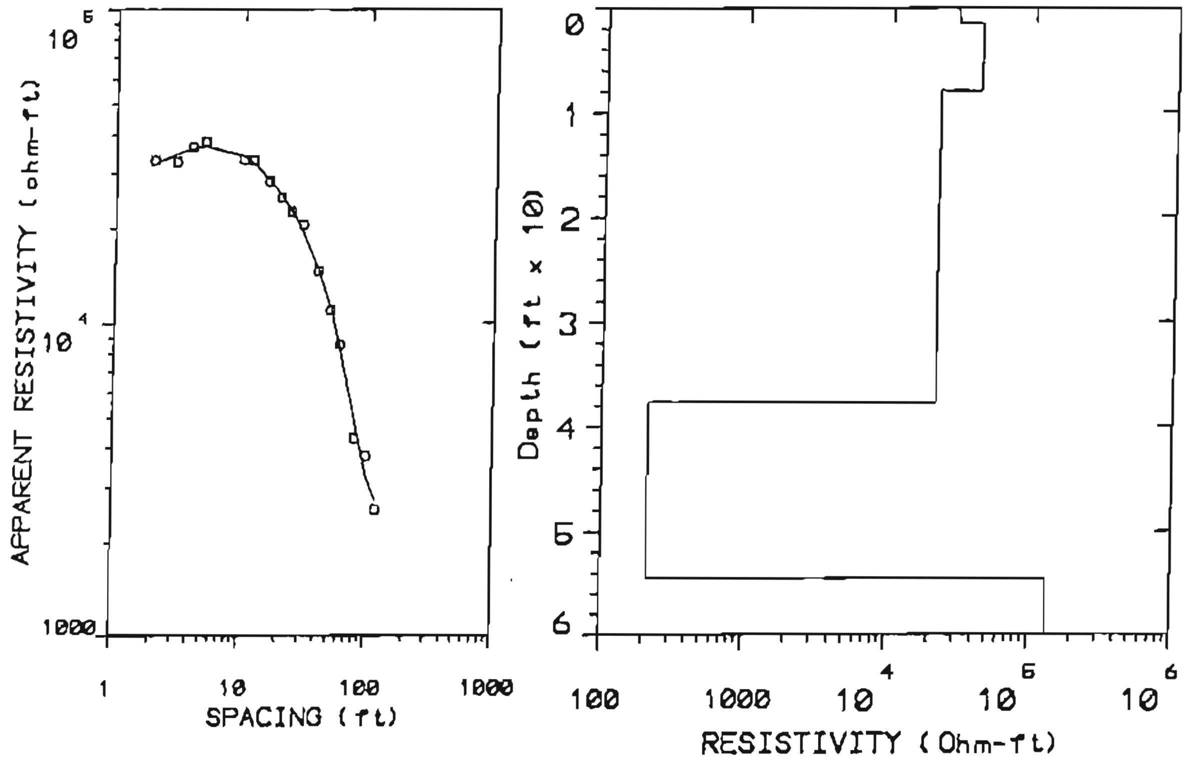
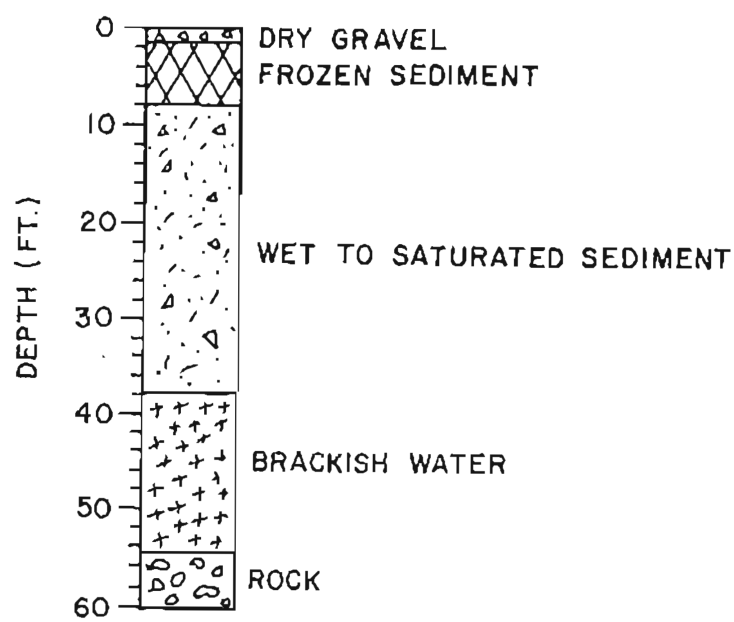
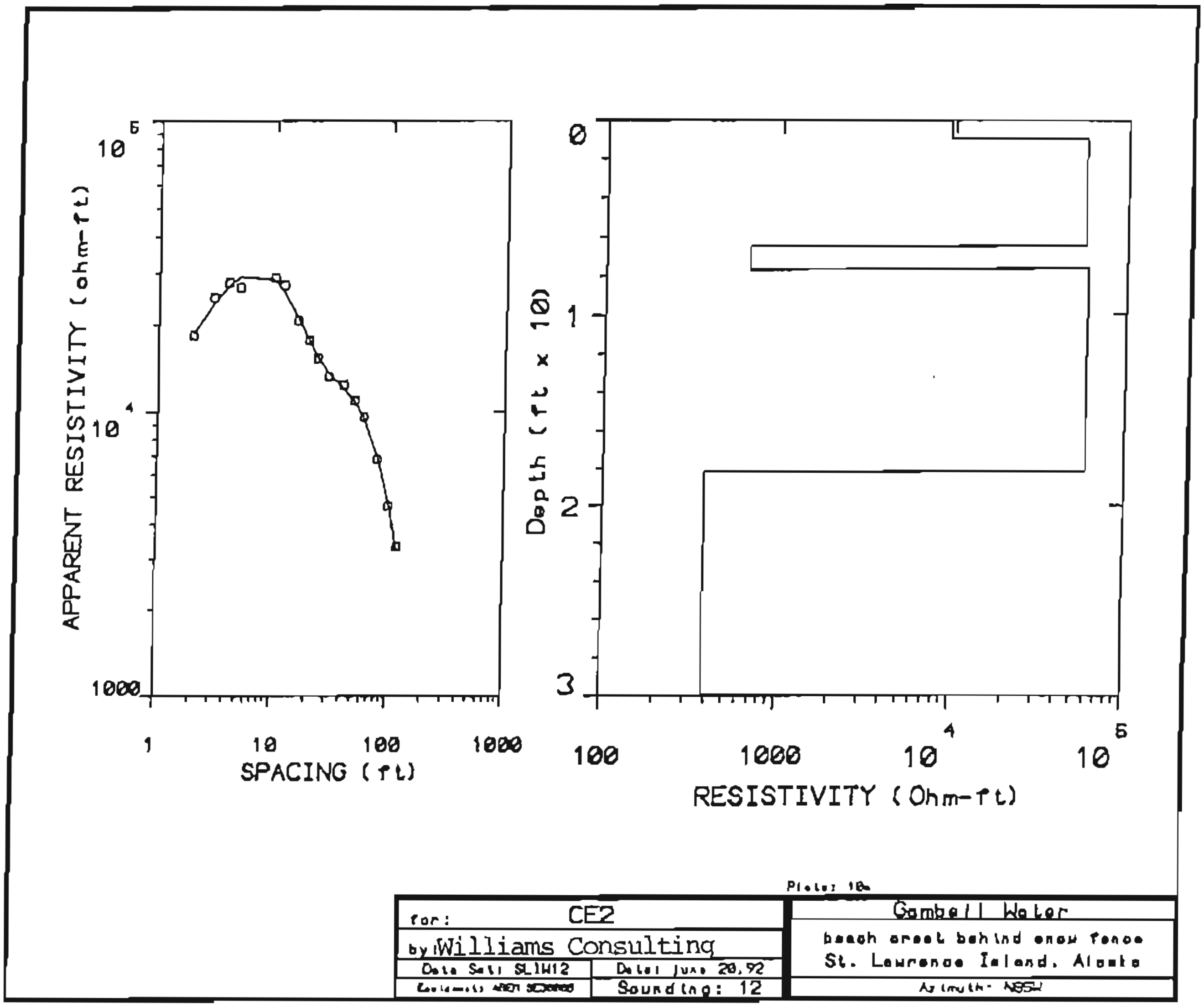


Plate: 10a

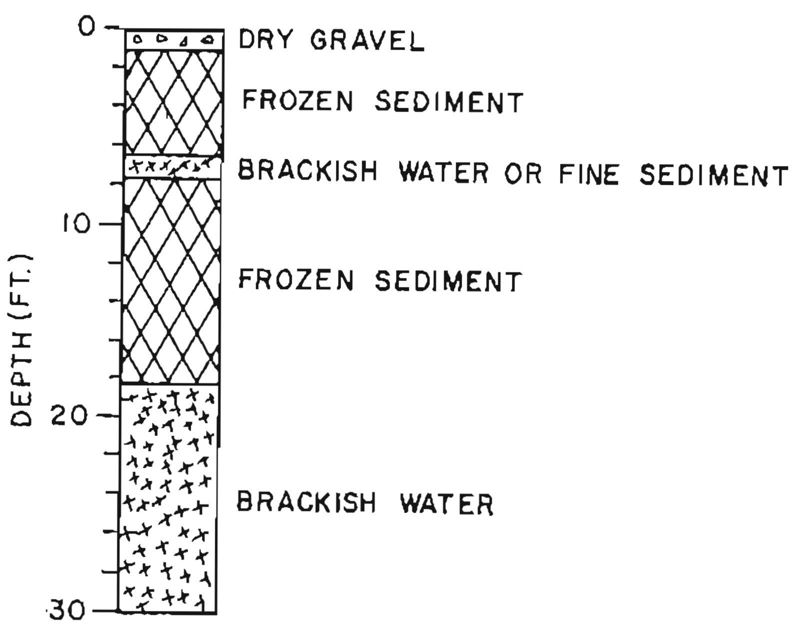
for: CE2	Gambell Water
by: Williams Consulting	between old villages east St. Lawrence Island, Alaska
Data Set: SL1W11 / Date: june 28.92	
Sounding: 11	Azimu'



SOUNDING 11

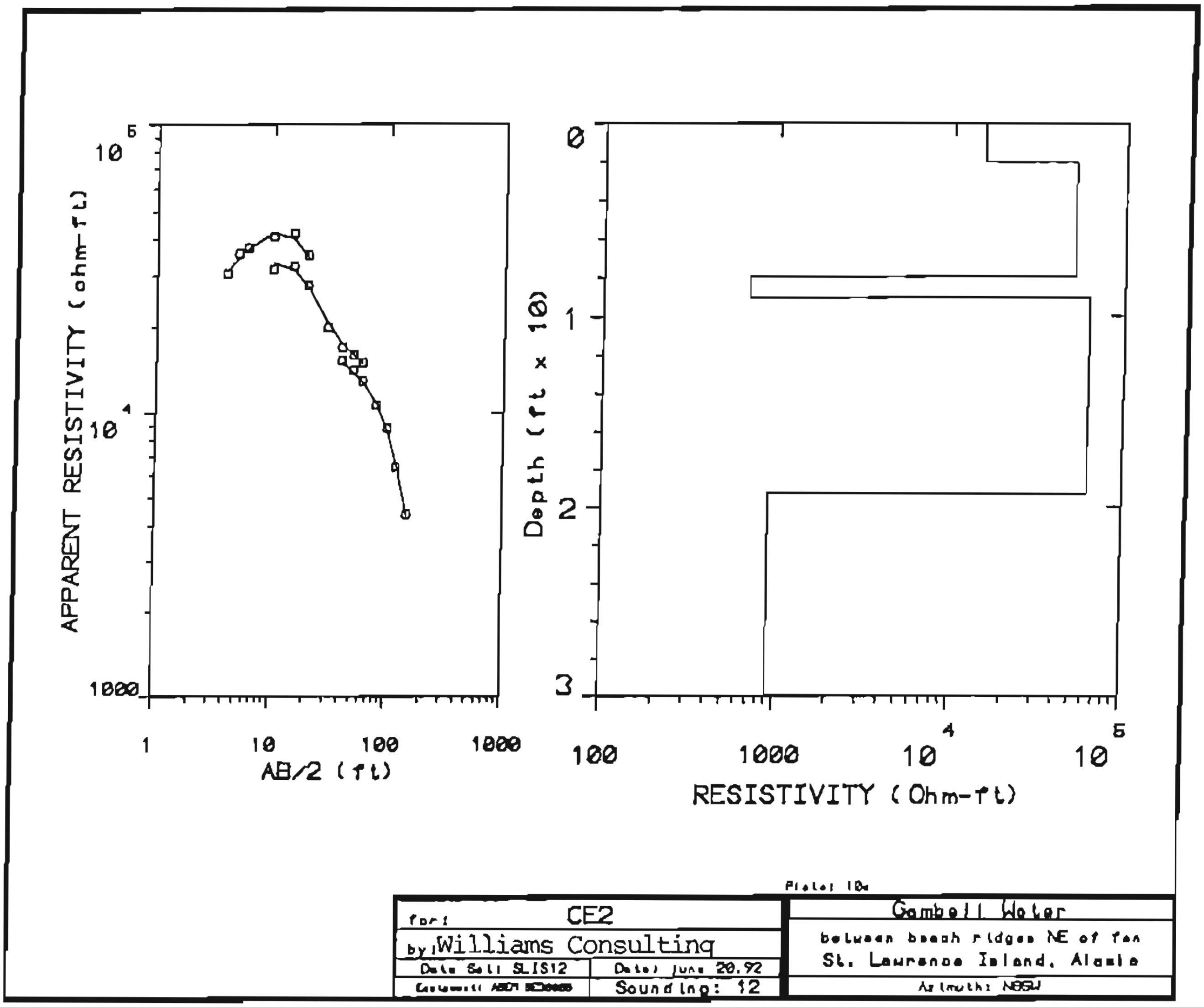


APPARENT RESISTIVITY (ohm-ft)
SPACING (ft)
1
10
100
1000
Depth (ft x 10)
0
1
2
3
RESISTIVITY (Ohm-ft)
100
1000
for: CE2
by: Williams Consulting
Data Set: SL1W12
Date: June 20,92
Sounding: 12
Gambell Water
beach crest behind snow fence
St. Lawrence Island, Alaska

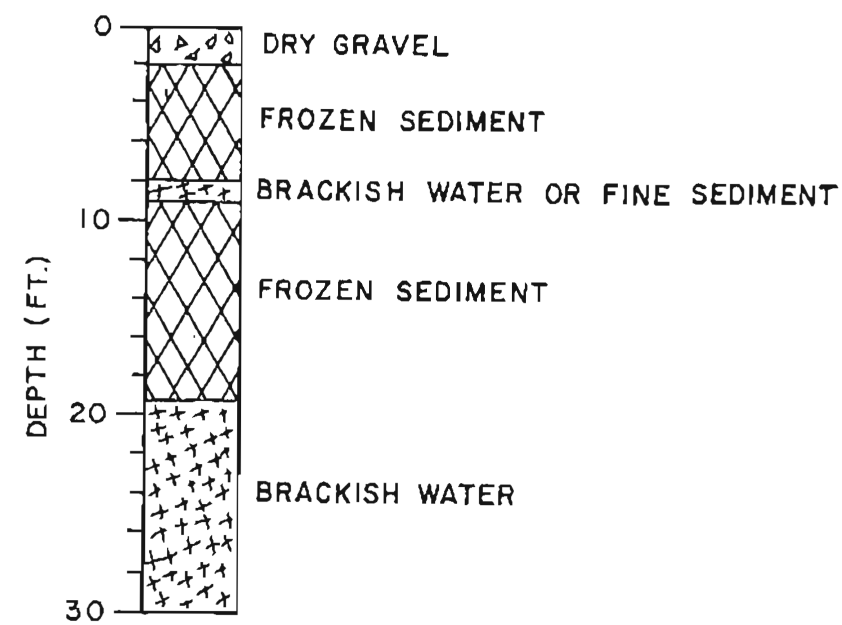


0
10
20
30
DEPTH (FT.)
DRY GRAVEL
FROZEN SEDIMENT
BRACKISH WATER OR FINE SEDIMENT
FROZEN SEDIMENT
BRACKISH WATER

SOUNDING 12

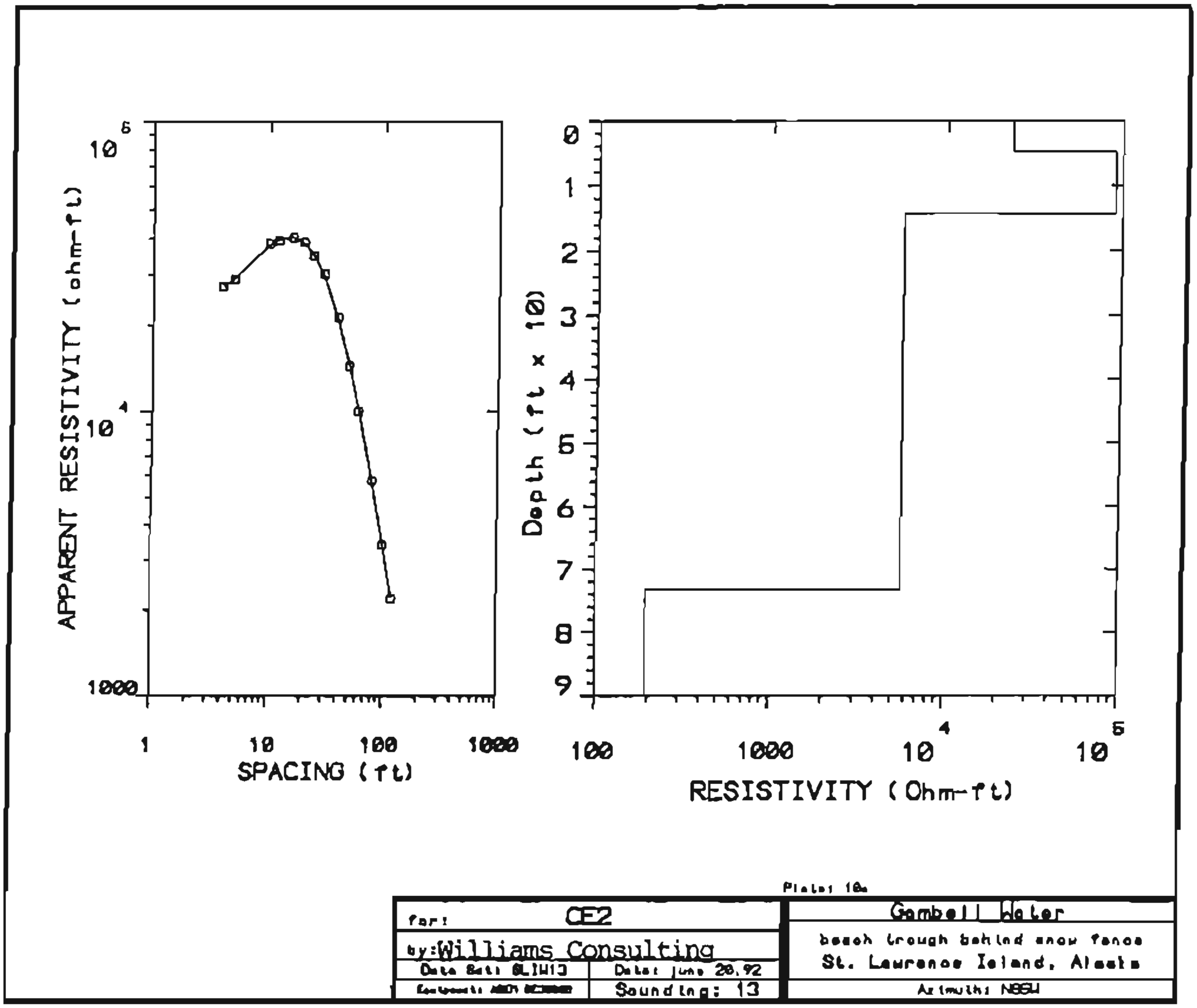


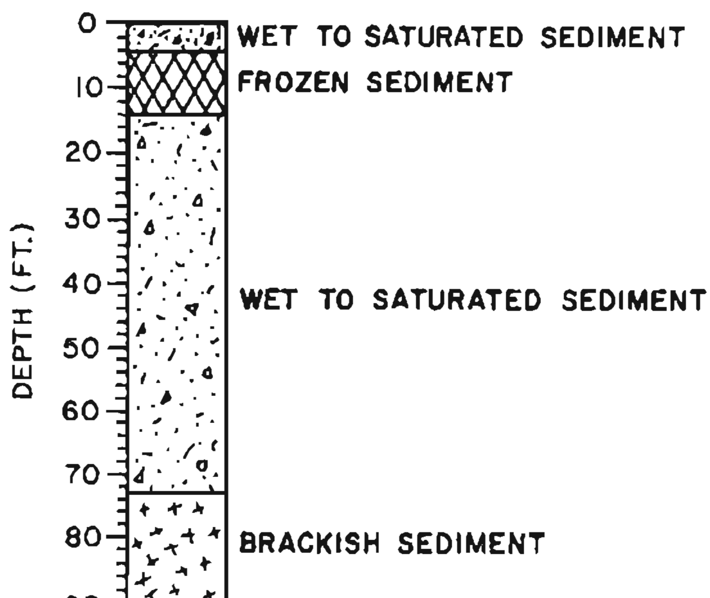
APPARENT RESISTIVITY (ohm-ft)
AB/2 (ft)
Depth (ft x 10)
RESISTIVITY (Ohm-ft)
for: CE2
by: Williams Consulting
Data Set: SLIS12
Date: June 20.92
Sounding: 12
Gambell Water
between beach ridges NE of town
St. Lawrence Island, Alaska
Azimuth: N85W



DEPTH (FT.)
DRY GRAVEL
FROZEN SEDIMENT
BRACKISH WATER OR FINE SEDIMENT
FROZEN SEDIMENT
BRACKISH WATER

SOUNDING 12


APPARENT RESISTIVITY (ohm-ft)
SPACING (ft)
Depth (ft x 10)
RESISTIVITY (Ohm-ft)
Plate: 10a
for: CE2
by: Williams Consulting
Data Set: GLIW13
Date: june 20,92
Sounding: 13
Gambell Water
beach trough behind snow fence
St. Lawrence Island, Alaska
Azimuth: N85W


DEPTH (FT.)
WET TO SATURATED SEDIMENT
FROZEN SEDIMENT
WET TO SATURATED SEDIMENT
BRACKISH SEDIMENT

SOUNDING 13

SCHLUMBERGER ARRAY

MN	AB/2	Resistivity
1	4	701 1 amp
1	5	492
1	6	373
1	10	173.9
1	15	92.9
1	20	54.2
3	10	363
3	15	192.2
3	20	112.9
3	30	5.60
3	40	11.56
3	50	10.41
3	60	4.39
10	40	66.4
10	50	59.9
10	60	85.6
10	80	88.9
10	100	153.9
10	120	149.7
10	150	51.8
10	200	63.1
30	120	
30	150	
30	200	
30	300	
30	400	
30	500	
30	600	
100	400	
100	500	
100	600	
100	800	
100	1000	
100	1200	
100	1500	
100	2000	

Sounding #: 13

Date: 6/20/92

Time Started: 13:15

Location: on flats behind high snow fence at tanks top of old beach ridge

Elevation:

Coordinates:

Bearing: N 85°W

Comments:

MN=1, AB/2

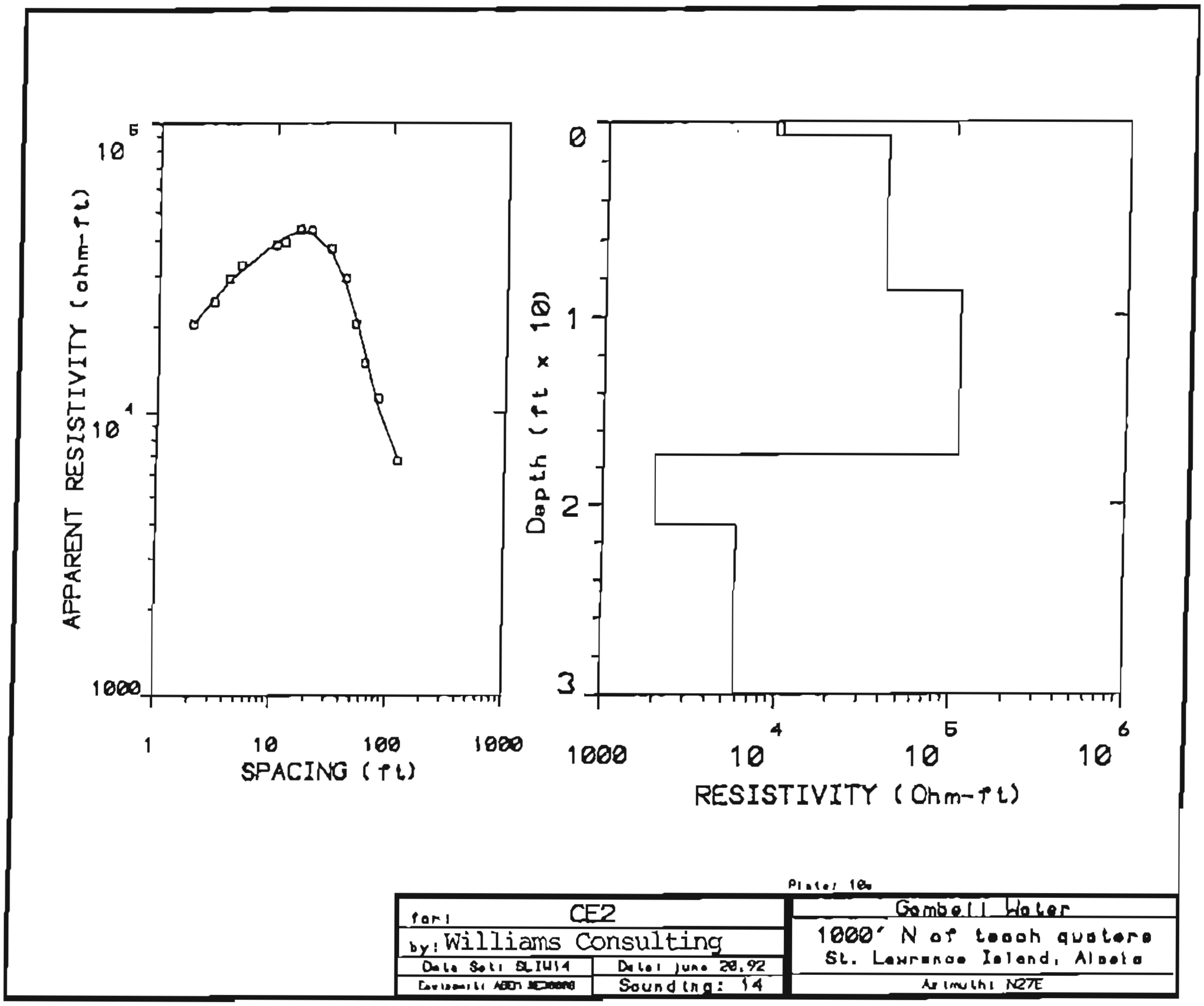
4	16,517
5	18,548
6	20,507
10	27,043
15	32,688
20	33,970

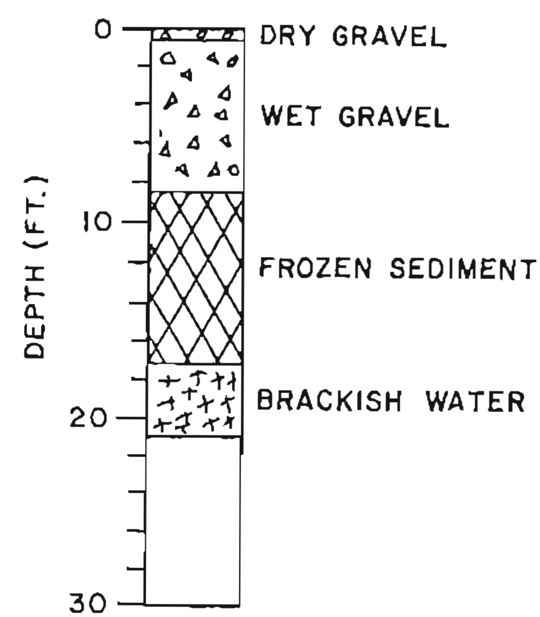
MN=3

10	17,296
15	21,737
20	23,114
30	2,613
40	9,630
50	13,578
60	8,254

MN=10

40	15,645
50	22,582
60	47,061
80	87,976
100	239,328
120	336,262
150	182,263
200	395,478


APPARENT RESISTIVITY (ohm-ft)
SPACING (ft)
1
10
100
1000
Depth (ft x 10)
0
1
2
3
RESISTIVITY (Ohm-ft)
1000
Plate: 10
for: CE2
by: Williams Consulting
Data Set: SLI414
Date: june 20,92
Sounding: 14
Gambell Water
1000' N of teach quaters
St. Lawrence Island, Alaska
Azimuth: N27E


DEPTH (FT.)
0
10
20
30
DRY GRAVEL
WET GRAVEL
FROZEN SEDIMENT
BRACKISH WATER

SOUNDING 14

SCHLUMBERGER ARRAY

MN	AB/2	Resistivity
1	4	636
1	5	465
1	6	369
1	10	16.78
1	15	88.5
1	20	56.0
3	10	385
3	15	201
3	20	126.8
3	30	58.7
3	40	27.5
3	50	20.7
3	60	11.34
10	40	80.1
10	50	58.7
10	60	31.1
10	80	11.41
10	100	6.05
10	120	4.04
10	150	1.59
10	200	1.58
30	120	
30	150	
30	200	
30	300	
30	400	
30	500	
30	600	
100	400	
100	500	
100	600	
100	800	
100	1000	
100	1200	
100	1500	
100	2000	

Sounding #: 14

Date: 6/20/92

Time Started: 14:50

Location: on flats ~ 1000' N of blue schoolhouse on east end of town

Elevation:

Coordinates:

Bearing: N 27°E

Comments:

MN=1

AB/2	
4	14,985
5	17,530
6	20,287
10	2,609
15	31,139
20	35,098

MN=3

10	18,344
15	22,733
20	25,959
30	27,385
40	22,909
50	26,999
60	21,322

MN=10

40	18,873
50	22,129
60	17,098
80	11,291
100	9,408
120	9,075
150	5,595
200	9,903