TEC-26

AMAX EXPLORATION, INC.
A SUBSIDIARY OF AMAX INC.

GEOTHERMAL BRANCH

INTER-OFFICE MEMORANDUM

SUBJECT: Hole 620-65, Livermore Project

DATE: Sept. 26, 1980

TO: W. Lodder
H. J. Olson

FROM: Jim Gross

Lithology

The hole was spudded into mixed landslide material near the bottom of James Creek. This thin mantle of debris consisted mostly of Franciscan formation graywacke but also had some volcanics, probably shed from nearby outcrops of the Sonoma Formation. The rest of the hole was drilled through a continuous section of Franciscan graywacke that is silicified in varying degrees. Metamorphism is not seen in any of the rocks cut, nor is it evident at the surface. Hydrothermal alteration is predominantly silicification and is manifested in veins and pore space flooding. More than one pulse of silicification is recorded in these rocks by the cross-cutting relations of silica veins. Both disseminated and vein pyrite are common. No cinnabar was observed in any of the drill cuttings despite the widespread occurrence of the mineral locally. However, the absence of cinnabar is to be expected since none of the major envionrments for mercury ore deposition (Yates and Hilpert, 1946) was encountered.

Structure and Fluid Movement

Known water zones at 1392' and 1547' are well defined since they were penetrated by air drilling. Both temperature and volume returned to surface were monitored. These two zones of hot water are probably fractures. They are not associated with such fault indicators as gouge, rock change, or mineralization. Decreased penetration at these water zones was observed but is not due to lithology change. Increased downhole pressure decreases the pressure gradient that drives the hammer, and consequently the hammer loses power. The sudden influx of water into the borehole, and the absence of a steadily increasing volume of water discharged argues for thin water zones controlled by fractures.

A water zone at 1650' below ground level is inferred on the basis of drilling response. The downhole hammer was flooded at 1660'. Unfortunately the volume of this water zone was not measured since the contractor immediately switched to mud drilling.

The isothermal interval in the hole is coincidental with a change in hole drift direction, and it is thought that the hole intersects a fault of the regional northwesterly trend at approximately 1750'. This level was also associated with a slightly increased drilling penetration rate. Cuttings were of poorer quality after switching to mud both because of their small size and because of recirculation of very fine material. It is not possible to document this fault with drilling cuttings.

The isothermal section of the hole from 1750' to 1950' may be due to the hole remaining in this fault zone for the 200' interval, or this may strictly be a borehole effect. It the latter is true water is running downhole to the identifiable aquifer at 1975'. This is believable since travel uphole would probably be blocked by cement. Drilling rates did not slow long enough to indicate a large fault, nor was there any circulation loss at this level. Also a 10' wide fault would likely have some surface manifestation. None was found.

The low gradient at the bottom of the hole below 2000' may be due in part to proximity to the above postulated fault and its circulating water. However, the straight line character of the temperature profile points to a less permeable section of rock transmitting heat by thermal conduction alone. Minor water movement is probably associated with the loss circulation zone at 2850'. This is probably cooler meteoric water percolating downward.

Hydrologic and thermal evidence suggest that 620-65 sits over a minor convective cell probably connected at depth to larger structural features such as the Corona or Oat Hill faults. Low volumes of water flow, dry rock uphole, and the appearance of water entries at varying temperatures indicate that warm water has reached the limits of its upward travel. Cooling thermal water begins to mix with meteoric water from above producing downward circulation.

Temperatures, Gradients

Two temperature logs have been run into the hole since completion. These two show nearly identical gradients. Thermal rebound is cooling above 500' and warming below this level.

The maximum temperature of 164.5°F (73.6°C) was recorded at bottom hole. Straight line approximations for gradient intervals were selected for both logs. They are recorded below.

1st log 8-3-80

interval	gradient	
1. 400'-1100'	4.81°F/100'	87.75°C/km
2. 1150'-1500'	5 90°F/100'	107.54°C/km
3. 2150'-2800'	1.31°F/100'	23.84°C/km

2nd log 8-21-80

1. 300'-600'	5.25°F/100'	95.69°C/km
2. 700'-1000'	5.17°F/100'	94.17°C/km
3. 1075'-1300'	6.04°F/100'	110.17°C/km
4. 1350'-1500'	5.87°F/100'	106.93°C/km
5. 2050'-2750'	1.24°F/100'	22.52°C/km

Conductivities, Heat Flow

Needle probe conductivity measurements were done by Dave Blackwell for 16 samples from 100' to 2800'. Table I shows the measured values. Figure 5 shows conductivity with respect to depth. This graph shows a wider range of k values for air drilled samples than for mud drilled samples. It also shows lower values for the mud drilled samples.

Several interpretations can be made from Figure 5. It can be seen that not all air drilled samples fall within the claimed 10% accuracy of needle probe techniques. Therefore the trend for decreasing conductivity in the air drilled interval is probably real. Since microscope observation of these samples shows very little variation, this trend is attributed to decreasing silicification. Note that maximum silicification would fall around 700'; approximately 700' higher than the first observed hot water.

Geothermal waters did reach ground level some time in the Tertiary as evidenced by local cinnabar deposits, and at one time they were probably shallower below hole 620-65. It is inferred that the geothermal system that exists locally is ebbing, probably by sealing of conduits but possibly also by dissipation of the thermal source.

The close agreement of conductivity values for mud samples is somewhat artificial. The thick mud used to drill this interval tended to homogenize cuttings by recirculating them and selectively removing only the larger cuttings. Also the presence of drilling mud itself (a clay) may be partly responsible for the lower values.

Heat flow calculations for the interval above the penetrated convective system are somewhat academic. However, it is well to note that the previously determined surface heat flow for this area agrees with the measured gradient and conductivity. A surface heat flow of 7.5 is the result of hot water at 1400-1550'. The calculated heat flow for the rocks below 2000' is quite low. The arithmetical mean conductivity has been corrected 5% upward for possible mud contamination, and a value of 7.0 is used. Heat flow is 1.6 for a gradient of 23°C/km.

The most recent surface heat flow map for the Livermore property shows the correspondence between geology and high heat flow. The heat flow high sits over the outcrop of Franciscan Formation, and isoflux lines nearly parallel the Oat Hill and Corona Fault traces. Steeply dipping faults and low primary permeability constrain water movement to a predominantly vertical direction, generating the heat flow high. Surface heat flow over the outcrops of Sonoma volcanics is lower than over the Franciscan. This is probably the result of hydrologic conditions in the volcanics. These rocks probably carry meteoric water more rapidly and uniformly, flushing heat downward and laterally. Heat flow at the surface of the Sonoma-Franciscan contact at depth would quite likely be the same as seen at the bottom of 620-65. Thus no geothermal reservoir is envisioned to account for heat flow patterns.

Conclusions

Surface heat flow patterns are largely the result of geologic and hydrologic parameters. A reachable high temperature (electrical) geothermal reservoir is not seen in the model for this property. No further work is recommended for the Livermore property and, because of high expense, leases should be relinquished.

Jim Gross

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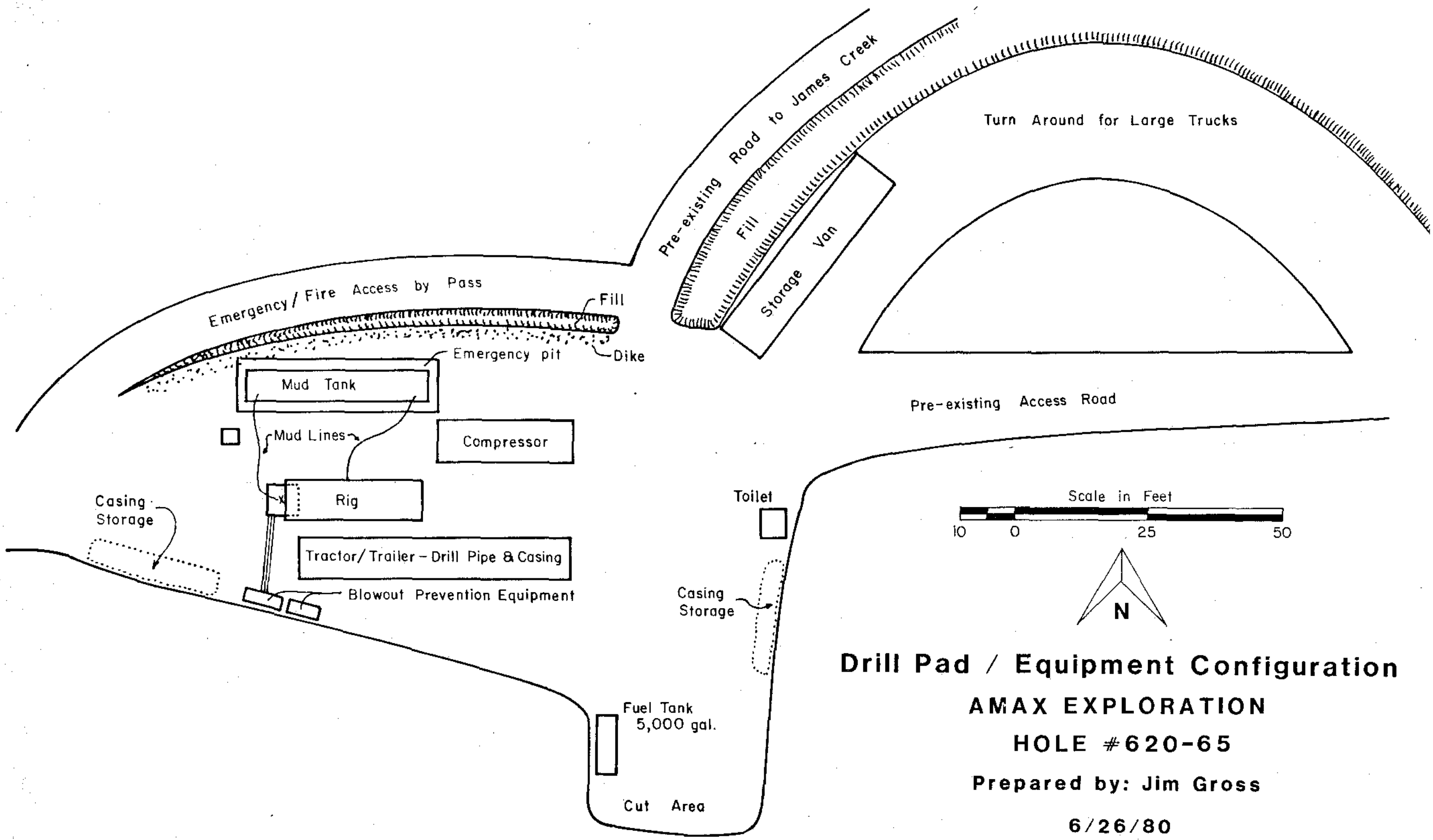


Drill Pad / Equipment Configuration

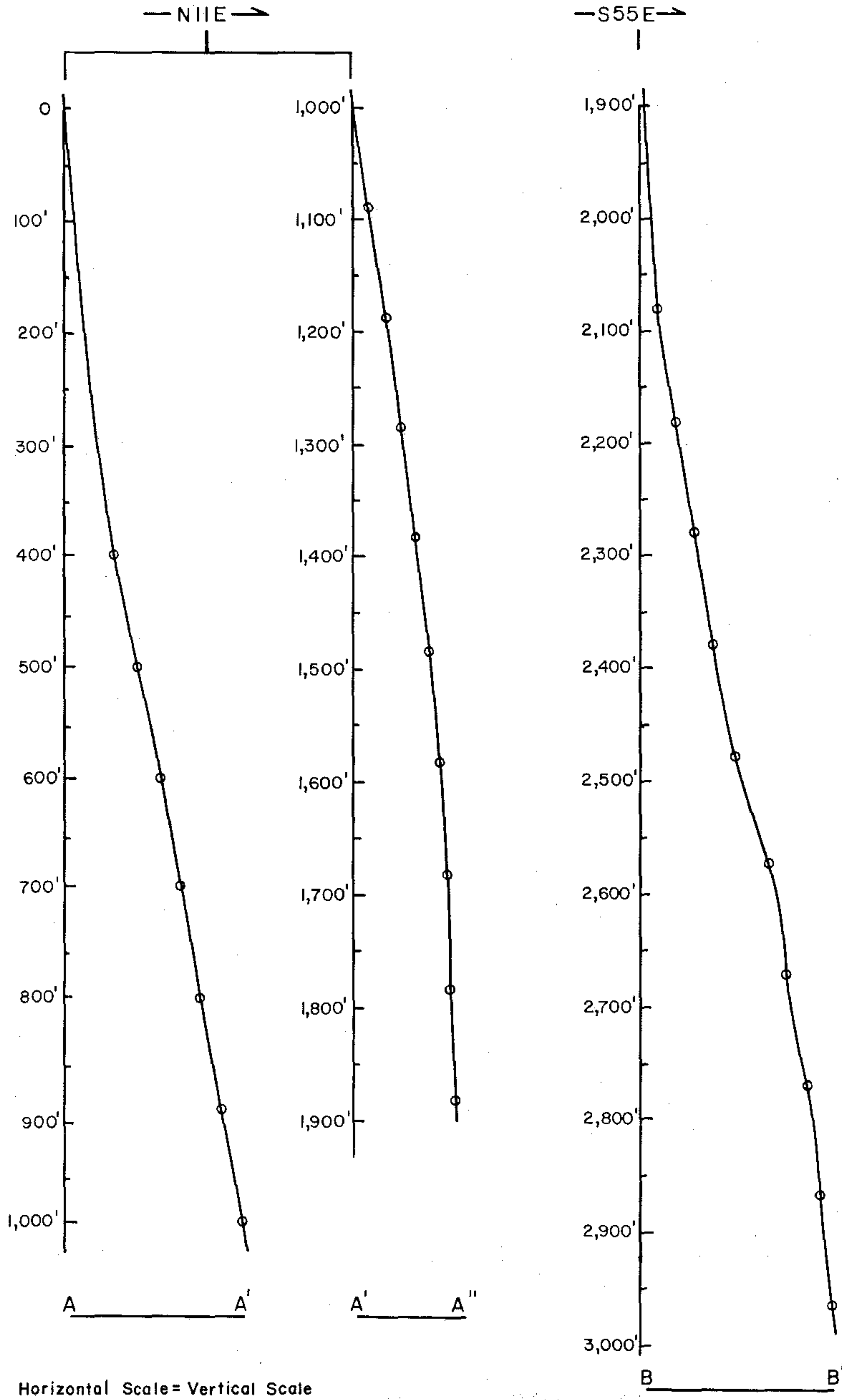
AMAX EXPLORATION

HOLE #620-65

Prepared by: Jim Gross

6/26/80

FIGURE 1



Horizontal Scale = Vertical Scale

FIGURE 2

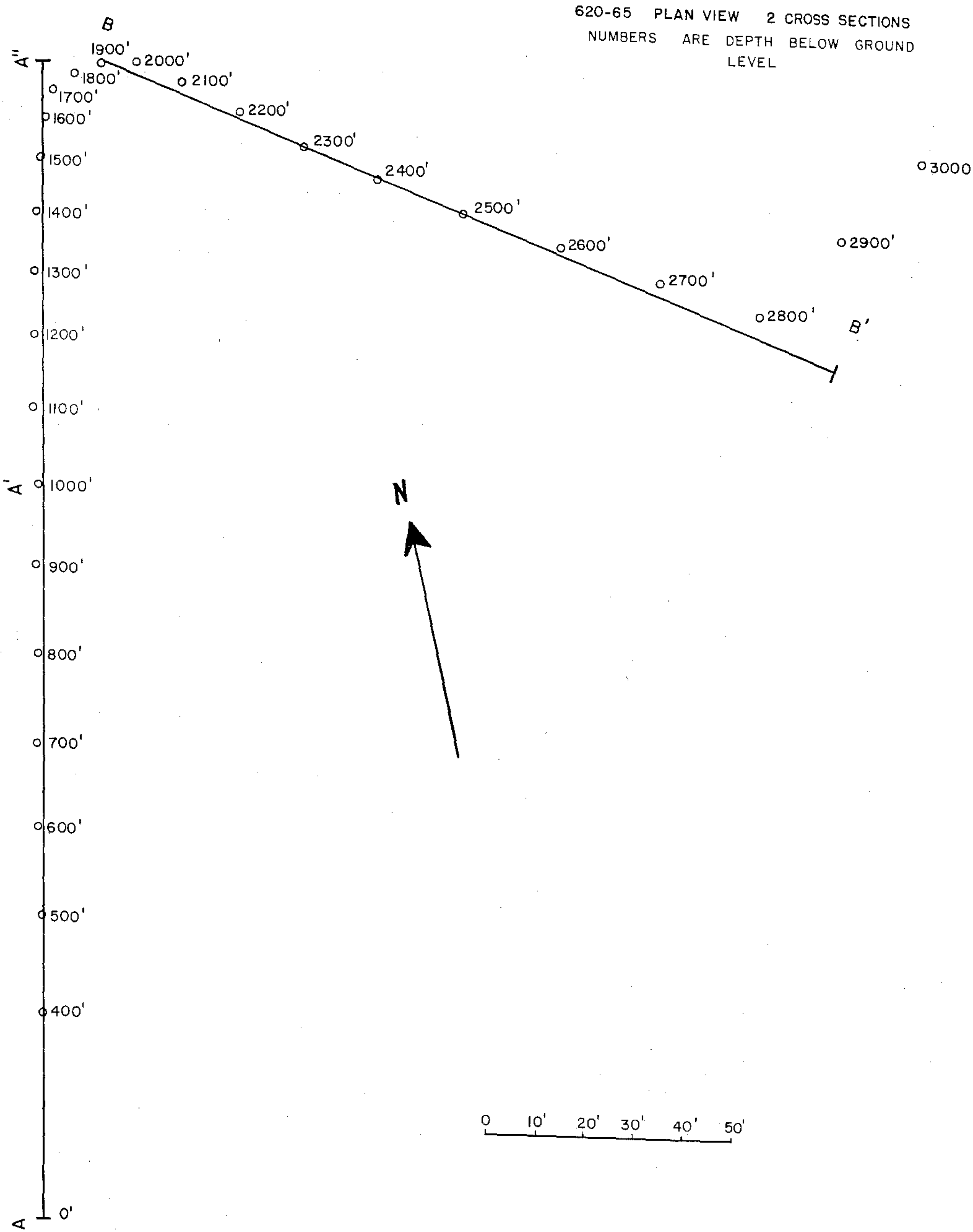

620-65 PLAN VIEW 2 CROSS SECTIONS
NUMBERS ARE DEPTH BELOW GROUND LEVEL
B
B'
A
A'
A''
0'
400'
500'
600'
700'
800'
900'
1000'
1100'
1200'
1300'
1400'
1500'
1600'
1700'
1800'
1900'
2000'
2100'
2200'
2300'
2400'
2500'
2600'
2700'
2800'
2900'
3000'
N
0 10' 20' 30' 40' 50'

FIGURE 3

620-65 PLAN VIEW 2 CROSS SECTIONS

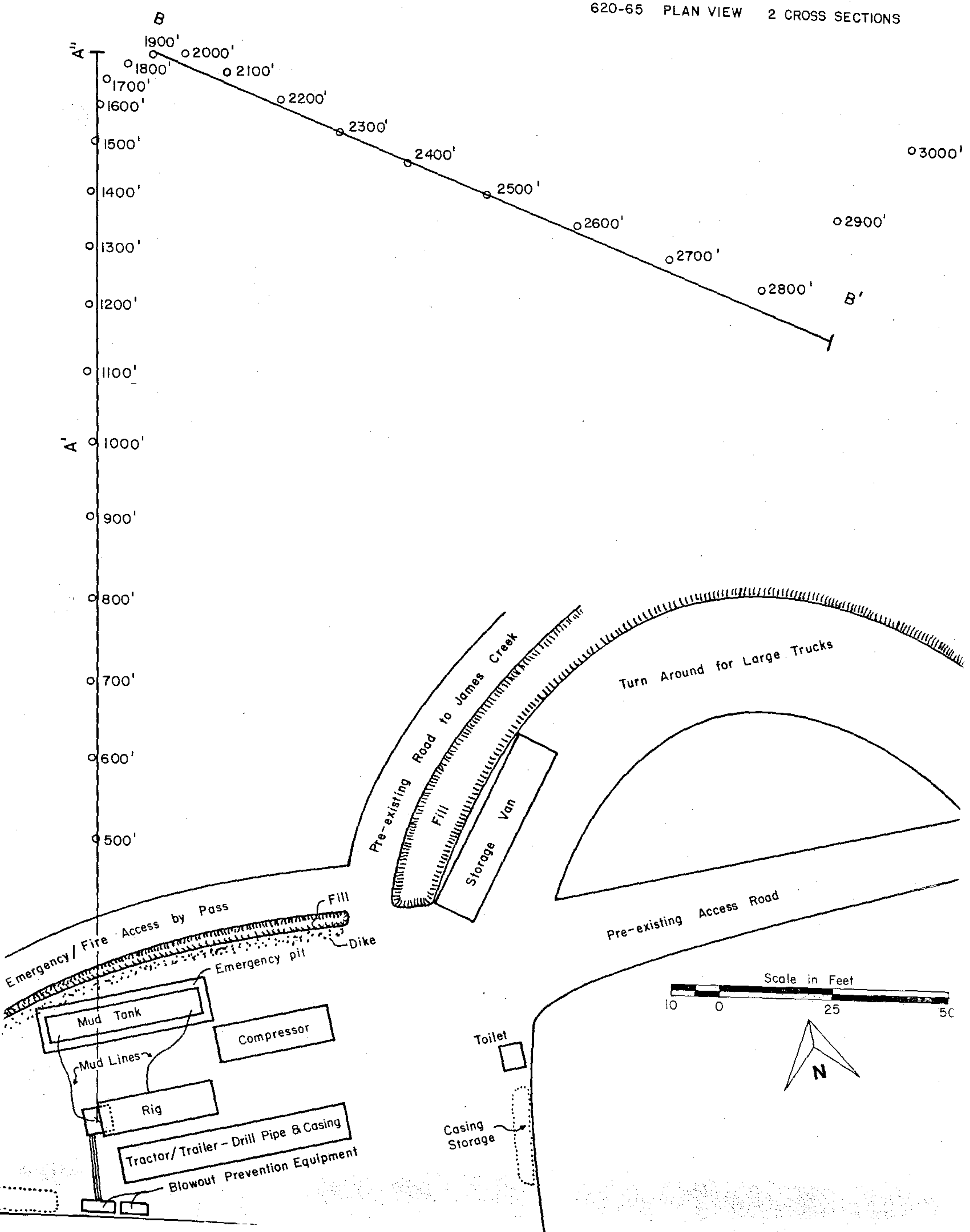


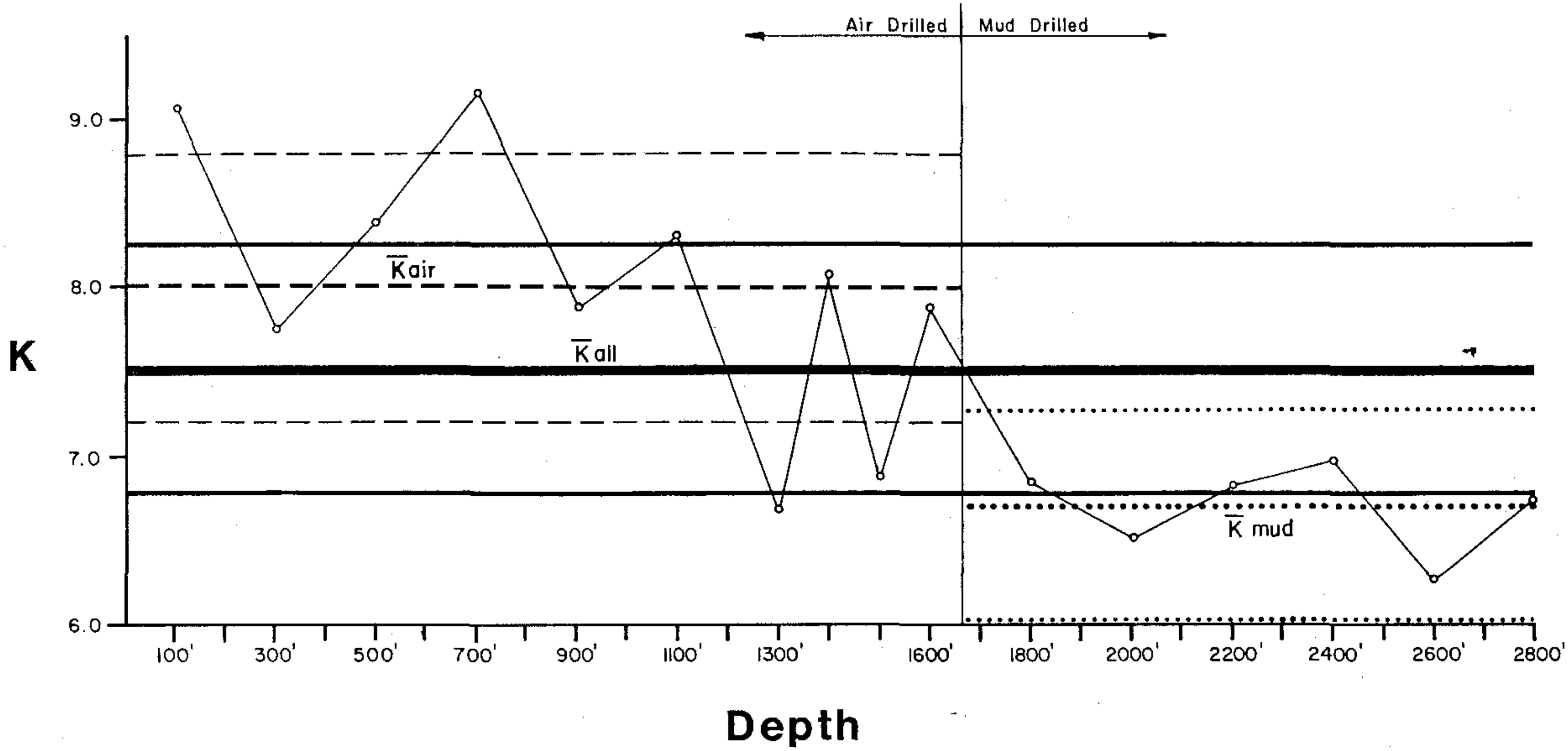
FIGURE 4

Conductivity Values Determined by Blackwell
For Hole 620-65

Depth	K
100'	9.07
300'	7.73
500'	8.39
700'	9.19
900'	7.89
1100'	8.32
1300'	6.69
1400'	8.09
1500'	6.87
1600'	7.90
1800'	6.85
2000'	6.52
2200'	6.83
2400'	6.98
2600'	6.25
2800'	6.75

Table I

Conductivity vs. Depth
Hole #620-65



o Thermal Conductivity Sample

K̄ Arithmetical Mean for Interval Shown

10% Accuracy Boundary About Arithmetical Mean.

FIGURE 5