ANNEX C GEOLOGY AND GROUNDWATER

ANNEX C GEOLOGY AND GROUNDWATER

CONTENTS

LIST OF TABLES

LIST OF FIGURES

ANNEX C GEOLOGY AND GROUNDWATER

C.1 An Outline of the Geological Features of the Santa Ana Area

Geologically, the district of Santa Ana and the surrounding hills are composed of alternating layers of sandstone and mudstone that were deposited over a period extending from the Carboniferous to the Silurian periods of the Paleozoic era.

On the whole, there has been relatively little deformation, and there are only a few places where the sandstone has turned into phylite.

Since the hills in the area are all very steep, weathering has been minimal. There are many areas where rocks are exposed.

In addition, the tectonic line running from the N - NE to S - SW is well developed and, influenced by this, the strike of the entire strata is parallel to it. The inclination is N 10^{o} - 20^{o}, and in the east the strata ranges from slightly tilting to the west to being essentially vertical. However, in Cerro Barbecho, Cerro Gamoneda, and other areas to the west, there are many places where the degree of inclination is a somewhat smaller (20^{o} - 30^{o}).

The area extending from around Santa Ana river (the upper stream region is Yesera river) towards the east, with its 80^{o} - 90^{o} inclination, is distinctive as it is close to being vertical, like the areas mentioned above.

Along the valley through which the Yesera river flows down from the northern end of the area to around the spot where the dam is planned, there is a succession of bluffs and exposed rocks. This makes it easier to determine the geological structure, sedimentation process, weathering conditions, and presence and scale of faults and fractures. The approximate inclination of the strike is N 10^{o} - 20^{o}, E 70^{o} - 90^{o}, and W vertical.

Although there are parts with intense folds, or broken by faults or areas that have suffered severe cracks, the overall condition of the entire region is similar.

Terraces formed by lakes and rivers, dating from the Quaternary period, and volcanic deposits are widely distributed and cover parts of the plateau (the hill areas).

The formation consists of alternating layers of course sand, sand, silt, and clay, partly mixed with volcanic ash. On close examination, it is found that layers of silt, clay, and such that consist of fine grains are more widespread than those of course sand and others that are made up of coarse grains. But in the area extending from Santa Ana to the surrounding areas of Santa Ana Dam, the ratio between the two kinds of layers changes to being half-and-half, or it is completely reversed with fine-grained layers becoming more frequent. These findings were the result of test drillings, the study of exposed rocks along the river and cross-sections of the formation.

The existence of at least three terraces is acknowledged.

Two are near the upper stream, around Santa Ana Dam on the Yesera river, and one is downstream along Santa Ana river. In addition, terraces situated lower down and formed by sediments currently being deposited on the river bed continue in unbroken succession along both sides of the river. These terraces on lower ground contain a large amount of fine grains, making them ideal for cultivation. Also, the ground-water level is close to the surface, which makes cultivation possible during periods of drought.

C.2 A Summary of the Geological Comparison of Dam Sites

2.1 The Downstream Regions of Yesera

Geologically, downstream of the Yesera district is made up of alternating, thin layers of sandstone and mudstone (partly turned to phylite), dating from the Silurian period of the Paleozoic era. The inclination is N 5^{0} - 10^{0}, E 85^{0} - 90^{0}, and W strike. Exposed solid rock covers the bed and both banks of the river. There are a few faults and fracture lines. The bottom of the river has a solid foundation, eliminating the need for excavation. Refining alone should be sufficient. In addition, the foundation is of such a well consolidated, fine quality rock as to make Cuatin Grout unnecessary in case a dam is constructed.

The upper parts of both banks of the river have been weathered to a dark reddish brown color, and there are also a large number of cracks. Since the layer of mudstone is very thin, it can easily be peeled off along the bedding. Although it has undergone fragmentation, a foundation of solid rock can be reached at a depth of 2 - 3 meters.

The area intersects with the axis of the dam at around 15^{0} - 20^{0}.

It will depend on the height of the dam, but supposing the height to be 35 m (maximum), it may be necessary to build a number of secondary dams on the upper reaches of the right bank of the river. The foundation of this area is also made up of alternating thin layers of sandstone and mudstone, but by excavating to a depth of only 2.0 m, sufficiently strong foundation is reached, and it should not present any problems.

In any case, the geological structure of the area is strong enough to allow the construction of a dam that, in the case of a gravity dam, could be as high as 40 m; that is, almost as high as the canyon walls.

However, in the case of this dam site, about 50 m from the embankment there are a number of successive fault fracture lines, starting downstream, and the area is weakened by severe weathering. Moreover, there are many places in the vicinity, such as to the west and east, where rock foundations have undergone displacements ranging from 1 - 2 m or much higher. This is due to the effect of reversed faults, having a westerly upthrow, that are part of a chain of small faults in the area. There are some low saddles downstream, along the right bank of the river; this region, too, is part of the above-mentioned belt of faults. The advance of erosion has caused depressions to appear.

However, the construction of a dam a few meters high should not pose any problems.

2.2 The Upstream Regions of Yesera

The geological features of the area in the upper stream regions of Yesera are entirely the same as those of the area downstream.

There is a succession of alternating thick layers of grayish brown sandstone and thin layers of mudstone, dating from the Silurian period of the Paleozoic era. These single layers with a thickness of 0.5 m minimum to 5.0 - 6.0 m maximum have partly turned to phylite. The inclination is N 10^{o} - 20^{o}, E 80^{o} - 90^{o}, and W strike. The walls of the valley are covered by exposed rock of good quality.

The strata lie at a right angle to the river.

There are a large number of cracks and joints in the sandstones, and they grow wider towards the upper parts of the valley walls. However, their width is only a few centimeters, and the depth is only 10 - 20 cm. Since the cracks are comparatively small, foundation-making should present no problems.

The weathering of the mudstone parts in the upper reaches of the canyon walls is naturally more severe and there has been erosion, though only 2 - 3 m. Excavation and refining to a maximum of 4 - 5 m should prove to be enough to obtain an excellent quality rock foundation.

In the areas that must have formed the embankment, the usual river bed deposits, such as boulders, cobble stones, and fine gravel, can not be found. The same can be said about the other dam sites that will be discussed later. Naturally, the slopes in this area, unlike the slopes of the river gorges in the other areas up- and down-stream, are steep.

In short, the parts of the gorge that consist of solid rock are narrow, deep, and sharply descending. Since the foundation for the embankment will have to decline backwards at a comparatively steep angle, the problem of stability will need special consideration during the process of refinement and excavation.

2.3 The Santa Ana Region

2.3.1 Topographical Study

The geological structure of the area around Santa Ana, as shown in Fig. C.2.1, consists of sandstone and mudstone bedrock dating from the Silurian period. On top of this, extending from a southerly direction towards the east, are layers of gravel, sand, and clay dating from the Quaternary period. These are overlaid by layers of a similar combination dating from the Pleistocene epoch, which have given rise to the low and flat hills found in the region.

In addition, along the Yesera river and towards the north, there are numerous sedimentary hills, some high and some eroded to medium size. Some smaller hills are also scattered near the north of the area close to the bridge over downstream Santa Ana river, between the upstream side and the dam. From the distribution of these hills and a study of the diameter and solidity of the grains of gravel in the layers that make up the deposited sedimentation, the following conclusions were made about the layer if sand found in boring No. 3 up to a depth of 30 m. The old Yesera, flowing through the southeast of the projected site of the dam, deposited the layers of gravel (Quaternary period). It then changed its course and, winding its way through the area east of the Santa Ana Dam, followed a course quite similar to its present one and formed the hills scattered in the regions lying between the downstream and upstream areas of the projected site. The layers mentioned above were deposited as a result of erosion at the time.

This means that conclusions drawn from the study of the basin (thought of as the old channel of the river) at the start of the survey and those drawn from the study of the deposition environment are the same.

2.3.2 Geological Studies

The Santa Ana region was pointed out by the CODETAR survey as the most suitable site for a dam on the Yesera river. The formation consists of alternating layers of sandstone and mudstone, with layers of mudstone being the more prevalent. The inclination is N 5^{o} - 10^{o}, E 85^{o} - 90^{o}, and S strike. The sandstone is dark brown with fine or medium-fine grains mixed with mica and similar material. It is well hardened but has many cracks and joints. The newer layers are bluish gray and form a good quality bedrock with few cracks and joints. The layers, ranging in thickness from 5 - 20 cm to 2 - 3 m, alternate with layers of mudstone.

The mudstone has been weathered up to 2 - 3 m and is weakened by fragmentation. Those on the river bed, however, have few joints and cracks, are quite hard, and are bluish gray. Layers 1 to 2 meters thick, forming phylite, and up to 20 to 30 meters or more in thickness extend with the breadth range of 3 to 5 meters or 7 to 8 meters.

The inclination of the strike for both banks is almost the same, but a fault fracture line, running from an area about 3 m upstream on the right side of the old axis to about 20 m upstream on the left bank, cuts through the axis diagonally. The fault has a wide fracture line that gets wider at its top. It is on top of a hill on the right bank and 3 - 5 m wide. The walls stick together, and there is almost no traces of fault clay or similar material.

However, the rock bounded by the fault has undergone folding to an extent of 8 - 10 m. Also, there is a small gorge on the right bank, about 60 m from the old axis, but the spot consists mainly of mudstone fractured by a fault running from the north to south. Especially, the side downstream has been affected greatly, and there has been severe weathering. (Some sources call this folding). Seemingly as a result of this, the entire downstream regions of the right bank have suffered severe weathering and are weakened. Though the foundation base of the left bank around EL 80 - 90 m to the regions downstream lies exposed, it is comparatively hard. On top of this foundation, widely distributed, are hard and well consolidated layers of gravel and clay, dating from the Diluvium epoch, with a maximum thickness of 3 - 5 m. These layers are deeply buried horizontally along the old river channel and along the gorges in the area, and their angle of inclination ranges from horizontal to a 3^{o} - 5^{o} SE inclination. A visible layer of maximum thickness can be seen about 130 m upstream from the junction of mountain torrents along the left bank. About 80 m upstream from the old axis it forms a cliff, rising from the bottom of the canyon, about 30 - 40 m high. This clearly vertical cliff is made up of layers of gravel, sand, and clay. Its foundation rock is loose to an extent and rises towards the southeast. The thickest part is less than 50 m.

Through the electric explorations of the CODETAR survey, the thickest parts on the old axis were found to be 35 m at probing point No.7, 40 m at point No.9, and 30 m at boring hole No.3. However, the survey does not clarify conditions relating to the southern extension of the region. Moreover, the report does not discuss the origins of these deep river roads and gorges, and it is for this reason that the present analysis is of great importance.

2.3.3 About the Faults and Fracture Lines along the Right Bank

Running from around the old axis of the dam to the surrounding area, and extending from the upstream regions of the right bank to the upstream regions of the left bank, there is a reversed fault that cuts diagonally through the river. The fault inclination is N 38^{o}, W 60^{o}, strike W and N 40^{o}, W 60^{o}, strike W in the middle, and N 12^{o}, W 66^{o}, strike W, N 36^{o}, W 38^{o}, strike W, land N 18^{o}, W 60^{o}, strike W in the lower parts. Causing a large number of displacements (5 - 6), along the way, it reaches down to the bottom of the river.

Though the displacement angle is different in each case, the sides in each displacement stick together and there is no fault clay. This fault seems to be the main reason for the presence of a reverse fault in the upper parts. It lies partly horizontal and partly inclined, the inclination being most prominent on the east bank N 32^{o}, W 32^{o}, strike E, N 50^{o}, W 20^{o}, strike E. It is a very irregular, small reversed fault that grows wider at the top as it rises. (There is strong evidence to suggest that an upthrust was the prime factor in its formation. It seems to have been produced as a result of the sideway compression that accompanied the formation of the large fault.)

As a result, in case the old dam axis is utilized, almost the entire area on the right bank, extending from the fault towards the river, will have to undergo 10 - 20 m of excavation. Even if the amount of excavation of the area is reduced, the foundation making of its lower part will be quite large.

If the dam axis is moved about 20 m downstream, the area deep inside the mountains on the right bank is reached. Thus, foundation-making should prove to be less of a problem.

Even if the new dam axis is decided upon, however, it will be necessary to perform adequate excavation work on the severely weathered parts of the large number of shirred sides that lie slightly elevated towards the area downstream. These were the result of the fault formations discussed above. If not that, then at least it will be necessary to use more than 4 - 5 m of contact grout along with consolidation grout.

No investigations using drilling had been performed on the right bank, and there are no exploratory edits. For this reason, an adequate analysis of the above points is not available. If plans are actualized, it is desirable that a number of borings be made and jack tests performed in the openings.

Consequently, a small amount of cutting grout will become necessary for the area on the right bank.

Since the belt of faults and fractures, extending over an area including the canyon downstream, pose no problems regarding the plans for the dam, the area can be dealt with as deemed necessary as foundation work progress downstream in the apron and water cushion parts. In addition, along with the small amount of work necessary for the protection of the sides of the small valley, the maintenance of the training wall and such, will have to be considered during design work.

2.3.4 Geological Characteristics

(1) The Foundation

On the river bed and along the side walls of both banks, upstream and downstream from the projected dam site, the Paleozoic layers that will form the foundation lie exposed. According to the GEOBOL report (unpublished) and data from the preliminary survey, the layers date from the Silurian period.

These layers that would form the foundation are distributed evenly, reaching all the way up to the upper reaches of the right bank and extending from the areas downstream to those upstream from the dam axis. They are, in turn, covered with thin layers dating from the Quaternary period. The strata on the left bank is also unconformable where, due to the erosion of the Quaternary layers that overlie those from the Silurian period, the distribution of layers is somewhat uneven.

The parts of the strata dating from the Silurian period consist of alternating layers of mudstone and sandstone, with mudstone being more predominant and the sandstone layers having more density. The strike of the strata is NNE-SSW with an almost vertical inclination. Although there has not been much dislocation, parts of the area show fractures and small faults that contain fault clay. There are also some cracks that have developed in a direction perpendicular to the surface of the strata.

According to their appearance, the mudstone layers forming the part of the strata that dates from the Silurian period can be roughly divided into two kinds: 1) alternating thin layers of blue mudstone and gray sandy mudstone, and 2) black-blue mudstone. The blue mudstones occur in the form of laminae, and the gray sandy mudstones are either in the form of laminae or they form ripples or both and exist in alternating layers of gray sandy mudstone and mudstone that are distal turbidite in nature (distal turbidite --- deposits originating on land that have been carried to deep seas through turbidity) and have turned to phylite in many places. The black blue mudstones on the other hand are considered to be muddy argillaceous slump deposits, since they are frequently accompanied by dehydration, slump folding, and deformed sandstone layers.

The sandstone has undergone a sifting-out process and consists of fine sand accompanied by muddy argillaceous imitation gravel of granule or pebble size and has a sedimentation structure that, among others, includes dehydrated structures, cross lamina, lamina, ripple lamina and. Without exception they have been designated to be turbidite. They are found in thick layers, in areas about 200 m upstream from the projected dam site.

From the above, we were able to conclude that the Silurian layers found distributed in this region are sediments that have been washed out. These accumulated on the alluvial fan on the sea bottom and also along the water channel on which they had been carried.

The mudstones along the swamp, which extends from the right bank 20 m downstream from the projected dam site toward the north, have been crushed to phylite and partly turned to clay. The splintering of the mudstone is presumed to have accompanied the progression of the fault with a NW-SE strike that cuts across the Yesera river, and which will be discussed later.

About 100 m upstream from the projected site, there is a fault with an alteration that appears to be a shift of about 8 m to the left and a N62^{o} W, 64^{o} S inclination on the left bank and a N35^{o} W, 52^{o} N inclination on the right bank. It cuts diagonally through the Yesera river. The width of the fracture line is less than 1 m and the breccia is comparatively well consolidated. The reason for the difference in strike and inclination of the fault on either bank is considered to be due to the presence in the region of a joint that is at right angles to the bedding of sediments. But since the river bed is full of water, it has not been possible to directory study the area that would be the center of the fault. The northwest extension of this fault is covered with mudstone layers that have turned to phylite, which were mentioned before.

Several reverse faults with low angle alterations of less than 50 cm were observed on the right bank, in an area which is covered with layers of sandstone about 200 m upstream from the projected site. These faults had a strike ranging from NW-SE to NNW-SSE and an inclination of 30-40^{o} E. Generally they are accompanied by unsolidified fault clay. The direction of alteration of this group of faults is congruous with that of the fault mentioned before. (as shown on Fig. C.3.2)

(2) The Quaternary (Holocene) Gravel Layer

The foundation rocks from the Paleozoic era on the left bank of the river Yesera are overlain with layers of unconformable inclination from the Quaternary period. Exposed areas where the unconformable strata is directly observable are limited, but it is possible to study these layers along the walls of the left bank of the Yesera as well as along the gorges that join the Yesera river.

Since exposed areas are limited, the base of the layers from the Quaternary period, that is the parts directly above the unconformable strata as well as the uppermost parts, are not directly observable. The total thickness of the layers is estimated to be more than 50 m, of which

46 m are exposed and directly observable. On the basis of the study of the exposed areas, the strata can be divided into two sections the lower part (layer thickness 24 m + 2 m) and the upper section (layer thickness 22m +).

The lower section consists mainly of conglomerate layers of matrix that have sand grains ranging from fine to coarse and that contain a large amount of cobble-size quartzy sand gravel. The degree of concretion of the matrix is comparatively high, and it is not easily crashed by hand. The diameter of the conglomerate higher up is less than that below. Throughout the entire lower section, the grains tend to have a smaller diameter as they get closer to the surface. The boundary line between the layers is not clearly marked, but they were found to possess an erosion base and to have a lenticular shape. In addition, cross lamina of the trough type and imbricate structure (the structure of sediments within the conglomerate that indicate the direction of flow) were often observed.

Judging from the appearance of the layers, it seems that in conformity with conditions that usually determine the accumulation of deposits within a network of rivers, where there are several river channels, the river had changed its course, and moving to the left caused the accumulation of deposits with coarse grains.

The layer that forms the base in the upper section is gravel and consists of boulder size pieces. It is overlain with a layer of gravel with cobble to pebble-size pieces, which is followed by a lenticular sand layer, a gravel layer of pebble-size pieces, a muddy sand layer, and finally a sandy mud layer. The same rule applies here as in the lower section. That is, the higher the layer the smaller the diameter of its grains. The lower section is also considered to consist of deposits from a braided river system, but it is peculiar in that overall the grains are finer (sandy), and the uppermost part is made up of layers of muddy deposits from floods and from swamps, something that is characteristic of river deposits. (as shown on Fig. C.2.1)

2.4 <u>The Site at San Agustin</u>

The geological make-up of the area in San Agustin is similar to all the other dam sites discussed above. It consists of grayish or black sandstone and weathered mudstone that has turned to phylite, all dating from the Silurian period of the Paleozoic era.

The inclination of the strike (N 10^{o} - 20^{o}, E 60^{o} - 90^{o}, strike W) is somewhat smaller, and there has been more folding than in other sites. As a result, there are numerous joints and cracks. Because of these, and the presence of a number of fractures, there are many spots that at a glance appear to consist of andesitic lava resulting from autobrecciation.

As a result of a sideway compression of the sandstone and mudstone layers and the resultant folding, the sedimentation layers were forced upwards to form an outcrop. The surface of the deposits that make up the anticlinal axis has cracked open as if peeled off, looking like crack or fault fissures anywhere from a few cm to 20 - 30 cm wide. Consequently, in order to get sufficiently strong rock and obtain protection against water leakage in case a dam is constructed here, this part will have to be fixed with the help of an anchor or the like. Also, the crevice will have to be filled up sufficiently with concrete or other material.

The valley is comparatively well suited to supply the rock foundation for the dam, but in order to get a bed of rock, that would not need any, compared to the other sites a larger amount of excavation will have to be performed.

The installation of the dam axis will also need some consideration, and it is feared that the embankment will have to be extended.

On the river bed, solid rock lies exposed and there is extremely little newly deposited sediments, making excavation work easier. Another point in favor of this site is that the river bed is comparatively even with only a few slopes.

C.3 A Comparison of Dam Sites

3.1 From a Topographical Viewpoint

Topographically, the areas upstream and downstream on Yesera river are probably the 2 best spots among the 4 sites. The widths of the canyons are narrow and there are few irregularities on the surface of the sides, which are nearly symmetrical. When everything is considered, the area downstream will probably take precedence over the area upstream, which would come in a close second. In the case of the area downstream, however, since there are a number of deep depressions around the downstream regions of the right bank, depending on the height of the dam being built, it might become necessary to build a very small secondary dam (5 - 10 m).

In the case of the projected dam site in the upstream region of Yesera, since the valley has very steep slopes and stretches along a zigzag line, the dam axis will have to be oblique. This could prove to be somewhat of a problem, but in the case of a dam not higher than 30 m it should not be too difficult to solve.

Naturally, the things that both sites have in common are that the valleys are narrow, the rock beds on both banks lie exposed, and the river slopes are steep. This is because Yesera river, as it flows downstream through the valley, cuts a wide, comparatively shallow path for itself as it passes through the area with softer sedimentation. Stretching in a zigzag line, it forms a river terrace a from a few meters to 20 m thick. When passing through geologically harder areas, it does not widen its path, making its passage through narrow and limited space. It widens again as it reaches softer ground (mostly areas with faults and fractures).

As a result of this phenomenon, the construction of a dam about 30 - 40 m high on any of the sites would mean that, due to the depth of the valley, 10 - 15 m of the dam from the bottom up would quickly fill with accumulated sand. In addition, the area is not very advantageous for storing adequate water.

As a result, and as will be discussed later, pockets and the amount of accumulated sand become important factors in choosing a site.

After considering all factors, the projected dam site at Santa Ana was judged to be the most suitable.

3.2 From a Geological Viewpoint

As discussed earlier, the formation in each site is of alternating layers of sandstone and mudstone, dating from the Paleozoic era. They have undergone great changes and dynamic-metamorphism from the ancient times. In each case, the strata is almost vertical. The ratio between the two kinds of layers is sandstone 3 - 4: mudstone 7 - 6, with mudstone having partly turned to phylite. The strike of the strata is NNE - SSW.

Except for the fault in the vicinity of Santa Ana, which needs special attention, there is nothing deserving of special consideration near any of the other sites. In the case of the site downstream on the Yesera, the area stretching further downstream as well as the projected site of the small secondary dam are part of a belt of faults and fractures, but this is not a significant negative factor.

In the case of the site at San Agustin, the winding of the river along its path is intense, but the foundation is solid rock and the slopes are comparatively small. However, the strata was cut during the folding that occurred due to a sideway compression, and the problem of dealing with this (including cutting and consolidation) is one of the weak points of this site.

In the upstream of Yesera, the upstream mudstone area (about 10 m) that runs across the river from the left bank to the right bank, slightly downstream, is somewhat fractured. It has the appearance of a belt of faults and fractures.

If, as a result, the sandstone projection is chosen as the dam axis, the axis will be aslant and narrow. However, if a debris barrier is constructed 50 m upstream from that spot, although both the left and right banks are severely weathered, the fact that 2/3 of the river bed is exposed rock should prove ideal. Such a dam, which can be 7 - 10 m high, should prove to be geologically sound and efficient from every other point. But a dam higher than 15 m is not suitable for this spot.

In the case of the Santa Ana Dam site on Yesera river, the valley is narrow and there are no other reasons for apprehension regarding the construction of a dam about 30 m high. However, as a result of the fault lying slantwise in the area somewhat upstream from the old axis and the small fault that is nearly horizontal and at an oblique axis with the larger fault, the area along the length of the right bank is not well suited. In addition, there is a small valley about 50 m downstream, which is related to the large fault and fractures. For these reasons, the axis will have to be limited to a narrow area. In the mountainous region of the left bank, there are places as high as 1953 m alternating with spots with depressions as deep as 30 m. This was considered to be one of the drawbacks of this site. But through the geological investigations this time (electric exploration, boring, etc.) these spots were found to be sloping backwards, eliminating fears of water leakage.

The construction of a dam 40 - 45 m high should not pose many problems.

3.3 Problems Concerning the Left Bank of Santa Ana Dam

The depression in the foundation rock of PO-3 is considered to have been the old river channel. Determining the direction of corrosion is big problem concerning this dam site. As a result, a number of questions had to be answered, such as. Should the axis be designed as planned? Is the construction of a dam 30 m high and 40 m across possible? What measures should be taken to stop the water in the basin? How will all this affect the construction cost?

Therefore, prior to seismic explorations and boring investigation, electric explorations were carried out at 30 points, and the approximate location of the old river channel was determined. To supplement these investigations, detailed studies were carried out at an additional 10 points. A provisional axis was selected and, on the basis of this, seismic explorations and boring investigations were carried out. However, due to the presence of the deluvial layer of gravel, the lower section is extremely tightly packed and because the badly weathered rocks of the mostly mudstone foundation have a very similar value for electrical resistivity, it was difficult to arrive at a conclusion. As a result, after carrying out twice as many measurements as was originally planned, it was tentatively concluded that the PO-3 gorge (old river channel) disappeared about 100 m to the west. In order to recheck these findings, an additional 10 points were selected and investigations carried out. This produced data indicating the presence of a north-south barrier about 140 m away. The condition of the erosion surface of the old river channel PO-3, which should rather be called the foundation, and which is generally shaped like the bottom of a boat, might present a slight problem. If the barrier is provisionally determined to be EL 1975 m, then with a water surface at 1985 m or even 1990 m there should be no fear of water leakage in that vicinity. When the findings from the geological survey and electric explorations are examined together, it becomes clear that the old river channel is not that small. On the left bank side there is an additional wide "old river bed" about 150-200 m wide (which has caused the corrosion of the foundation, moving from the west to the east) and a height of less than EL 1945 m that probably reaches EL 1955 in m the east. For this reason, further thorough investigations will have to be carried out, which in conjunction with data from seismic explorations and boring investigations might provide answers to other questions regarding this area. What is the thickness of the layer of gravel that seems to posses a high level of permeability? What amount of permeation should be considered permissible? Will treatment of the foundation be necessary? These and other questions will have to be answered. The minimum length of permeation is thought to be about 500 m, and the maximum about 2.0 km. But since the slope of the water, which at minimum 40 m:500 m (1/12) and maximum 20 m:2000 m (1/1000), is comparatively small, the thickness of the semi-permeable layers (including the gravel layer) only about 1/2 and the permeation coefficient about 10-5. The total amount of permeation, if there should be any, is considered to be small.

3.4 The Fault and Fracture Line on the Right Bank of Santa Ana Dam

Extending from a point somewhat upstream from the right bank of the old axis to an area upstream from the left bank, there is a reverse fault that cuts diagonally through the river. The fault inclination in the upper regions of the right bank is N38° W, 60° W, in the mid section N40° W, 60° W, and lower down N12° W, 66° W, N36° W, 38° W, N18° W, 60° W. It reaches down to the bottom of the river, causing a large number of close displacements (5-6 times) of column foundation. Although the displacement angle is different in each case, the sides in the case of each displacement are glued to each other, and there is no fault clay. This fault seems to be the main reason for the presence of a reverse fault in the upper parts. It lies partly horizontal and partly inclined, the inclination being most prominent on the east bank N32° W, 32° E, N50° W, 20° E. It is a very irregular, small reversed fault that grows wider at the top as it rises. (There is strong evidence to suggest that an upthrust was the prime factor in its formation. It seems to have been produced as a result of the sideway compression that accompanied the formation of the large fault.)

As a result, if the old dam axis is utilized, almost the entire area on the right bank, extending from the fault towards the river, will have to undergo 10-20 m of excavations. Even if the amount of excavation in the area is reduced, the amount of work needed in the lower parts will be great.

If the dam axis is moved about 20 m downstream, the area deep inside the mountains on the right bank is reached. Thus, foundation-making should prove to be less of a problem.

Even if the new dam axis is used, however, it will be necessary to perform adequate excavation work on the severely weathered parts of the large number of shirred sides that lie slightly elevated towards the area downstream. These were the result of the fault formations discussed above. If not that, then at least it will be necessary to use more than 4-5 m of contact grout along with the consolidation grout, especially in the areas along the axis.

No investigations using drilling had been performed for the area on the right bank, and there are no exploratory adits. For this reason, an adequate explication of the above points is not available. If plans are actualized, it is desirable that a number of borings be done and jack tests performed in the openings. Consequently, a small amount of cutting grout will be necessary for the area on the right bank.

Since the belt of faults and fractures extending over an area including the canyon downstream pose no problems regarding the plans for the dam, the area can be dealt with as seems necessary, as foundation work downstream in the apron and water caisson parts progresses. In addition, along with the small amount of work necessary for the protection of the sides of the small valley, the maintenance of the training wall and such will also have to be considered during design work.

3.5 The Gorge Downstream from the Santa Ana Dam Site

Simple maintenance work to prevent further deepening or widening of the gorge is necessary.

Concretely speaking, it will be necessary to construct ground shill at several spots.

In order to protect a slight amount of work near the spot where the gorge joins the Yesera river will be necessary.

To prevent the inflow of soil gravel into the bucket part of the main levee, a training wall will have to be constructed on the upstream side of the end part.

Gunite, Gabion, and trihedral tensity are some of the construction methods used for the protection.

3.6 The Treatment of the Area Around Santa Ana Dam (the Dam Body, the Front Side, and the Back Side)

Since erosion in the mudstone parts tends to progress quickly, it is unwise to leave the excavated side behind the embankment untouched. Some measures such as spraying will have to be considered.

Along with some excavation of the terrace deposits around the surface to make the slope less sharp, an area about 20-30 m wide in the front part will have to undergo treatment and be cleared of rocks that might fall.

3.7 About Dam Types and the Workability of Santa Ana Dam

A comparison of each of the dam sites, whether the dam is of the rock fill or the gravity type, will make it clear that structurally and geologically there are no obstacles. This is especially true when seen from the point of view of the condition of the foundation in each case. However, the following can be said when the superiority of one site or type over another is being considered.

3.7.1 About the Different Types of Valley

The valleys in the case of each of the four projected dam sites have steep walls and may be called canyons. However, as was mentioned during the discussion of geological features, due to the weathering of the upper parts and the accumulation of terrace deposits in some parts, it will be necessary to perform cutting of up to 3.0-5.0 m. After excavation work, the slopes will naturally be gentler, but since the degree of strength of the foundation for the sandstone and mudstone parts is different, and the former tends to stick out more while the latter has more depressions, a large amount of wasteful excavation work will have to take place for the excavation work to proceed evenly. Moreover, since more detailed information about the small faults, fractures, cracks, and such in the area is not available, the treatment process should prove to be more difficult. The concrete will have to be applied soon after the excavation is completed or the weathered rocks, especially in the mudstone parts, affected by the release of pressure will become weak, making repeated excavation work necessary for some parts. This will in turn result in an increase in the amount of concrete needed, which is especially a problem in the case of the fill dam in which the slope of the excavated side should not be higher than 60^{0} or it will create problems regarding the material for and management of the core. Moreover, if the valley is too narrow, it will limit the free movement of the construction machinery, and will result in an insufficient pressure build-up at the two ends, causing trouble regarding construction and construction management.

3.7.2 The Material for the Embankment

If the dam is a fill dam, the material available would not be well suited for the water barrier.In addition, volcanic ash or deposits with a high level of permeability are not appropriate material for the core. Even if they are used, it would only result in an enlarged embankment, which would raise the cost.

Material of random does not present any problems, and the stones which are needed to cover the front surface can also be obtained locally.

In the case of a gravity dam, the sandstone from the surrounding areas and other appropriate building material taken from the layers of gravel should prove to have sufficient levels of abrasion resistance, compressive strength and shear strength, after they have been subjected to crushing and such. However, the question whether it would be better to produce concrete on site or to bring in ready mixed concrete from elsewhere will have to be sufficiently considered in light of the overall construction plan.

3.7.3 Temporary Tightening

In the case of a fill dam, a by-pass sufficiently capable of functioning in conjunction with a temporary tightening is needed.

The land structure of the basin, with the exception of the mountainous regions, is comparatively gentle with few slopes. The quality of vegetation is extremely poor. The hills in the upper and lower reaches as well as the mountainous regions that are devoid of surface layers show a high level of run-off. Only the water from the first rainfalls are absorbed by the dry and parched, powdered fine sand and silt and other such sediments and doesn't flow away. The spot at which the temporary tightening is to be constructed, its by-pass section, length, and such are at present unclear. If the dam is going to be a fill dam, then the length will need to be at least 250 m, and it will have to be located at least 20 m from the excavated surface of the dam body. Considering that it will result in the loosening of the foundation, using a sufficient amount of consolidation and curtain grout, the areas around the plug and particularly the dam body will have to be carefully constructed.

Judging from the present geological features, the location will undoubtedly have to be on the left bank. Since that would mean a spot about 20 m down from the surface of the foundation rock, it should present no problems except that it would necessitate the use of curtain grout. Positioning it on the right bank would mean that the fault and fractures that cut diagonally through the river bed would pass right in front of the dam axis. This would create somewhat of a problem and make the use of consolidated grout and curtain grout absolutely necessary. Moreover, since the small gorge downstream is within the zone of the large fault and fracture, work around the exit here in addition to that necessary for the protection of the gorge should prove to be troublesome. If it were to be a gravity dam, then the tightening of only half of the river, or the laying of concrete in blocks of about 10 m each every 3-5 lifts, would also create a by-pass that could be used if the need arose, resulting in a reduction of cost.

3.7.4 Spillway

The construction of a spillway will be necessary no matter what type of dam is used. In the case of a fill dam, to guarantee the safe passage of 1000 m^3/sec, which is close to the maximum quantity, the overflow trap will have to be more than 50 m. In addition, if the overflow water depth is set at 3.0 m or more, in then consideration of the geological features and the structure of the land, the left bank should prove to be the most suitable spot. When the freeboard, the overflow depth, the scale of the foundation for the overflow trap, and such are taken into account, then excavation would have to be at least to a depth of 12.0 m around the N. boring No.1 or at least about 15.0 m around the N. boring No.2. In both cases, this would result in an almost full exposure of the foundation rock. Although a sufficiently strong foundation could be obtained this way, it would mean a larger amount of excavation work and thus greater cost. Furthermore, the hill will have to be excavated slantwise, from near the dam axis to a spot about 100 m downstream, which would also result in much higher costs.

Thus, in the case of a fill dam, if the spillway does not posses the capacity to handle the maximum amount mentioned above, it might result in the overflow of the dam body during floods, which would be extremely dangerous.

From all this, it becomes very clear that instead of the construction of an excessively large spillway for a fill dam, it would be much more practical to build a gravity dam for which the danger of collapse, even in case of an overflow, does not exist.

	Rock classification	Elastic wave velocity km/sec	Bulk density E(106 Bar)	Young's modulus
Sand-stone	Weathered zone CL-CM	1.5-2.5	2.0	
	Unweathered zone CM-CH	2.5-3.5-4.0	2.6-2.7	0.745-1.0
	Fracture D-CL	2.0		
Mud-stone	Weathered zone D-CL	0.5-1.8	1.8-2.0	0.19-0.44
	Unweathered zone CM	2.0-3.0	2.5-2.6	(W) (D)
	Fracture D	1.0-1.5		

		Compressibility G	Poisson's ratio
Sand-stone	Weathered zone		
	Unweathered zone	0.345-0.42	0.11-0.15
	Fracture		

Silurian period 400-430 millon years flabellate strata on the bottom of the sea and the deposit layer on the watercourseleading to it.

		Compressibility G	Poisson's ratio
Mud-stone	Weathered zone		
	Unweathered zone		0.1-0.12
	Fracture		

Silurian period 400-430 millon years flabellate strata on the bottom of the sea and the deposit layer on the watercourseleading to it.

	Rock classifi-casion	Compression strength (kg/cm^2)	Tensile strength (kg/cm^2)	Shear force (kg/cm^2)	Brittle-ness
Sand-stone	CM-CH	1,500-2,000	150-170	300-350	10-12
Mud-stone	CL-CM	300- 400	35- 40	50- 60	5-6.5

	Schmitt hammer repulsion rate	Adhesive force (kg/cm^2)	Internal frictional angle $\phi(^{\circ})$
Sand-stone	50-60	1(Parallel to the joint)	50-60
Mud-stone	15-20		50

3.7.5 Conclusions

As was mentioned before briefly, a comparison of the relative qualities of a fill dam with those of a gravity dam will show a gravity dam to be a better choice.

	Fill	Gravity
1. Topographically	+	-
2. Geologically	-	-
3. Sand deposits	+	+
4. Temporary water cut-off	+	-
5. By-pass	+	-
6. Spillway	+	-
7. Dam capacity	+	-
8. Construction time	+	-
9. Safety	+	-
10. Cost	+	-
11. Temporary dam	-	-
12. Management	+	-
13. Appearance after completion	+	-
14. Lever raising	+	-

note
- : presents no problems
(not needed)
(is low)

+ : inferior
(is needed)
(is high)

1. Fewer problem geologically
2. Less time needed for construction
3. Lower cost
4. Higher safety rate

As can be seen from the above, from almost every point of view, a gravity dam would be superior.

Point of Survey, Geological Section of Dam Site and Comparison of Geological Profiles are given in Fig. C.3.1, C.3.2 and C.3.3.

C.4 Electric Exploration

4.1 Explanation

In regard to the electrical prospecting of the Santa Ana Dam site, first the findings of the CODETAR study were considered. According to that data, the lower parts of the layer of gravel dating from the Diluvium epoch, which has thickly accumulated on the left bank, is piled up about 30 m at maximum from the ground surface. That is no more than 10 m difference in height in relation to the present bed of Yesera river. This rock base forms a basin that gets gradually shallower as it continues along the left bank. At boring No.4, rock is reached at about 25 m, a height difference of 20 m with the present river bed. As a result of additional electrical prospecting performed in the area, the rock bed was found to get more and more shallow further down.

Therefore, without understanding the formation, in relation to the whole area of the left bank of this rocky basin, which may be thought of as the "old channel" of the river, it will not be possible to consider some of the problems regarding the construction of a dam, such as those concerning the dam axis, dam height, and the problem of the still water in this thick layer of gravel. For this reason, lateral lines for seismic exploration (total 1000 m) and 3 borings (total 120 m) were planned.

However, since even this amount of data was inadequate, and in order to investigate the "old river bed" as closely as possible, before the above data was compiled, measurements using Wenner's method of 4 electric poles was carried out at about 30 points.

Because the surface of the ground is extremely dry and there is a large amount of conglomerate, however, the grounding condition for the electric poles was bad and measuring was difficult. In addition, analysis was difficult because the value for electrical resistance that was obtained was very similar to that obtained for the weathered part of the bedrock. This was partly due to the fact that the gravel sticking together tightly forms a well consolidated layer.

To counter this, the space between the points of measurement were made smaller, and the data obtained was checked against that obtained from the old borings 3, 4, 2 and others. In addition, starting from the point close to the exposed parts of the river bank, measurements were made at a total of about 80 points.

4.2 Measurements

As a measurement instrument, the MCOHM resistivity meter based on the principles of applied geology was used. Using Wenner's Quadropolar method, depths of up to 70m were measured.

(1) Transmitter
- a. Output voltage : 400 VP-V
- b. Output current : 1, 2, 5, 10, 50, 100, 200 mA
- c. Operation voltage : 12 VDC

(2) Receiver
- a. Input impedance : 1M
- b. Measurement potential: ± 0.6V, ± 6V (AUTO RANGE)
- c. Resolution : 10 V
- d. Stack frequency : 1, 4, 16, 64 (can be stopped as
- e. Cycle time : 3.5 sec

(3) Data Memory
- a. File registration : max. 128 files
- b. Data point : max. 1100 data
- c. 1 file : max. collected 110 data

(4) Interface : RS-232C
(5) Power Source : DC 12 V (built in um 1x8)
External power sources can be
(6) Dimensions : 206(W) x 181(H) x 200(D) mm
(7) Weight : 10kg

For analysis, the standard curvature method was abandoned because it has a strong tendency to show results a little too deep (details omitted). Instead, the direct sight method was employed.

4.3 Measurement Results

As a result of these measurements the foundation was found to be shallower than was concluded previously on the basis of the CODETAR data. The structure was as is shown on Fig. C.4.1.

As can be seen from the contours of the foundation in the figure, there is a gorge in the shape of a boat, located between old borings No.4 and No.3. Extending from the downstream side towards the east, it disappears after 100 to 150 meters.

This means that previously a shallow gorge had its start about 100m west of old borings 3 and 4, and the stream flowing it from the northeast deposited the layers that made up the foundation. It then flowed on to join the "old channel" of the Yesera river which, after reversing its course, started flowing to the west and deposited the thick layer of gravel found in the basin.

As can be concluded from this, even if the dam is constructed at the presently planned site, there is practically no danger of any downstream leak occurring at nearly right angles to the dam axis.

However, when the area under investigation was extended to Quebrada and measurements were performed in conjunction with the geological investigation of the layers of gravel in the area southwest, it was found that the old channel of Yesera river, taking a course that extended diagonally from the area somewhat upstream from Santa Ana Dam towards NNE - SSW, had flowed downstream heading towards Santa Ana.

The p-a curve line and the table of values is shown on Fig. C.4.2 and C.4.3 and Table C.4.1.

4.4 Summary

The analysis results of the above measurements can be seen in Fig. C.4.1.

Based on the these results, the axis of the Santa Ana Dam was moved 20 m downstream from the old axis. This decision was taken for the following reasons.

(1) The depth of the old channel of the river that was measured at the old boring No.3 sharply decreases, becoming shallower as it continues downstream. For this reason, the work required for foundation-making and water stoppage will be less with the new axis.

(2) It is possible to move the axis further down (it would improve the direction it faces), but considering the relationship with the positioning of the right bank, this seems to be the limit of how far it can be moved.

(3) Regarding the right bank, electric prospecting was carried out at 5 locations along the new axis.

As a result, it was found that about 0.5 m - 4.2 m thick layers of gravel dating from the Diluvium epoch had been deposited on top of the foundation bed. From this, it can be concluded that fixing the main body of the main dam on the rock foundation will be easy. Also, there should be few problems concerning water stoppage.

(4) However, 5.0 m upstream from the old axis, stretching diagonally towards the direction upstream on the left bank, there is a belt of faults and fractures that has caused displacement as wide as 8 m. Due to this, the area around the old axis has been fractured. Even without the findings of electric prospecting, the axis had to be moved. It was moved (20 m), a distance equivalent to that on the left bank. It was impossible to obtain clarifications regarding the fault with the help of analysis based on electric exploration.

C.5 Seismic Exploration

5.1 Outline

From the existing investigations regarding the Santa Ana Dam it is clear that measures will have to be taken to counter the problem of water leaking through the layers of gravel on the left bank. The seismic explorations were planned as part of the studies to help decide what these measures should be. These were carried out along the 500 m-long lateral line along the old axis and another 500 m-long line extending slantwise from around the old boring No.1 on the left bank to the mountain stream.

The position of the slanting lateral line was not clear, and it was decided to use the line along the rock base under the layer of gravel (including the old river channel) for obtaining the basic data required to decide the location of the water cut-off wall, in case it is decided to locate one on the left bank.

The building of a curtain wall was also suggested, but after a detailed study of the site, it was decided that construction would be extremely difficult. Since the cost would also be much higher than that for the main levee, there was a change in plans. It was decided to study the actual conditions concerning the "permeable layer."

As a result, measurements were planned to be carried out along a lateral line starting from the old boring No. 4 and extending slantwise 100 m downstream and 400 m upstream. The findings in conjunction with those obtained from electric explorations were to be utilized in deciding the location of boring points.

5.2 Explorations

For measurements, the Seismic Exploration Measuring Instrument for application purposes was used. Pick-ups were set at intervals of 5 m along the lateral line mentioned above and, using the refraction method, measurement was carried out. Since the rocks in the Yesera river region and on the right bank lie exposed and the surface layer is extremely thin, surface wave measurements were also carried out for those areas.

5.3 Results

The results are as shown in Fig. C.5.1. The elastic wave velocity of the clayey, surface layers of the uppermost part is about 300-500 m/sec, and that of the flabellate deposits of the gravel layer below is 1500-2000 m/sec. The Paleozoic mudstone and sandstone layers are at a total depth of 7.0 m to 30.0 m below.

According to the findings of the original GEOBOL report, the foundation rock was concluded to be slate and shale. This difference in findings seems to be due to a difference in subjectivity and does not seem to present a problem.

However, it is not clear how the conclusion was reached that the sediment environment of the foundation around the new boring No.2 had undergone inversion. It might have been due to the difficulty of clearly determining the boundary line between the layer of gravel and the foundation, among the badly weathered layers, or it may have been due to the badly weathered condition of the thin alternate layers.

In any case, judging from the cross-section that was obtained as a result of the findings and the findings from the electric explorations and borings and such, we can conclude that the tests were successful.

In the area within the zone of the lateral line on the left bank, the foundation rock, at a maximum depth of 44 m, was deepest in the eastern end of the region. It was found to be the least deep, at around EL. 1,951 m, near the new boring No.3.

This is only 7-8 m higher than even the present Yesera river.

From this it was made clear that the old Yesera river flowing through this area must have taken a southerly course with a foundation height not very much different from those of the rivers flowing through the area right on top of the projected dam site.

The geological features and velocity values obtained as a result of analysis are as follows:

First layer	Cubierto Superficial (Arena Suelte)	300-500 m/sec
Second layer	Capa Areilla, Compacta	1,500-2,000 m/sec
Third layer	Colluvio-fluvial(Till)	2,500 m/sec
Fourth layer	Lulitas o Pizarras	Major a 2,500 m/sec

As can be seen from the numbers, the zoning does not necessarily represent the whole of the region; but generally speaking, these conclusions should suffice. However, places in the foundation rock that would be only slightly weathered and have no faults or fractures should prove to have a value somewhere between 3,000 m/sec and 3,500 m/sec.

Values obtained for the areas affected by the faults and fractures on the right bank of the northern part of Yesera river were also found to be appropriate, and overall the foundation itself, as was anticipated, was found to be comparatively sound and of a good quality. Thus, it was concluded that the construction of a gravity dam would also present no problems.

C.6 Exploration Using Boring

6.1 Outline

Since the 3 borings and the total of 120 m used in explorations related to the Santa Ana Dam were thought to be inadequate, the number of exploration spots was changed, and it was decided to use 138 m for the explorations.

As mentioned before, the exploration findings had made it clear that the foundation height was bigger at the site for the new axis than that of the old one. As a result, it was decided to make 2 new borings, one with a depth of 15 m, at a distance of 20 m downstream from the old boring No.2, and a second one with a depth of 30 m at a distance of 40 m downstream from the old boring No.3. Rock was reached at a depth of 10.9 m at the new boring No.1 and at a depth of 16.8 m at the new boring No.2.

These results were almost the same as the values obtained through the analysis of the electric exploration findings. At the same time, permeability tests were carried out inside the holes. Since, among other things, the amount of water poured in was comparatively small, the permeability coefficient was judged to be much smaller compared to previous data.

The remaining 2 holes were used mainly to find the depth of the bed (foundation surface) of the old Yesera river and to perform permeability tests for the layers of gravel that show a high level of permeation.

6.2 Investigations

Regarding the structure of the layers of gravel, the stratification is in the form of parallel bedding. In many cases the single layers are very thick and lie tiled up, but there are also numerous larger rocks the size of cobbles or larger, which lie irregularly an don't form graded beddings. In addition, the fine sand, silt, clay, and such that form the matrix are also extremely dry and tightly packed with the level of consolidation resembling sun-dried bricks. In some places, they look like granite that might have been badly weathered right before . They may also be likened to concrete that contains coarse stones and pebbles and only a little cement.

On the other hand, the gravel here seems to come mostly from sandstones dating from the latter Paleozoic or early Mesozoic eras. However there has not been much weathering, and the level of consolidation is also very high. All these serve to make, boring through these diluvial layers of gravel technically one of the most difficult tasks involved. It can easily result in the destruction of the boring walls or cause the rig to jam. Ordinarily, the percussion or rotary style of excavation is used. In the case of the rotary style, methods such as casing or cementation are utilized. Due to the circumstances regarding the equipment and such, we had to implement the rotary style on this occasion.

Consequently, in order to perform water permeability tests by flooding holes of different depths, we considered making use of methods such as cementation, casing, and soft-air packer in conjunction with each other. Due to limitations regarding the equipment available on-site, we were unable to do so, however and experienced difficulties that are discussed below (as shown on Fig. C.6.1).

The value obtained from the permeability tests for the layer of gravel was K≑ 0 x 10-2 - 10-3 cm/sec.

Such a high value would ordinarily be obtained for gravel layers of current river beds or other similar sedimentation layers that are as yet unsolid. In Japan, for example, the value for ancient deluvium gravel layers, sand layers, or clay mud layers and such would be lower than K≑ 0 x 10-4 cm/sec.

Judging from the geological survey results and the conditions observed in the test drilling holes, the value should not have been higher than K≑ 0 x 10-4 cm/sec.

When the high pressure of the boring machine and the torque are applied to bouldora in the layer of gravel, larger once with diameters of 1.0 m or 2.0 m may withstand the shock. In the case of smaller diameters such as 3 cm, 5 cm, 10 cm and 30 cm however, where the surrounding areas are not hardened by cement, the resultant vibration, shock and such can, as they did this time, cause a loosening all around.

The areas around the boulder were fully separated from the sand and silt of the matrix. The surrounding matrix itself was also thought to have sustained some slight damage.

The inside of the boring did not turn out truly circular, but was uneven. Some of the stones and coarse grains that had come off fell into the boring.

Under such conditions, even when a short solid packer were to be utilized and inserted inside, the water would have been stopped only at the part that was in contact with the rubber. However, stopping the water from leaking in a matrix that has been once loosened by tightening the packer at only one point around the matrix (considering the boulder diameter was probably about 20 - 50 cm across) is considered impossible.

Therefore, when the boring was flooded under such conditions, piping appeared in the surrounding matrix, and water leaked. On on its return, the leaked water passed through an area mainly about 10 cm below the surface that had a large number of cavities. In doing so, it was lost through infiltration.

The gauge needle was moving at a high speed between 0 - 2.0 kg/cm^2, and since the pressure could not have been 0, about 2.0 kg/cm^2

should be added here. (This was due to the malfunction of the pump control systems, and as is mentioned elsewhere, it was 61% maximum, 13% minimum, and 41.2% on the average, which means a decrease of about 60%.) Also, since the area inside the boring had enlarged in an irregular manner, the value used in calculations had undergone a change and was bigger.

In case there was water leakage through piping, it is not appropriate to calculate the permeability coefficient through the flooding method.

The fact that the foundation rock of the gully, which is close to being a valley and is located in the diluvium gravel layer, is not very deep was one of the reasons why boring No. 3 was chosen. Another was the desire to study the extremely recent and loose gravel sediments that have accumulated in the gully (arroyo-quebrada). There were places in the foundation rock that were considered to be small faults or fractures, but as to whether they dated from the Quaternary period (that is, active faults etc.), or had any relation to the fault found in Yesera river or the NE-SW tectonic line by which the whole area has been affected, could not be determined.

6.3 Leakage

When the figure 2.0 kg/cm^2 from the permeability test data, which seems to have been the result of a pump malfunction, is added, and simple calculations performed, then the average figure for the present 15 locations would be 0.412 (minimum 13%, maximum 61%).

That would mean a 40% decrease in the data 10-2 - 10-3 that had been obtained before. Since the conditions discussed earlier would also have to be considered, the actual decrease would not be 60% but would go lower than 1/100. (A figure that was estimated on the basis of experience as a geology specialist.)

However, since there is no clearly calculated figure regarding this 1/100, if we assume the data available at present to be correct, then in the case of the area surrounding boring No.3, which seems to be the most affected by permeation, a rough estimate for the total cross-sectional area EL.1952 m, assuming the full water level is EL.1980 m, would be 4200 m^2. Since, as was mentioned elsewhere, the clay layers and the sandy clay layers account for about 1/3 of the total, then the final figure would be about 4200 x 2/3 = 2800 m^2.

Of course, I don't suppose the strata to have accumulated exactly in this way, throughout an area extending over 1.0 km, but if we suppose this to be the case, then if the water, from a dam in which the water is stored up to the full water level, does not decrease and the maximum available figure is used, and furthermore, if the length of infiltration is set at minimum 500 m - 1,5 km maximum, then :

If $Q = A.K \cdot H/L$

Q	= Rate of discharge (leakage)	cm^3
A	= Cross-sectional area	cm^2
K	= Permeability coefficient	cm/sec

H = Water pressure (from the high water level down) cm
L = Length of infiltration cm

Case 1

$$Q\,1 = 2{,}800 \times 10{,}000 \times 0.01 \times 3{,}000/50{,}000$$
$$= 28{,}000{,}000 \times 0.01 \times 0.06$$
$$= 2{,}800 \times 6$$
$$= 16{,}800\ (cm^3/sec)$$
$$\fallingdotseq 1{,}450\ m^3/day$$

Case 2

$$Q\,2 = 2{,}800 \times 10{,}000 \times 0.0025 \times 3{,}000/150{,}000$$
$$= 28{,}000{,}000 \times 0.0025 \times 0.02$$
$$= 280 \times 2.5 \times 2$$
$$= 1{,}400\ (cm^3/sec)$$
$$\fallingdotseq 120\ m^3/day$$

If K is 1 x 10-2 cm/sec max. and 2.5 x 10-3 cm/sec min., then according to a rough calculation, leakage would be 1,450 m^3/day at maximum and 120 m^3/day at minimum.

The above figures represent leakage for one day, but even assuming the water is stored for 3 months without a decrease in the water level, then Q ≒ 1,450 m^3 x 90 = 130,500 m^3 (90 days).

This would mean a leakage of 130,000m^3 in 3 months, which in the case of a dam with a storage capacity of 2,500,000, for example, would be about 5% of the total. At minimum, it would be 120 x 90 = 10,800 m^3, which is not more than 0.4% of the total.

For 150 days, the maximum would be 220,000 m^3 or 9%, and the minimum 18,000 m^3 or not more than 0.7%. But since in reality the full water level will decrease more than 10 m, the actual figure will be even smaller. Assuming that the leakage V is 0.4%, or about 10,000 m^3/90 days, and that the the layer of gravel forms the main body of the dam, then even in comparison to the 0.05% Q/day, which is the allowable limit of leakage for the protection of a natural dam body, the 4.5% (90 days) would amount to no more than 1/10.

Although, the above calculations contain numerous assumptions, these rough estimations should make it clear that leakage would be extremely small and would pose no problems. For this reason, it was concluded that a treatment of the water barrier on the left bank of the dam site, which was mentioned before, would not be necessary.

C.7 Exploratory Drilling

Investigations, using electric exploration, seismic exploration, boring, and such have already been carried out. Regarding the area on the left bank where the dam is to be fixed, however, even without boring it was obvious by studying the area around the cliff that only slime, conglomerate, and such would be found in the core of the layer of gravel. Therefore, in order to study the area directly, it was decided to carry out excavations 7 - 8 m deep. In addition, since during the permeability tests in the boring there had been some problem with the packer's effectiveness, and also there was a feeling that piping might be needed, it was decided to measure the permeation level by pouring water directly. For this purpose ø2.0 m - D = 4.0 m ø1.5 m - D = 4.0 m, a total of 8.0 m was planned.

However, starting at a depth of 2 meters, conglomerate of a large diameter, ø 30cm, 60cm, 70cm or more, was found sticking together tightly. It was decided that the matrix was tightly packed with sand, silt, and some clay, making excavation extremely difficult. Manual excavation was made impossible at D = 6.6 m. Partly for this reason, it was decided to try to measure the amount of permeation by pouring water at D = 6.6 m mentioned above and at 4.0 m.

7.1 Sample Leakage Survey (1)

At 4.0 m, there was a comparatively soft spot in the conglomerate about 30 cm wide. It was thought that, if boring were performed, fine sand mixed with clay would be found. The hole was filled up with water, and when left standing from 5 pm to 9 am the next morning, there was a loss of only 4.0 mm. The 4.0 mm in 16 hours meant 1 mm/4 h, but it was not clear whether there was real permeation or whether the water loss was due to capillary action or maybe water escaping up the sides.

7.2 Sample Leakage Survey (2)

Two drums of water were poured into the hole D = 6.6 at 6 pm. When measured at 9 am the next morning, there was no change at all in the water level. This was true even after 2 and then 3 days. At this spot, too, all the sediments except for the conglomerate are stuck together tightly, making excavation difficult, but when fragmented it should be found to consist of clay.

From the above, it can be concluded that the layer of gravel spread out over a large area exists under different conditions at different spots. It was concluded, however, that there would be no water leakage in the area between boring No.1 and boring No.2, an area corresponding to the lower reaches of the new axis.

C.8 Sediments

The quality of the sediment is mainly decided by the land structure and geological features of the valley. This is also true of Yesera river. The Paleozoic base, in each case, is overlain by gravel layers, sand, clay, volcanic ash, and such that date from the Quaternary period. The pattern of distribution, degree of solidity, number of gullys, intensity of rainfall, amount of flood, grade of valley, vegetation, level of cultivation, possible negative effects on livestock, etc. may differ a little, but generally speaking conditions within the valleys in each case are very similar.

The amount of sedimentation in the case of each dam site is proportional to its location and size; that is, the more upstream the location of a site, the less sedimentation it will have. Consequently, upstream Yesera with 200 km^2 has the smallest, and Santa Ana dam with 250 km^2 the largest amount of sediments. This ranking would naturally be different if other sites were planned. The deposits within the present river consist mainly of boulders (including very large rocks), which roughly estimated would probably account for about 90% of the total. That there is little sand, silt, clay and such does not mean that they do not flow into the river. It is rather due to the fact that, during the flood-like waters of the rainy season, they get suspended and are carried away by the water. In actual terms, the sediments that make up the dam are rocks, sand, silt, and such that are thought to occur in equal amounts. The greater the storage capacity of a dam and the larger and more massive it is, the greater will be the decrease in the velocity of the river as it enters the dam. For this reason, the Nueva Santa Ana dam, which would be located lower downstream than any of the other dams, would have the largest deposit of fine grains.

Through the investigations of the area, it was determined that the fine sand, silt, and fine grains of clay that were found to have accumulated in those parts of the river bed, that are rugged and uneven, and where the water velocity is low, had almost fully disappeared in mid-December, which is the dry season. Moreover, the study of the boulders that stick out in the upper parts of the hills reveals that 20 cm-30 cm of the matrix surface has been washed away. It is not clear over what length of time this might have occurred, but the amount is quite large.

Aside from these, sand control dams may be constructed around the upstream regions of the Yesera river. The foundation stones on both sides are exposed, and if it is a spot where the foundation of the river bed is also easily accessible, then by building a concrete structure that would act as a stopper for boulders maybe as large as 2.0 m, with this as the center, a sand control dam could be built by simply placing a somewhat wider rock fill (stones would also do) there. However, since a spot where the foundation on both sides is exposed would mean a river bed with a sharp slope, there would be a loss in height of more than 2 m or 3 m.

C.9 The Site for the Sand Control Dam at the Yesera River

9.1 Topography and Geological Structure

Both banks are almost vertical. The left bank is about 10 - 15 m, and the right bank is close to 8 m (rather soft). The river bed is almost flat and, except for the middle parts, consists of a sandstone and mudstone rock base that lies exposed. Like the foundation base at the Santa Ana site, it is well-consolidated rock and does not need to be treated for foundation-making. In the middle parts, too, a rock base is easily reached by removing the large conglomerates.

9.2 Observations

The construction of a dam 8 - 10 m high and 40 m or more long, which will be more than capable of functioning efficiently as a sand control dam, is very much possible.

If the base is treated with concrete, storage of a few meters of water is also possible. In case it is used as an underground dam, a valve should be installed.

If the position of the axis is moved lower down the left bank, it will result in its being based on a soft layer of mudstone. Therefore, the present plan should be adhered to. The slope of the right bank is not steep enough and it is also severely weathered, resulting in division into blocks and looseness. However, it should be possible to reach sufficiently good quality rock with only 1 - 2 m of cutting. It is overlaid only with a thin layer of gravel, and its treatment should prove to be easy.

C.10 The Planned Site for the Head Works (Intake Dam)

10.1 The San Agustin River Site

The site is about 3 km upstream from the junction of the two rivers the Santa Ana river and the Agustin river. It is at the end part of the area where Agutin river flows west across the top of the long and narrow stretch of mountains that extend like a wall from Cerro Mesor to San Antonio in the southwest. Geologically, therefore, it is made up of alternating layers of sandstone and mudstone (mudstone has partly turned to phylite) dating from the Silurian period of the Paleozoic era, which the mountains are also made up. Overall, the area is predominantly mudstone, except for that part where the river takes a turn, and where thick, well consolidated layers of sandstone are extremely predominant. The strike of the strata is mostly N 20^{o} - 30^{o}, E 80^{o}, W.

10.2 The Site at the Gamoneda River

Under the Gamoneda river, the spot at the intersection point 22-23 on the map, which is about 50 m upstream from the river crossing point, about 200 m to the west, is most suitable for the construction of the head works.

Gamoneda river, orginating at Cerro San Pedro, takes a course almost parallel to the mountains and valleys as it flows to the south. It turns east in the southern part of Cerro Payayo, and sill flowing east passes through the northern part of Estancia Gamoneda and joins the Payayo river near Cancha de Futbol. It crosses the road leading to Yesera. After continuing on its course for another 2 km, it joins Yesera river and becomes Santa Ana river. After the Agustin river, it is the third largest river in the area.

But at the spot where presently the head works is planned to be constructed, the river is narrow. As shown in figure , the maximum height is 7 - 8 m, and at normal times (high water season) it is 3 - 4 m; the width is 4 m at the lower part and in the upper parts it is 6 - 7 m (high water season). As can be seen, it flows through a comparatively small area. The geological make-up is the same as that of Cerro Gamaneda or Cerro Payayo; namely, it is made up of sandstone from the Silurian period, which is well consolidated and will not present any problems if a dam is constructed. The exposed parts are of extremely good quality. The direction is N-S, and the strike is about 50^{o} - 60^{o} E. In case of construction, remodeling alone should suffice.

It is not clear what size the head works to be constructed here will be, but the foundation base of the right bank is low and the layer of gravel is thick. It will be necessary to perform 2 - 3 m of cutting to reach a rock base. Moreover, the area upstream on the left bank consists of low lying arable land, and a cofferdam of about 7 m, for example, would mean the submersion of several hectares. (Though details are unclear, storage of water is also thought possible.)

The location of the waterway is also unclear at this stage, but if water is to reach the arable land in the southern parts, a long stretch of hilly land (300 - 500 m)(layers of gravel) will have to undergo cutting. Since this seems to be an impossible task, detailed measurements during the designing stage will be required.

Presently it is dry season, and the river has little water of its own. There seems to be several l/sec (about 200 300m /day).

In search of a suitable site, the area upstream was also explored, but both from a topographical and geological point of view, this spot seems to be the most suitable.

C.11 Groundwater

11.1 Introduction

The geological structure of the areas around Tarija city, like those of areas discussed before, is of sandstone and mudstone dating from the Silurian, Devonian, or Carboniferous periods of the Paleozoic era. They not only make up the mountainous regions, but also form the foundation of the surrounding lowlands. The inclination for the area is 70^{o} - 80^{o} NNE - SSW (partly 20^{o} - 30^{o}). Later deposits consists mainly of alternate layers of gravel and clay from the Holocene epoch, more than 150 m thick, which covers the foundations of the lowlands, and alternate layers of gravel and clay, about 10 - 30 m thick and alluvial in nature, that cover the areas along the river. Since the aforementioned mountain areas are entirely made up of well-consolidated bedrock and the lathered layer is very thin or non-existent, the only underground water found is the accumulated rain water in the cracks (1), joints (2) and the fissures of faults and fractures (3) and the slight amount that is found in layers of deposits on mountainside bluffs.

But even these small amounts that accumulate during the rainy season soon percolate downward until there is almost none left during the dry season. (Areas lower than the present river bed are an exception.)

Conditions for water accumulation are better for the low lying and hilly areas, which consist of layers of gravel and clay. But since these are tightly packed, it seems that rain water at the start of the rainy season, after saturating several meters of the surface layers, renders these layers impermeable thus preventing a smooth downward percolation of water, which then quickly evaporates from the surface.

A detailed study of bluffs underneath the terraces, consisting of layers of gravel, showed evidence of erosion due to the flow and evaporation of surface water. But there were no signs, such as capillary-like lines, that usually indicate permeation, nor was there any sign of the end-point of a line, along which water might have permeated downward.

To study the permeability at the projected site of the Santa Ana Dam, 2 holes 4.0 m and 6.6 m deep, were excavated and water was poured in. There was almost no decrease in the water level, which seems to indicate the presence of a well-consolidated and tightly-packed matrix other than conglomerate, such as clayey soil, sandy soil and gravel mixed with silt, which results in impermeability or semi-impermeability. As far as could be judged by the naked eye, it was less than 10^{-5} cm/sec.

The above findings are all that is presently available, and unfortunately conditions during the rainy season are not clear, so that passing a final judgment is made more difficult. Consequently, with the data obtained from this limited period of investigation alone, it is not possible to describe the permeability in detail.

During the rainy season when the observation of conditions governing underground water are most difficult, it is also hard to draw conclusions about the relationship between the river flowing downstream and its traction force, or about whether the underground water is the main reason for the formation of gullys or whether they are the result of water acting as it does in the erosion process regarding shirasu (a part of volucanic ash soil). These are some of the questions that remain unanswered.

In the case of alluvial layers of gravel, because the force conveying water through the comparatively thick layers on the river bed, are small, even the slightest amount of surface water tends to accumulate, forming a useful source of water for deep and shallow wells.

In summary, regarding underground water in the area, the following conclusions can be drawn, (1) It is non-existent in the mountainous areas. (2) At the foot of the mountains also, it is almost non-existent.

(3) In the filly area, during the rainy season it is also no-existent.
(4) Small amounts are available in the saturated layers of gravel on the river bed. If, in the future, the use of underground water is to be carried out vigorously, building culverts or comparatively wide and shallow wells (ponds) and using the water accumulated there would seem to be the most reliable and efficient way.

However, since the total amount of water is comparatively small, the area can not be used as a major source of water for irrigation. This is also clear from the results of electric explorations of the Santa Ana area, which are contained in the reports compiled by GEOBOL, the Bolivian Institute for Geological Studies. The conclusions here are the same as those mentioned before: the acquisition of large amounts of water is impossible, and a reliance on underground water should not be considered.

However, if the water infiltrated in the alluvial layers of gravel is to be forcefully increased, a large number of consolidation dams of a few meters may be built. These will serve as a form of channel storage or underground dam and may make the efficient use of the large percentage of cavities in the alluvial layers of gravel possible.

Next we will discuss, briefly, our conclusions based on the cross-sectional analysis of electric exploration also contained in the report mentioned above.

11.2 A Study of the Findings from the Electric Explorations

In 1978 and 1980, the Servicio Geologico de Bolivia and Las Naciones Unidas (PUND) carried out a hydro-geological investigation of a wide area, with Tarija city as the center that covered an area exceeding 3,200 km^2. It mainly consisted of electric explorations utilizing a total of 265 points to carry out measurements based on the Slchlucmberger method (as shown on Fig. c.11.1).

The Santa Ana region was part of the eastern end of the area under investigation, and data from the 4 lateral lines, (9), (22), (21), (20) was relevant. The total depth measured amounted to 300 m.

As a result of these investigations, it was found that the area was extremely poor in layers of gravel which is most useful as aquifers. Also, since there are thick layers of deposits with fine grains, it was concluded that underground water did not exist.

As mentioned elsewhere, geologically, the area forming a basin has a base that mainly consists of layers of sandstone and mudstone from the paleozoic era. The Yesera river and Santa Ana river flow through the center of this area from the south to the north and are joined by the San Agustin river, Gamoneda river, and other smaller streams. However, except for the small amount of gravel found in the present river bed, there are no other aquifers.

The amount of water obtained from the deep wells in the area is bellow 1,000 m^3/day and is not sufficient for the irrigation of cultivatable land in the area.

Following is an explanation regarding each of the aforementioned lateral lines in the investigation.

11.2.1 Lateral Line (9)

The analysis and classification of deposit layers and such, when considered in the light of the resistance value, seem appropriate. The only discrepancy might be the question of whether a 300 m high accumulation of extremely thick sand layers is possible in No. 25 and 26 as suggested. If the canyon and the river bad formerly taken a course leading from east to west, then larger amounts of coarse grained gravel (including stones) should have accumulated on the upper parts. With No. 27 and 28 both consisting of alternate layers of clay mixture, could the river have had a low flow velocity? This is one point about which there remains some doubt.

Also, in the next section under (8), the depth of the foundation base is about EL. 1,500 m in 16, 17, 18 - 21, 22, 23 and seems to be correct. However, the fact that fine-grained deposits are said to be more prevalent here seems to contradict the claim that coarser grains are predominant in an area that is wider.

In any case, judging from the resistance value, there can not be any underground water except under the sand. In this case, too, the water seems to be coming either from the hinterland, or conversely from the direction of Tarija city in the west.

11.2.2 Lateral Line (22)

Near Santa Ana, where at EL. 1,660 m clayey layers serving as aquifer are scattered widely to the west and east, there is a basin, which at EL. 1,640 m lies lower. Here, between No. 158 and 167, there is a boring 180 m deep.

The well with a diameter of 8 inches has an output of 4.0 l/sec - 345 m^3/day. Its natural water level is 40 - 50 m, the dynamic water level (pump depth) is 74 m, and it is situated near La Crug and La Cavama. In this region of predominantly clayey layers, it is impossible to obtain more water than this.

According to the results of the electric explorations, a rock base is reached at near EL. 1,540 m, but in reality even if excavations close to 300 m were carried out from EL. 1,820 m in order to reach the alternating layers of the sand and gravel mixture, found between EL. 1,650 m and 1,540 m, the amount of water would be probably less than 5 - 600 m^3 - 1,000 m^3/day. But excavation work to reach such depth would be very costly and economically not feasible.

11.2.3 Lateral Line (21)

In this region, the rock base of Devonian layers of sandstone that form the mountains in San Agustin, descend sharply to the west. This is most probably due to the effect of the large fault. In the west of Santa Ana at EL. 1,640 m, it comes in at 1/3 of the inclination, at about 20^o. There are muddy deposits almost until near the foundation. The fact that there is an accumulation of fine-grained deposit in an area where the flow velocity is supposedly high, something that would be natural in areas such as along the lateral line (22) of La Crug, where a bend in the old river channel forms a stagnant spot is hard to explain.

It was not possible to observe the core of the boring, but may be the strong influence of a certain amount of inorganic salt has made it impossible to claim with certainty that sand lies higher than clay there.

Since these observations are based on available data. It can be concluded that if Poso No. 18 is considered to be representative of San Miguel area, then underground water does not exist anywhere except at a depth of 20 - 30 m in the layers of gravel. If excavation is carried out through the alternating layers of gravel and clay at EL. 1,760 m, it might be possible to obtain 300 - 500 m^3/day of water. Moreover, it is possible that the aquifer in the wells at San Miguel are also alluvial layers of gravel from present Santa Ana river. Thus, even increasing the depth would not make more water available.

11.2.4 Lateral Line (20) (the Santa Ana Community)

Here, starting at the left bank, the Paleozoic sandstone layers of the base are exposed and, in the regions near Santa Ana river, they descend sharply up to near EL. 1,820 m. However, the data from No. 162 shows some irregularities, indicating that even at lower than EL. 1,700 m this foundation is not to be seen. Judging from No. 165, which lies further to the west and where foundation rock is seen at EL. 1,790 m, the rock forming base covers and area extending from where the Santa Ana Dam is presently planned to the areas along the Santa Ana river. Rather than having been influenced by the large fault that runs from the NNE - SSW, apparently it is influenced by the fault as it passes through the area that has the electric exploration point 16 as its center. In fact, since this fault covers an extremely wide area, both No. 163 and 165 lie within the line of fracture, and according to electric exploration findings, have a value higher than 70 ohm-m, which would indicate an impressive foundation rock. No. 162 alone, however, lies lower compared to the adjacent areas, and there is a possibility that this may have caused the difficulty in judgment.

Presently, there are 2 wells that have been excavated manually (depth 11 m and 8 m). The 11 m one has no water during the dry season. The depth of water in the 8 m wall is about 1.0 m, and it is presently being used. However, since this well seems to have been excavated through parts of the layers of gravel of the present bed of Santa Ana river, the water should more appropriately be considered infiltrated rather than underground water.

In addition, there is a 60 m deep well near the health center, which is not used now. And even when in use, pumping discharge is said to have been small. (W.L. - 18m, water would stop coming out after 10 minutes of pumping.)

Nearby, about 20 m away, there is another manually excavated well (13 m deep). Its present water level is somewhere around 11.8 - 11.5, which rises another 2.5 - 3.5 m during the high water season. In this case, too, the location seems to be on parts of the bed of present Santa Ana river, and as in the case mentioned before, the water discharged should rather be considered infiltrated water.

11.2.5 Summary

The foregoing was an outline of data obtained from the study of wells and the electric explorations regarding underground water in the Santa Ana area. On the basis of these, it can be concluded that the largest amount of underground water that could be pumped out from the alluvial layers of gravel as well as from the extremely thick layers of clay and gravel dating from the Holocene epoch would not exceed 500 m^3/day, or at most 1,000 m^3/day. This would suggest that the development of underground water would be costly and inefficient, and unless the development and utilization of surface water (such as the construction of a dam or farm ponds) becomes impossible, it would be impractical to seek underground water in the Santa Ana area.

For the development of surface water, the construction of farm ponds and such will not only result in the storage of water directly, but by using about 30% of the cavities in the diluvium layers of gravel, it will also be possible to store water underground. Since, it is considered that half of that, (about 15 - 20%) would be lost through percolation, in conjunction with the elimination of gullys a large number of these should be built.

C.12 Reference Data

In addition, geological survey that was carried out with Bolivia side (GEOBOL) is as shown on end of this chapter.

Table C.4.1 Data of Electrical Prospecting Survey (1)

a(m)	2πa	R	1	R	2	R	3	R	4	R	5
1	6.	15.71	99.	3.09	19.	2.22	14.	2.30	14.	5.18	32.
2	13.	6.76	85.	1.24	18.	1.42	18.	1.11	14.	2.41	30.
3	19.	6.02	95.	0.80	15.	0.87	18.	0.95	18.	1.88	35.
4	25.	3.42	88.	0.74	19.	0.95	24.	0.85	21.	1.69	42.
5	31.	2.18	88.	0.70	22.	0.85	27.	0.79	26.	1.43	45.
6	38.	1.60	60.	0.69	22.	0.80	30.	0.88	25.	1.22	48.
7	44.	1.25	55.	0.81	23.	0.74	32.	0.84	28.	1.03	48.
8	50.	0.96	48.	0.35	18.	0.68	34.	0.81	31.	1.01	51.
9	57.	0.80	45.	0.43	24.	0.81	36.	0.55	30.	0.93	53.
10	63.	0.82	51.	0.42	26.	0.55	35.	0.51	32.	0.86	55.
11	69.	0.67	46.	0.37	25.	0.63	38.	0.49	34.	0.86	59.
12	75.	0.82	47.	0.39	29.	0.51	38.	0.50	38.	0.76	58.
13	82.	0.87	65.	0.40	33.	0.51	42.	0.53	44.	0.70	57.
14	88.	0.67	59.	0.45	39.	0.49	43.	0.49	43.	0.87	59.
15	94.	0.66	62.	0.41	38.	0.48	48.	0.49	48.	0.83	60.
16	101.	0.62	62.	0.37	37.	0.48	48.	0.51	52.	0.81	61.
17	107.	0.63	67.	0.39	42.	0.48	51.	0.48	51.	0.58	62.
18	113.	0.61	69.	0.36	41.	0.49	55.	0.49	55.	0.55	62.
19	119.	0.59	71.	0.37	44.	0.49	58.	0.48	55.	0.53	63.
20	126.	0.59	74.	0.37	46.	0.47	59.	0.46	58.	0.50	63.
22	138.	0.57	79.	0.37	50.	0.47	65.	0.44	61.	0.48	66.
24	151.	0.53	80.	0.35	53.	0.46	70.	0.43	65.	0.45	68.
26	163.	0.50	88.	0.37	60.	0.46	74.	0.42	69.	0.42	68.
28	176.	0.48	81.	0.36	63.	0.42	75.	0.42	74.	0.40	70.
30	188.	0.47	88.	0.35	66.	0.39	74.	0.40	75.	0.38	71.
32	201.	0.44	89.	0.34	69.	0.35	78.	0.38	73.	0.36	73.
34	214.	0.45	96.	0.33	70.	0.35	76.	0.37	79.	0.35	74.
36	226.	0.40	90.	0.38	71.	0.34	79.	0.35	79.	0.33	75.
38	239.	0.39	93.	0.31	74.	0.32	77.	0.33	78.	0.33	78.
40	251.	0.38	91.	0.29	73.	0.33	84.	0.34	84.	0.32	81.
42	264.	0.34	91.	0.28	74.	0.33	88.	0.33	88.	0.32	83.
44	276.	0.32	89.	0.28	77.	0.32	88.	0.32	88.	0.31	85.
46	289.	0.34	97.	0.29	82.	0.31	89.	0.31	90.	0.30	88.
48	302.	0.30	90.	0.29	87.	0.30	90.	0.31	92.	0.30	89.
50	314.	0.33	103.	0.29	90.	0.32	99.	0.30	95.	0.29	92.
52	327.	0.43	140.	-	-	-	-	-	-	-	-
54	339.	0.32	108.	-	-	-	-	-	-	-	-
56	352.	0.31	108.	-	-	-	-	-	-	-	-
58	364.	0.31	111.	-	-	-	-	-	-	-	-
60	377.	0.28	105.	-	-	-	-	-	-	-	-

a(m)	2πa	R	6	R	7	R	8	R	9	R	10
1	6.	6.84	43.	4.93	31.	5.13	32.	4.22	27.	5.78	36.
2	13.	2.75	35.	2.90	36.	3.50	44.	2.08	26.	3.37	42.
3	19.	3.65	69.	2.26	43.	2.60	49.	1.55	29.	2.84	50.
4	25.	2.31	58.	1.92	48.	1.87	47.	1.37	34.	2.31	58.
5	31.	1.98	62.	1.65	52.	1.45	46.	1.63	55.	1.76	55.
6	38.	1.76	66.	1.69	62.	1.24	47.	1.48	58.	1.55	58.
7	44.	1.51	66.	1.30	57.	1.10	48.	0.95	42.	1.46	64.
8	50.	1.35	69.	1.18	59.	0.99	50.	0.88	44.	1.18	59.
9	57.	1.19	67.	1.09	61.	0.90	51.	0.82	46.	1.06	60.
10	63.	1.05	66.	0.99	62.	0.76	48.	0.69	43.	0.91	57.
11	69.	0.99	68.	0.91	63.	0.79	55.	0.62	43.	0.77	53.
12	75.	0.93	70.	0.85	64.	0.77	58.	0.57	43.	0.72	54.
13	82.	0.87	71.	0.79	65.	0.77	63.	0.53	43.	0.71	58.
14	88.	0.81	71.	0.73	64.	0.76	66.	0.51	45.	0.63	55.
15	94.	0.76	72.	0.70	66.	0.72	68.	0.49	46.	0.58	55.
16	101.	0.71	72.	0.65	66.	0.68	68.	0.51	51.	0.58	58.
17	107.	0.68	72.	0.68	67.	0.68	70.	0.51	54.	0.55	59.
18	113.	0.63	72.	0.61	69.	0.58	66.	0.50	56.	0.53	60.
19	119.	0.60	71.	0.59	70.	0.58	69.	0.49	59.	0.53	63.
20	126.	0.58	71.	0.57	71.	0.57	72.	0.50	62.	0.48	62.
22	138.	0.50	69.	0.52	72.	0.51	71.	0.50	69.	0.49	67.
24	151.	0.46	69.	0.49	74.	0.49	73.	0.50	76.	0.47	70.
26	163.	0.43	70.	0.47	76.	0.51	83.	0.50	82.	0.45	73.
28	176.	0.41	72.	0.46	80.	0.49	85.	0.48	87.	0.44	77.
30	188.	0.39	73.	0.45	85.	0.47	89.	0.48	91.	0.43	82.
32	201.	0.36	73.	0.41	83.	0.42	85.	0.49	99.	0.44	88.
34	214.	0.35	75.	0.39	84.	0.43	91.	0.46	98.	0.43	92.
36	226.	0.34	78.	0.38	85.	0.40	90.	0.45	102.	0.40	91.
38	239.	0.33	78.	0.38	85.	0.40	95.	0.44	104.	0.39	94.
40	251.	0.32	81.	0.33	87.	0.39	98.	0.42	106.	0.38	96.
42	264.	0.31	83.	0.33	87.	0.38	102.	0.38	101.	0.35	91.
44	276.	0.31	86.	0.32	87.	0.38	108.	0.41	113.	0.37	103.
46	289.	0.28	82.	0.31	89.	0.39	111.	0.37	105.	0.36	104.
48	302.	0.29	87.	0.30	91.	0.40	119.	-	-	0.35	110.
50	314.	0.29	90.	0.28	89.	-	-	-	-	0.36	112.
52	327.	-	-	-	-	-	-	-	-	-	-
54	339.	-	-	-	-	-	-	-	-	-	-
56	352.	-	-	-	-	-	-	-	-	-	-
58	364.	-	-	-	-	-	-	-	-	-	-
60	377.	-	-	-	-	-	-	-	-	-	-

a(m)	2πa	R	11	R	12	R	13	R	14	R	15
1	6.	4.08	25.	5.94	37.	4.42	28.	2.90	18.	4.53	29.
2	13.	2.05	26.	3.67	46.	3.27	41.	1.39	17.	2.68	38.
3	19.	2.31	44.	3.09	57.	1.73	33.	1.20	23.	2.48	48.
4	25.	1.58	40.	2.22	58.	1.58	39.	1.04	26.	2.11	53.
5	31.	1.47	46.	1.74	55.	1.34	42.	1.08	33.	1.65	56.
6	38.	1.44	54.	1.64	58.	1.22	46.	1.03	39.	1.58	59.
7	44.	1.43	63.	1.55	68.	1.09	48.	0.95	42.	1.32	58.
8	50.	1.37	69.	1.48	73.	0.88	48.	0.82	41.	1.05	53.
9	57.	1.24	70.	1.30	74.	0.84	47.	0.67	38.	0.87	49.
10	63.	1.11	70.	1.15	72.	0.79	50.	0.62	39.	0.75	47.
11	69.	0.99	69.	1.04	72.	0.78	52.	0.64	44.	0.62	43.
12	75.	0.92	69.	0.95	71.	0.71	53.	0.58	44.	0.58	44.
13	82.	0.87	71.	0.93	76.	0.68	55.	0.55	45.	0.53	43.
14	88.	0.80	70.	0.85	74.	0.64	56.	0.49	43.	0.48	42.
15	94.	0.74	69.	0.78	74.	0.59	56.	0.48	46.	0.48	45.
16	101.	0.67	67.	0.73	74.	0.60	60.	0.49	50.	0.42	42.
17	107.	0.65	69.	0.69	73.	0.59	63.	0.49	52.	0.41	44.
18	113.	0.63	72.	0.62	70.	0.58	64.	0.46	51.	0.42	47.
19	119.	0.60	72.	0.62	73.	0.52	62.	0.41	49.	0.42	50.
20	126.	0.56	70.	0.55	69.	0.48	60.	0.44	56.	0.42	53.
22	138.	0.51	70.	0.49	67.	0.46	64.	0.42	58.	0.39	53.
24	151.	0.47	70.	0.45	67.	0.44	67.	0.39	59.	0.38	54.
26	163.	0.45	73.	0.44	72.	0.41	66.	0.36	63.	0.36	59.
28	176.	0.45	78.	0.42	73.	0.38	68.	0.37	66.	0.34	60.
30	188.	0.44	83.	0.42	79.	0.34	64.	0.37	70.	0.35	66.
32	201.	0.44	88.	0.41	83.	0.36	71.	0.35	71.	-	-
34	214.	0.42	90.	0.42	90.	0.34	73.	0.34	72.	-	-
36	226.	0.40	90.	0.42	95.	0.34	76.	0.30	67.	-	-
38	239.	0.38	91.	0.38	91.	0.33	79.	0.26	61.	-	-
40	251.	0.38	94.	0.38	94.	0.33	83.	0.28	69.	-	-
42	264.	0.37	98.	0.36	94.	0.29	76.	0.27	70.	-	-
44	276.	0.36	99.	0.37	101.	0.29	80.	0.26	72.	-	-
46	289.	0.35	103.	0.32	93.	0.27	78.	0.26	75.	-	-
48	302.	0.35	105.	0.34	104.	0.27	80.	0.25	75.	-	-
50	314.	0.34	106.	0.34	105.	0.28	82.	0.24	77.	-	-
52	327.	-	-	-	-	-	-	-	-	-	-
54	339.	-	-	-	-	-	-	-	-	-	-
56	352.	-	-	-	-	-	-	-	-	-	-
58	364.	-	-	-	-	-	-	-	-	-	-
60	377.	-	-	-	-	-	-	-	-	-	-

a(m)	2πa	R	16	R	17	R	18	R	19	R	20
1	6.	17.38	109.	18.20	114.	23.22	184.	79.93	503.	7.50	47.
2	13.	10.66	134.	11.55	145.	20.19	254.	16.28	203.	2.47	31.
3	19.	7.18	135.	7.29	137.	12.78	241.	8.26	156.	1.63	31.
4	25.	4.33	109.	4.45	112.	9.47	238.	4.81	121.	1.23	31.
5	31.	2.84	89.	3.00	94.	6.52	205.	3.74	118.	1.06	33.
6	38.	2.32	87.	2.21	83.	4.59	173.	2.99	110.	0.91	34.
7	44.	2.03	89.	1.74	77.	3.65	160.	2.51	110.	0.88	39.
8	50.	1.88	94.	1.42	71.	2.88	144.	2.18	109.	0.79	40.
9	57.	1.62	92.	1.31	74.	2.19	124.	2.03	115.	0.73	41.
10	63.	1.60	101.	1.22	77.	1.78	112.	1.78	110.	0.68	43.
11	69.	1.41	97.	1.19	82.	1.51	104.	1.57	108.	0.68	47.
12	75.	1.30	98.	1.09	82.	1.33	100.	1.43	108.	0.65	49.
13	82.	1.25	102.	1.03	84.	1.26	103.	1.28	103.	0.61	50.
14	88.	1.10	96.	1.00	88.	1.08	95.	1.19	105.	0.59	51.
15	94.	1.05	99.	0.95	89.	0.95	90.	1.13	106.	0.52	49.
16	101.	0.96	97.	0.94	94.	0.91	91.	1.06	106.	0.52	52.
17	107.	0.91	98.	0.90	96.	0.85	91.	0.99	106.	0.48	52.
18	113.	0.88	100.	0.84	95.	0.73	83.	0.94	106.	0.45	51.
19	119.	0.82	99.	0.81	97.	0.75	89.	0.92	110.	0.45	55.
20	126.	0.77	98.	0.78	99.	0.67	84.	0.88	108.	0.42	53.
22	138.	0.72	100.	0.68	95.	0.60	82.	-	-	0.41	58.
24	151.	0.66	100.	0.61	101.	0.54	82.	-	-	0.42	63.
26	163.	0.65	106.	0.59	96.	0.52	84.	-	-	0.40	65.
28	176.	0.65	114.	0.55	98.	0.48	85.	-	-	0.39	68.
30	188.	-	-	0.52	97.	0.43	81.	-	-	0.38	71.
32	201.	-	-	0.47	94.	-	-	-	-	0.38	77.
34	214.	-	-	0.47	100.	-	-	-	-	0.38	81.
36	226.	-	-	0.47	105.	-	-	-	-	0.37	83.
38	239.	-	-	0.45	108.	-	-	-	-	0.35	83.
40	251.	-	-	0.43	108.	-	-	-	-	0.36	90.
42	264.	-	-	-	-	-	-	-	-	0.33	88.
44	276.	-	-	-	-	-	-	-	-	0.38	104.
46	289.	-	-	-	-	-	-	-	-	0.37	107.
48	302.	-	-	-	-	-	-	-	-	0.37	112.
50	314.	-	-	-	-	-	-	-	-	0.35	110.
52	327.	-	-	-	-	-	-	-	-	0.34	112.
54	339.	-	-	-	-	-	-	-	-	0.33	113.
56	352.	-	-	-	-	-	-	-	-	0.33	115.
58	364.	-	-	-	-	-	-	-	-	0.33	118.
60	377.	-	-	-	-	-	-	-	-	0.33	124.

a(m)	2πa	R	21	R	22	R	23	R	24	R	25
1	6.	2.18	14.	6.58	41.	10.93	69.	6.82	43.	1.88	12.
2	13.	1.05	13.	3.02	38.	4.89	61.	2.27	29.	0.82	10.
3	19.	0.75	14.	2.24	42.	3.87	73.	1.19	22.	0.70	13.
4	25.	0.69	17.	1.88	47.	3.18	79.	0.80	20.	0.63	16.
5	31.	0.84	20.	1.89	33.	2.52	78.	0.54	17.	0.59	19.
6	38.	0.80	22.	1.53	58.	2.18	81.	0.49	19.	0.56	21.
7	44.	0.82	23.	1.45	63.	1.85	81.	0.47	21.	0.51	23.
8	50.	0.57	29.	1.33	67.	1.63	82.	0.44	22.	0.46	23.
9	57.	0.54	30.	1.19	68.	1.42	80.	0.40	23.	0.45	26.
10	63.	0.53	33.	1.08	68.	1.19	75.	0.41	26.	0.44	28.
11	69.	0.52	36.	1.01	70.	1.01	70.	0.39	27.	0.41	29.
12	75.	0.49	37.	0.91	68.	0.91	68.	0.37	28.	0.39	30.
13	82.	0.48	39.	0.87	71.	0.88	72.	0.39	32.	0.39	32.
14	88.	0.45	39.	0.81	72.	0.88	77.	0.35	31.	0.43	37.
15	94.	0.45	42.	0.76	71.	0.78	74.	0.37	34.	0.39	37.
16	101.	0.44	44.	0.75	75.	0.79	80.	0.37	37.	0.39	39.
17	107.	0.43	45.	0.66	71.	0.79	84.	0.37	40.	0.43	46.
18	113.	0.41	47.	0.60	68.	0.72	81.	0.36	41.	0.37	42.
19	119.	0.41	49.	0.57	68.	0.68	79.	0.35	45.	0.37	44.
20	126.	0.41	51.	0.52	66.	0.64	81.	0.34	42.	0.38	48.
22	138.	0.39	54.	0.47	65.	0.57	79.	0.32	44.	0.34	48.
24	151.	0.37	56.	0.45	68.	0.52	78.	0.33	49.	0.33	50.
26	163.	0.35	57.	0.43	70.	0.48	79.	0.35	57.	0.35	57.
28	176.	0.34	60.	0.40	71.	0.45	80.	0.32	56.	0.31	54.
30	188.	0.33	63.	0.38	71.	0.43	82.	0.31	58.	0.28	54.
32	201.	0.33	66.	0.39	78.	0.41	82.	0.31	62.	0.26	53.
34	214.	0.30	65.	0.38	81.	0.38	81.	0.29	61.	0.25	54.
36	226.	0.30	68.	0.35	78.	0.34	76.	0.27	61.	0.24	55.
38	239.	0.32	77.	0.34	80.	0.34	82.	0.26	63.	0.22	53.
40	251.	0.30	78.	0.33	82.	0.28	71.	0.23	68.	0.22	54.
42	264.	0.31	82.	0.31	81.	0.24	73.	0.24	64.	0.20	53.
44	276.	0.32	89.	0.32	88.	0.31	86.	0.24	67.	0.24	66.
46	289.	0.31	89.	0.31	90.	0.27	78.	0.24	70.	0.24	68.
48	302.	0.30	91.	0.30	91.	0.29	88.	0.25	75.	0.22	67.
50	314.	0.29	90.	0.29	90.	0.27	85.	0.23	73.	0.24	77.
52	327.	0.29	96.	0.28	92.	0.23	74.	0.24	77.	0.22	71.
54	339.	0.28	93.	0.28	90.	0.24	81.	0.20	67.	0.22	74.
56	352.	0.27	94.	0.27	96.	0.22	77.	0.25	88.	0.20	70.
58	364.	0.26	95.	0.27	98.	0.25	90.	0.25	91.	0.21	77.
60	377.	0.26	98.	0.26	98.	0.23	88.	0.25	95.	0.20	74.

a(m)	2πa	R	26	R	27	R	28	R	29	R	30
1	6.	1.78	11.	5.58	35.	2.73	17.	3.32	21.	12.47	78.
2	13.	0.13	2.	1.65	21.	1.51	19.	1.18	15.	3.33	43.
3	19.	0.78	14.	0.85	16.	0.94	18.	0.79	15.	1.64	31.
4	25.	0.48	12.	0.90	23.	0.77	19.	0.65	16.	1.05	26.
5	31.	0.39	12.	0.48	15.	0.64	20.	0.53	16.	0.79	25.
6	38.	0.31	12.	0.35	14.	0.55	21.	0.47	18.	0.66	25.
7	44.	0.34	15.	0.37	16.	0.48	21.	0.43	19.	0.55	24.
8	50.	0.35	17.	0.34	17.	0.43	22.	0.44	22.	0.49	25.
9	57.	0.37	21.	0.32	18.	0.40	23.	0.42	24.	0.44	25.
10	63.	0.38	23.	0.33	21.	0.35	22.	0.40	25.	0.40	25.
11	69.	0.38	26.	0.32	22.	0.38	26.	0.38	26.	0.36	25.
12	75.	0.33	25.	0.32	24.	0.36	27.	0.38	29.	0.34	26.
13	82.	0.34	28.	0.29	24.	0.35	29.	0.37	30.	0.34	27.
14	88.	0.33	29.	0.31	28.	0.34	30.	0.35	31.	0.32	29.
15	94.	0.33	31.	0.31	29.	0.33	31.	0.33	31.	0.32	30.
16	101.	0.35	35.	0.31	31.	0.33	33.	0.32	32.	0.32	32.
17	107.	0.33	35.	0.27	28.	0.33	35.	0.31	34.	0.30	32.
18	113.	0.31	35.	0.27	31.	0.30	34.	0.31	35.	0.29	33.
19	119.	0.31	37.	0.28	34.	0.29	35.	0.32	38.	0.30	36.
20	126.	0.30	38.	0.29	36.	0.29	36.	0.30	37.	0.31	39.
22	138.	0.33	45.	0.25	35.	0.29	40.	0.30	41.	0.29	40.
24	151.	0.30	45.	0.27	41.	0.28	42.	0.28	41.	0.32	49.
26	163.	0.28	46.	0.24	40.	0.28	45.	0.27	44.	0.28	46.
28	176.	0.28	49.	0.24	42.	0.29	51.	0.24	43.	0.29	51.
30	188.	0.28	52.	0.22	42.	0.27	51.	0.27	51.	0.28	50.
32	201.	0.28	57.	0.23	47.	0.28	55.	0.27	54.	0.27	55.
34	214.	0.30	64.	0.21	45.	0.23	50.	0.26	55.	0.27	58.
36	226.	0.27	61.	0.23	52.	0.27	61.	0.24	55.	0.26	59.
38	239.	0.28	66.	0.23	56.	0.26	62.	0.22	53.	0.28	67.
40	251.	0.25	62.	0.24	61.	0.23	59.	0.23	58.	0.30	76.
42	264.	0.25	65.	0.24	62.	0.23	62.	0.22	59.	0.28	88.
44	276.	0.21	59.	0.23	65.	0.23	64.	0.23	63.	0.25	65.
46	289.	0.22	64.	0.25	71.	0.24	70.	0.21	60.	0.21	61.
48	302.	0.25	76.	0.23	69.	0.21	64.	0.21	64.	0.21	62.
50	314.	0.24	77.	0.24	76.	0.20	63.	0.21	66.	0.20	62.
52	327.	0.25	81.	0.21	67.	0.21	70.	0.21	69.	0.19	62.
54	339.	0.22	74.	0.21	71.	0.21	70.	0.21	71.	0.17	58.
56	352.	0.21	75.	0.22	78.	0.23	81.	0.20	70.	0.16	56.
58	364.	0.23	85.	0.24	87.	0.22	79.	0.19	69.	0.16	59.
60	377.	0.24	89.	0.23	87.	0.20	74.	0.18	68.	0.16	62.

Table C.4.1 Data of Electrical Prospecting Survey (2)

a(m)	2πa	ρ	31	ρ	32	ρ	33	ρ	34	ρ	35
1	6.	3.10	19.	48.60	305.	6.88	43.	2.72	17.	2.92	18.
2	13.	1.27	16.	25.55	321.	5.02	63.	1.84	23.	1.38	17.
3	19.	0.77	14.	14.65	276.	3.73	70.	1.67	32.	0.95	18.
4	25.	0.60	15.	8.22	207.	2.90	73.	1.35	34.	0.98	24.
5	31.	0.60	19.	5.90	185.	2.56	60.	1.10	35.	0.94	29.
6	38.	0.53	22.	4.07	153.	2.37	59.	1.03	38.	0.84	32.
7	44.	0.49	21.	2.95	127.	2.02	59.	0.83	35.	0.78	34.
8	50.	0.35	20.	2.41	121.	1.66	83.	0.70	35.	0.78	38.
9	57.	0.35	20.	2.07	117.	1.40	78.	0.65	37.	0.74	42.
10	63.	0.31	20.	1.72	108.	1.26	79.	0.64	40.	0.74	46.
11	69.	0.33	23.	1.51	104.	1.12	77.	0.60	41.	0.72	50.
12	75.	0.28	21.	1.16	88.	1.04	75.	0.59	45.	0.69	52.
13	82.	0.28	23.	1.12	91.	0.97	78.	0.58	48.	0.66	53.
14	88.	0.29	25.	0.93	78.	0.95	81.	0.55	49.	0.65	55.
15	94.	0.26	24.	0.93	87.	0.94	88.	0.53	50.	0.63	60.
16	101.	0.28	28.	0.90	91.	0.88	88.	0.50	50.	0.64	65.
17	107.	0.21	23.	0.84	90.	0.73	84.	0.54	57.	0.61	65.
18	113.	0.24	27.	0.79	89.	0.71	80.	0.55	62.	0.61	69.
19	119.	0.22	26.	0.78	91.	0.67	80.	0.57	68.	0.61	73.
20	126.	0.25	32.	0.73	92.	0.64	83.	0.57	71.	0.64	83.
22	138.	0.25	35.	0.70	97.	0.59	82.	0.57	78.	0.62	84.
24	151.	0.25	38.	0.69	104.	0.57	89.	0.58	85.	0.58	88.
26	163.	0.26	42.	0.68	110.	0.55	90.	0.53	88.	0.53	87.
28	176.	0.26	45.	0.65	112.	0.53	93.	0.48	84.	0.48	84.
30	188.	0.25	47.	0.67	128.	0.52	98.	0.46	87.	0.49	89.
32	201.	0.25	50.	0.61	122.	0.50	100.	0.43	88.	0.45	90.
34	214.	0.24	51.	0.58	123.	0.51	109.	0.40	84.	0.45	92.
36	226.	0.24	55.	0.59	133.	0.48	109.	0.38	86.	0.43	98.
38	239.	0.24	57.	0.61	145.	0.48	115.	0.36	86.	0.42	101.
40	251.	0.22	55.	0.56	142.	-	-	0.39	94.	0.41	102.
42	264.	0.21	56.	0.54	142.	-	-	0.35	99.	0.40	105.
44	276.	0.20	56.	0.53	141.	-	-	0.35	105.	0.37	103.
46	289.	0.20	58.	0.52	150.	-	-	0.35	105.	0.35	102.
48	302.	0.19	56.	0.50	151.	-	-	0.35	105.	0.33	98.
50	314.	0.18	57.	0.47	148.	-	-	0.34	107.	0.31	99.
52	327.	0.18	55.	0.45	149.	-	-	0.34	109.	0.34	111.
54	339.	0.15	53.	0.45	153.	-	-	0.34	116.	0.29	98.
56	352.	0.16	55.	0.44	154.	-	-	0.33	116.	0.28	100.
58	364.	0.14	52.	0.41	155.	-	-	0.32	111.	0.28	102.
60	377.	0.13	49.	0.41	163.	-	-	0.31	118.	-	-

a(m)	2πa	ρ	36	ρ	37	ρ	38	ρ	39	ρ	40
1	6.	2.16	14.	3.49	22.	2.74	17.	2.18	14.	7.38	18.
2	13.	1.45	18.	2.34	29.	1.73	22.	1.10	14.	2.44	31.
3	19.	1.13	21.	2.17	41.	0.92	17.	0.77	14.	1.20	23.
4	25.	0.83	21.	1.74	44.	0.59	15.	0.57	14.	0.91	23.
5	31.	0.80	25.	1.31	41.	0.55	17.	0.50	16.	0.76	24.
6	38.	0.71	27.	1.05	39.	0.54	20.	0.37	14.	0.65	24.
7	44.	0.64	28.	0.85	37.	0.55	24.	0.32	14.	0.59	26.
8	50.	0.59	33.	0.72	36.	0.54	27.	0.32	16.	0.49	25.
9	57.	0.65	37.	0.60	34.	0.49	28.	0.36	21.	0.52	30.
10	63.	0.64	40.	0.53	33.	0.46	28.	0.28	18.	0.51	32.
11	69.	0.64	44.	0.50	34.	0.39	27.	0.24	18.	0.49	34.
12	75.	0.63	48.	0.48	36.	0.40	30.	0.25	19.	0.48	36.
13	82.	0.61	49.	0.48	39.	0.38	31.	0.27	22.	0.44	36.
14	88.	0.57	50.	0.47	41.	0.38	34.	0.26	23.	0.43	38.
15	94.	0.56	53.	0.45	42.	0.37	35.	0.27	26.	0.42	40.
16	101.	0.57	57.	0.45	45.	0.35	36.	0.27	27.	0.43	43.
17	107.	0.54	58.	0.43	46.	0.35	38.	0.27	29.	0.42	45.
18	113.	0.58	63.	0.42	46.	0.34	38.	0.27	30.	0.38	43.
19	119.	0.52	62.	0.39	47.	0.31	41.	0.26	31.	0.37	44.
20	126.	0.52	65.	0.40	50.	0.34	43.	0.25	32.	0.36	46.
22	138.	0.48	66.	0.41	57.	0.32	44.	0.29	38.	0.34	47.
24	151.	0.49	74.	0.39	59.	0.32	49.	0.27	40.	0.33	49.
26	163.	0.47	76.	0.39	64.	0.32	52.	0.22	36.	0.32	53.
28	176.	0.44	78.	0.38	67.	0.30	53.	0.27	47.	0.30	53.
30	188.	0.41	78.	0.40	75.	0.31	58.	0.27	50.	0.31	58.
32	201.	0.38	76.	0.40	79.	0.28	57.	0.23	47.	0.31	61.
34	214.	0.37	80.	0.37	79.	0.24	50.	0.23	49.	0.32	68.
36	226.	0.37	83.	0.37	84.	0.29	65.	0.22	49.	0.30	68.
38	239.	0.38	88.	0.37	88.	0.27	64.	0.21	51.	0.33	78.
40	251.	0.38	91.	0.37	92.	0.27	68.	0.23	58.	0.32	79.
42	264.	0.37	97.	0.37	97.	0.27	70.	0.23	60.	0.31	81.
44	276.	0.36	100.	0.36	98.	0.23	63.	0.21	57.	0.30	84.
46	289.	0.35	102.	0.37	106.	0.22	62.	0.20	59.	0.30	86.
48	302.	0.35	105.	0.33	99.	0.27	68.	0.20	59.	0.29	85.
50	314.	0.32	101.	0.30	94.	0.22	70.	0.19	60.	0.29	90.
52	327.	0.35	105.	0.30	97.	0.23	74.	0.18	58.	0.28	91.
54	339.	0.31	105.	0.27	91.	0.20	68.	0.18	61.	0.29	99.
56	352.	0.31	110.	0.28	99.	0.20	71.	0.16	57.	0.29	103.
58	364.	0.32	116.	0.26	95.	0.20	73.	0.16	59.	0.29	106.
60	377.	0.33	123.	0.25	94.	0.20	76.	0.18	69.	0.29	108.

a(m)	2πa	ρ	41	ρ	42	ρ	43	ρ	44	ρ	45
1	6.	3.43	22.	3.84	24.	2.55	16.	4.29	27.	5.78	35.
2	13.	2.29	29.	1.79	23.	2.38	33.	1.59	20.	2.16	27.
3	19.	1.39	28.	1.03	19.	1.81	35.	1.08	20.	1.18	22.
4	25.	1.09	27.	0.98	24.	1.83	41.	0.89	22.	0.90	23.
5	31.	1.00	31.	0.94	29.	1.27	40.	0.85	26.	0.75	24.
6	38.	0.86	32.	0.35	35.	1.19	44.	0.71	27.	0.73	27.
7	44.	0.80	35.	0.91	40.	1.12	49.	0.61	27.	0.70	31.
8	50.	0.79	40.	0.87	44.	1.07	54.	0.58	29.	0.71	39.
9	57.	0.75	42.	0.83	47.	0.97	55.	0.58	33.	0.83	39.
10	63.	0.69	43.	0.75	47.	0.91	57.	0.51	38.	0.68	43.
11	69.	0.68	49.	0.69	47.	0.83	58.	0.50	35.	0.67	46.
12	75.	0.63	48.	0.57	50.	0.80	60.	0.47	35.	0.65	45.
13	82.	0.61	50.	0.65	53.	0.73	64.	0.43	40.	0.62	51.
14	88.	0.58	51.	0.64	58.	0.82	72.	0.48	41.	0.63	55.
15	94.	0.55	52.	0.63	59.	0.82	77.	0.47	44.	0.60	57.
16	101.	0.54	54.	0.61	61.	0.80	80.	0.44	44.	0.57	57.
17	107.	0.53	58.	0.60	65.	0.76	81.	0.43	46.	0.51	55.
18	113.	0.51	58.	0.60	67.	0.78	80.	0.43	48.	0.47	53.
19	119.	0.50	59.	0.58	69.	0.65	78.	0.42	50.	0.44	53.
20	126.	0.43	60.	0.57	72.	0.64	80.	0.42	53.	0.42	52.
22	138.	0.43	60.	0.53	74.	0.61	84.	0.39	54.	0.39	54.
24	151.	0.41	62.	0.50	75.	0.59	88.	0.38	54.	0.38	58.
26	163.	0.42	68.	0.47	77.	0.57	93.	0.38	56.	0.37	61.
28	176.	0.41	72.	0.44	78.	0.53	94.	0.34	61.	0.35	62.
30	188.	0.38	72.	0.42	79.	0.51	97.	0.37	63.	0.34	63.
32	201.	0.37	75.	0.41	82.	0.50	100.	0.36	71.	0.33	68.
34	214.	0.36	77.	0.40	85.	0.48	104.	0.36	76.	0.34	72.
36	226.	0.35	80.	0.39	87.	0.47	106.	0.36	81.	0.33	75.
38	239.	0.35	84.	0.37	88.	0.43	110.	0.35	83.	0.33	79.
40	251.	0.35	87.	0.36	89.	0.42	105.	0.36	83.	0.32	81.
42	264.	0.34	93.	0.32	84.	0.40	106.	0.34	91.	0.31	82.
44	276.	0.34	95.	0.31	87.	0.38	109.	0.36	101.	0.31	86.
46	289.	0.32	94.	0.31	89.	0.37	107.	0.34	99.	0.32	91.
48	302.	0.31	94.	0.30	90.	0.35	107.	0.35	106.	0.32	96.
50	314.	0.31	98.	0.30	94.	0.33	105.	0.33	105.	0.32	102.
52	327.	0.32	105.	0.29	96.	0.34	119.	0.32	109.	0.32	108.
54	339.	0.31	106.	0.29	97.	0.31	107.	0.31	114.	0.32	109.
56	352.	0.32	111.	0.28	100.	0.30	109.	0.34	121.	0.33	114.
58	364.	0.31	114.	0.29	104.	0.29	107.	0.33	119.	0.31	118.
60	377.	0.30	114.	0.28	104.	0.28	104.	0.33	124.	0.33	124.

a(m)	2πa	ρ	46	ρ	47	ρ	48	ρ	49	ρ	50
1	6.	4.20	28.	4.32	31.	2.33	16.	4.07	28.	42.39	168.
2	13.	2.50	31.	2.81	33.	1.18	13.	2.12	27.	25.14	328.
3	19.	1.38	35.	1.83	34.	0.82	15.	1.76	33.	16.91	311.
4	25.	1.49	37.	1.56	38.	0.70	17.	1.64	39.	10.58	269.
5	31.	1.18	37.	1.37	41.	0.53	20.	1.39	44.	7.14	224.
6	38.	1.02	38.	1.20	46.	0.58	22.	1.29	49.	4.70	177.
7	44.	0.88	39.	1.03	48.	0.59	26.	1.15	51.	3.38	149.
8	50.	0.78	39.	0.99	50.	0.58	29.	1.05	53.	2.44	117.
9	57.	0.83	39.	0.90	51.	0.80	34.	0.92	52.	1.79	101.
10	63.	0.58	42.	0.85	56.	0.57	36.	0.85	52.	1.39	87.
11	69.	0.65	45.	0.84	58.	0.63	37.	0.76	52.	1.09	76.
12	75.	0.61	48.	0.80	60.	0.62	49.	0.83	52.	0.93	70.
13	82.	0.63	51.	0.78	64.	0.52	43.	0.65	53.	0.88	79.
14	88.	0.61	54.	0.72	64.	0.51	44.	0.59	52.	0.78	85.
15	94.	0.59	58.	0.64	64.	0.49	45.	0.57	53.	0.73	69.
16	101.	0.57	58.	0.68	67.	0.47	47.	0.53	54.	0.71	71.
17	107.	0.56	60.	0.55	59.	0.45	48.	0.52	55.	0.69	73.
18	113.	0.54	61.	0.55	73.	0.44	50.	0.49	55.	0.66	74.
19	119.	0.52	63.	0.61	73.	0.42	50.	0.43	57.	0.63	75.
20	126.	0.50	63.	0.58	73.	0.41	51.	0.48	60.	0.60	75.
22	138.	0.47	65.	0.52	72.	0.39	54.	0.47	65.	0.61	84.
24	151.	0.43	65.	0.45	69.	0.40	60.	0.45	68.	0.62	93.
26	163.	0.41	67.	0.42	68.	0.39	65.	0.44	71.	0.53	98.
28	176.	0.39	64.	0.39	68.	0.38	68.	0.42	73.	0.63	111.
30	188.	0.38	71.	0.35	65.	0.36	68.	0.41	78.	0.64	121.
32	201.	0.35	71.	0.32	65.	0.37	73.	0.40	80.	0.64	123.
34	214.	0.35	74.	0.30	64.	0.37	79.	0.38	81.	0.62	130.
36	226.	0.33	75.	0.32	71.	0.36	85.	0.36	81.	0.62	139.
38	239.	0.33	73.	0.31	74.	0.37	87.	0.34	82.	0.69	140.
40	251.	0.34	88.	0.30	74.	0.36	90.	0.34	85.	0.54	138.
42	264.	0.34	90.	0.29	79.	0.37	98.	0.34	91.	0.54	143.
44	276.	0.30	84.	0.29	81.	0.35	97.	0.32	90.	0.53	147.
46	289.	0.31	89.	0.29	83.	0.35	102.	0.32	91.	0.51	148.
48	302.	0.30	90.	0.27	80.	0.34	103.	0.32	98.	0.50	149.
50	314.	0.30	94.	0.26	87.	0.33	103.	0.30	94.	0.47	148.
52	327.	0.30	97.	0.28	93.	0.32	103.	0.29	96.	0.45	146.
54	339.	0.30	103.	-	-	0.31	106.	0.29	97.	0.47	158.
56	352.	0.30	106.	-	-	0.30	107.	0.26	92.	0.44	154.
58	364.	0.30	111.	-	-	0.31	113.	0.28	98.	0.41	149.
60	377.	0.32	121.	-	-	0.30	116.	0.28	100.	0.33	147.

a(m)	2πa	ρ	51	ρ	52	ρ	53	ρ	54	ρ	55
1	6.	30.46	131.	3.75	24.	9.78	61.	61.75	225.	8.54	52.
2	13.	14.21	178.	2.17	27.	7.72	97.	18.54	233.	3.55	46.
3	19.	6.43	121.	1.57	32.	6.31	111.	10.60	200.	2.49	47.
4	25.	3.00	75.	1.25	31.	4.89	121.	7.08	178.	2.32	58.
5	31.	0.94	31.	1.22	38.	3.58	121.	5.18	169.	2.35	74.
6	38.	1.07	40.	1.08	40.	3.02	114.	3.84	145.	1.83	81.
7	44.	2.19	92.	1.04	47.	2.23	101.	2.11	127.	1.35	90.
8	50.	1.66	81.	1.02	51.	1.96	98.	2.81	141.	1.31	71.
9	57.	1.52	93.	0.94	53.	1.53	92.	1.75	151.	1.22	67.
10	63.	1.23	78.	0.87	55.	1.44	90.	2.41	152.	1.03	64.
11	69.	1.18	82.	0.71	54.	1.28	87.	2.17	160.	0.98	68.
12	75.	0.93	73.	0.70	53.	1.18	89.	1.97	149.	0.84	63.
13	82.	0.84	29.	0.57	55.	1.08	88.	1.77	145.	0.75	61.
14	88.	0.86	74.	0.63	56.	0.93	86.	1.79	150.	0.76	61.
15	94.	0.94	85.	0.57	62.	0.84	83.	1.67	157.	0.70	66.
16	101.	0.81	82.	0.66	58.	0.85	85.	1.65	148.	0.68	64.
17	107.	0.87	93.	0.52	55.	0.81	88.	1.21	128.	0.61	65.
18	113.	0.61	82.	0.64	60.	0.78	88.	1.13	127.	0.51	57.
19	119.	0.77	92.	0.61	61.	0.72	88.	1.04	124.	0.54	65.
20	126.	0.78	99.	0.45	58.	0.79	98.	0.96	121.	0.61	64.
22	138.	0.74	102.	0.45	62.	0.69	96.	0.85	117.	0.44	66.
24	151.	0.71	107.	0.41	64.	0.62	100.	0.78	114.	0.41	62.
26	163.	0.92	126.	0.38	62.	0.64	104.	0.68	111.	0.38	55.
28	176.	0.82	105.	0.41	72.	0.60	106.	0.62	108.	0.36	63.
30	188.	0.59	112.	0.41	77.	0.56	105.	0.59	111.	0.34	63.
32	201.	0.58	118.	0.41	83.	0.57	114.	0.54	109.	0.36	72.
34	214.	0.54	116.	0.44	95.	0.55	117.	0.44	94.	0.34	72.
36	226.	0.56	116.	0.47	105.	0.53	119.	0.38	86.	0.32	73.
38	239.	0.48	109.	0.48	109.	0.51	121.	0.40	96.	0.28	66.
40	251.	0.51	127.	0.48	118.	0.47	118.	0.36	89.	0.28	70.
42	264.	0.47	125.	0.44	115.	0.45	118.	0.34	90.	0.25	67.
44	276.	0.47	129.	0.45	126.	0.45	125.	0.30	84.	0.25	69.
46	289.	0.46	132.	0.38	111.	-	-	0.31	88.	0.24	70.
48	302.	0.43	131.	0.44	131.	-	-	0.31	92.	0.22	66.
50	314.	0.41	128.	0.41	128.	-	-	0.31	98.	0.23	73.
52	327.	0.42	136.	0.40	130.	-	-	0.30	98.	0.21	68.
54	339.	0.41	138.	0.37	125.	-	-	0.29	99.	0.21	71.
56	352.	0.36	128.	0.39	138.	-	-	0.28	100.	0.19	66.
58	364.	0.36	132.	0.40	146.	-	-	0.28	103.	0.20	74.
60	377.	0.38	141.	0.39	146.	-	-	0.27	102.	0.20	75.

a(m)	2πa	ρ	56	ρ	57	ρ	58	ρ	59	ρ	60
1	6.	1.71	11.	77.97	490.	17.39	109.	27.95	176.	10.75	68.
2	13.	0.95	12.	40.35	507.	7.41	94.	7.60	95.	5.28	66.
3	19.	0.69	13.	23.65	446.	5.14	97.	2.72	51.	3.47	65.
4	25.	0.62	16.	14.16	356.	3.46	87.	2.12	53.	2.42	61.
5	31.	0.47	15.	8.82	277.	2.60	82.	1.69	53.	1.66	52.
6	38.	0.42	16.	5.51	208.	2.17	82.	1.32	50.	1.77	67.
7	44.	0.32	14.	3.66	160.	1.81	80.	1.27	56.	1.43	63.
8	50.	0.37	18.	2.92	147.	1.60	80.	1.20	60.	1.29	65.
9	57.	0.38	21.	2.65	150.	1.45	81.	1.07	60.	1.04	61.
10	63.	0.37	23.	2.02	127.	1.27	80.	0.97	61.	0.88	64.
11	69.	0.38	25.	1.79	124.	1.28	87.	0.78	64.	0.75	52.
12	75.	0.36	28.	1.38	104.	1.11	84.	0.80	62.	0.68	51.
13	82.	0.35	28.	1.46	119.	1.12	91.	0.65	63.	0.68	54.
14	88.	0.34	29.	1.23	117.	1.02	89.	0.64	56.	0.68	60.
15	94.	0.33	31.	1.21	114.	0.81	85.	0.68	65.	0.54	61.
16	101.	0.33	34.	1.11	111.	0.85	85.	0.58	58.	0.59	60.
17	107.	0.33	36.	1.06	113.	0.77	82.	0.68	69.	0.57	60.
18	113.	0.33	38.	0.98	110.	0.7	81.	0.53	60.	0.54	61.
19	119.	0.34	40.	0.93	111.	0.64	77.	0.53	63.	0.52	62.
20	126.	0.35	42.	0.88	110.	0.58	74.	0.66	68.	0.55	67.
22	138.	0.33	46.	-	-	-	-	-	-	-	-
24	151.	0.31	47.	-	-	-	-	-	-	-	-
26	163.	0.29	48.	-	-	-	-	-	-	-	-
28	176.	0.29	51.	-	-	-	-	-	-	-	-
30	188.	0.27	51.	-	-	-	-	-	-	-	-
32	201.	0.26	56.	-	-	-	-	-	-	-	-
34	214.	0.23	49.	-	-	-	-	-	-	-	-
36	226.	0.27	60.	-	-	-	-	-	-	-	-
38	239.	0.25	60.	-	-	-	-	-	-	-	-
40	251.	0.22	68.	-	-	-	-	-	-	-	-
42	264.	0.18	47.	-	-	-	-	-	-	-	-
44	276.	0.17	48.	-	-	-	-	-	-	-	-
46	289.	0.19	54.	-	-	-	-	-	-	-	-
48	302.	0.16	49.	-	-	-	-	-	-	-	-
50	314.	0.16	51.	-	-	-	-	-	-	-	-
52	327.	0.16	53.	-	-	-	-	-	-	-	-
54	339.	0.16	53.	-	-	-	-	-	-	-	-
56	352.	0.18	66.	-	-	-	-	-	-	-	-
58	364.	0.18	65.	-	-	-	-	-	-	-	-
60	377.	0.16	58.	-	-	-	-	-	-	-	-

Table C.4.1 Data of Electrical Prospecting Survey (3)

a(m)	2πa	R	61	R	62	R	63	R	64	R	65
1	6.	62.23	391.	9.32	58.	19.18	121.	38.74	243.	71.50	449.
2	13.	40.12	504.	5.92	74.	8.18	103.	17.72	223.	26.71	336.
3	19.	26.11	492.	4.09	77.	4.78	90.	12.12	228.	12.51	236.
4	25.	16.88	424.	2.75	69.	3.68	92.	8.56	215.	8.21	206.
5	31.	10.03	315.	2.10	66.	3.03	95.	6.20	195.	5.21	164.
6	38.	5.79	218.	1.79	68.	2.89	109.	4.54	171.	4.17	157.
7	44.	3.83	168.	1.58	68.	2.52	111.	3.41	150.	3.25	143.
8	50.	2.57	129.	1.44	72.	2.07	104.	2.83	142.	2.46	124.
9	57.	1.78	100.	1.33	75.	1.78	101.	2.36	133.	1.96	111.
10	63.	1.37	86.	1.21	76.	1.66	104.	2.09	131.	1.63	102.
11	69.	1.14	79.	1.10	76.	1.46	101.	1.76	121.	1.45	100.
12	75.	1.01	76.	1.00	75.	1.30	98.	1.62	122.	1.31	99.
13	82.	0.89	73.	0.88	72.	1.20	98.	1.44	118.	1.19	97.
14	88.	0.85	75.	0.79	70.	1.10	97.	1.32	116.	1.07	94.
15	94.	0.76	72.	0.73	69.	1.04	98.	1.19	113.	1.02	96.
16	101.	0.74	74.	0.72	72.	0.98	98.	1.12	112.	0.95	95.
17	107.	0.71	76.	0.68	73.	0.90	96.	1.00	107.	0.89	95.
18	113.	0.70	80.	0.66	75.	0.85	96.	1.00	113.	0.84	95.
19	119.	0.68	81.	0.64	76.	0.82	98.	0.95	113.	0.80	95.
20	126.	0.66	83.	0.62	78.	0.79	100.	0.90	113.	0.76	96.
22	138.	-	-	0.56	77.	0.76	104.	-	-	-	-
24	151.	-	-	0.53	80.	0.72	109.	-	-	-	-
26	163.	-	-	0.51	83.	0.69	113.	-	-	-	-
28	176.	-	-	0.52	91.	0.66	116.	-	-	-	-
30	188.	-	-	0.52	98.	0.63	118.	-	-	-	-
32	201.	-	-	-	-	-	-	-	-	-	-
34	214.	-	-	-	-	-	-	-	-	-	-
36	226.	-	-	-	-	-	-	-	-	-	-
38	239.	-	-	-	-	-	-	-	-	-	-
40	251.	-	-	-	-	-	-	-	-	-	-
42	264.	-	-	-	-	-	-	-	-	-	-
44	276.	-	-	-	-	-	-	-	-	-	-
46	289.	-	-	-	-	-	-	-	-	-	-
48	302.	-	-	-	-	-	-	-	-	-	-
50	314.	-	-	-	-	-	-	-	-	-	-
52	327.	-	-	-	-	-	-	-	-	-	-
54	339.	-	-	-	-	-	-	-	-	-	-
56	352.	-	-	-	-	-	-	-	-	-	-
58	364.	-	-	-	-	-	-	-	-	-	-
60	377.	-	-	-	-	-	-	-	-	-	-

a(m)	2πa	R	66	R	67	R	68	R	69	R	70
1	6.	50.53	317.	18.32	115.	5.67	36.	7.41	47.	12.38	78.
2	13.	16.85	212.	10.64	134.	4.81	60.	4.83	61.	6.88	86.
3	19.	8.30	156.	7.04	133.	3.68	69.	3.80	72.	4.68	88.
4	25.	5.69	143.	4.44	112.	2.70	68.	2.92	73.	3.51	88.
5	31.	3.96	124.	2.87	90.	2.25	71.	2.39	75.	2.74	86.
6	38.	3.07	116.	2.24	84.	2.10	79.	1.95	74.	2.22	84.
7	44.	2.52	111.	1.86	82.	1.78	78.	1.75	77.	1.88	83.
8	50.	2.03	102.	1.62	82.	1.62	81.	1.55	78.	1.67	84.
9	57.	1.73	98.	1.45	82.	1.40	79.	1.42	80.	1.57	89.
10	63.	1.50	94.	1.30	82.	1.25	79.	1.22	77.	1.41	89.
11	69.	1.33	92.	1.18	82.	1.11	77.	1.10	76.	1.28	89.
12	75.	1.17	88.	1.09	82.	0.99	75.	0.95	72.	1.18	89.
13	82.	1.03	84.	1.02	83.	0.90	73.	0.87	71.	1.05	86.
14	88.	0.94	83.	0.93	82.	0.82	72.	0.81	71.	0.94	83.
15	94.	0.88	83.	0.85	80.	0.74	70.	0.75	71.	0.86	81.
16	101.	0.82	82.	0.79	80.	0.72	72.	0.71	71.	0.80	80.
17	107.	0.79	84.	0.73	78.	0.70	75.	0.67	72.	0.76	81.
18	113.	0.75	85.	0.70	79.	0.65	74.	0.64	72.	0.72	81.
19	119.	0.73	87.	0.66	79.	0.64	76.	0.59	70.	0.69	82.
20	126.	0.69	87.	0.63	79.	0.59	75.	0.56	70.	0.66	83.
22	138.	-	-	-	-	0.55	75.	0.51	71.	0.60	83.
24	151.	-	-	-	-	0.52	79.	0.50	78.	0.54	81.
26	163.	-	-	-	-	0.51	83.	0.48	78.	0.51	83.
28	176.	-	-	-	-	0.48	85.	0.47	83.	0.49	86.
30	188.	-	-	-	-	0.46	87.	0.46	87.	0.46	87.
32	201.	-	-	-	-	-	-	-	-	-	-
34	214.	-	-	-	-	-	-	-	-	-	-
36	226.	-	-	-	-	-	-	-	-	-	-
38	239.	-	-	-	-	-	-	-	-	-	-
40	251.	-	-	-	-	-	-	-	-	-	-
42	264.	-	-	-	-	-	-	-	-	-	-
44	276.	-	-	-	-	-	-	-	-	-	-
46	289.	-	-	-	-	-	-	-	-	-	-
48	302.	-	-	-	-	-	-	-	-	-	-
50	314.	-	-	-	-	-	-	-	-	-	-
52	327.	-	-	-	-	-	-	-	-	-	-
54	339.	-	-	-	-	-	-	-	-	-	-
56	352.	-	-	-	-	-	-	-	-	-	-
58	364.	-	-	-	-	-	-	-	-	-	-
60	377.	-	-	-	-	-	-	-	-	-	-

a(m)	2πa	R	71	R	72	R	73	R	74	R	75
1	6.	12.47	78.	41.10	258.	62.33	392.	2.34	15.	2.45	15.
2	13.	7.39	93.	9.81	123.	21.58	271.	1.25	16.	2.84	36.
3	19.	5.19	98.	6.01	113.	11.90	224.	0.83	16.	0.55	10.
4	25.	3.67	92.	4.20	105.	7.28	183.	0.51	13.	0.45	11.
5	31.	2.80	88.	3.32	104.	5.07	159.	0.42	13.	0.39	12.
6	38.	2.39	90.	2.84	107.	4.05	153.	0.38	14.	0.37	14.
7	44.	1.98	88.	2.46	108.	3.20	141.	0.36	16.	0.35	15.
8	50.	1.63	82.	2.07	104.	2.56	129.	0.33	17.	0.31	16.
9	57.	1.37	78.	1.90	107.	2.21	125.	0.36	20.	0.34	19.
10	63.	1.19	75.	1.69	106.	1.89	119.	0.39	24.	0.31	19.
11	69.	1.05	73.	1.50	104.	1.65	114.	0.39	27.	0.27	19.
12	75.	0.96	72.	1.45	109.	1.38	104.	0.40	30.	0.29	22.
13	82.	0.89	73.	1.37	112.	1.25	102.	0.40	32.	0.29	24.
14	88.	0.82	72.	1.26	111.	1.15	101.	0.38	33.	0.27	24.
15	94.	0.74	70.	1.23	116.	1.06	100.	0.35	33.	0.28	26.
16	101.	0.69	69.	1.18	118.	0.99	100.	0.34	34.	0.27	27.
17	107.	0.65	70.	1.12	120.	0.95	101.	0.33	35.	0.27	29.
18	113.	0.64	72.	1.04	117.	0.91	103.	0.33	37.	0.27	30.
19	119.	0.62	74.	1.05	125.	0.82	98.	0.34	40.	0.26	31.
20	126.	0.61	76.	1.03	129.	0.83	104.	0.34	42.	0.25	32.
22	138.	0.57	79.	0.97	134.	0.80	111.	0.34	47.	0.25	35.
24	151.	0.48	73.	0.86	129.	0.77	116.	0.33	50.	0.25	38.
26	163.	0.45	73.	0.63	103.	0.73	119.	0.33	54.	0.25	41.
28	176.	0.42	74.	0.58	102.	0.71	125.	0.32	56.	0.25	44.
30	188.	0.41	77.	0.56	106.	0.71	134.	0.31	58.	0.25	47.
32	201.	-	-	-	-	-	-	-	-	0.25	50.
34	214.	-	-	-	-	-	-	-	-	0.24	52.
36	226.	-	-	-	-	-	-	-	-	0.24	55.
38	239.	-	-	-	-	-	-	-	-	0.24	57.
40	251.	-	-	-	-	-	-	-	-	0.24	60.
42	264.	-	-	-	-	-	-	-	-	0.24	63.
44	276.	-	-	-	-	-	-	-	-	0.24	66.
46	289.	-	-	-	-	-	-	-	-	0.24	69.
48	302.	-	-	-	-	-	-	-	-	0.24	71.
50	314.	-	-	-	-	-	-	-	-	0.23	72.
52	327.	-	-	-	-	-	-	-	-	0.22	72.
54	339.	-	-	-	-	-	-	-	-	0.23	78.
56	352.	-	-	-	-	-	-	-	-	0.23	80.
58	364.	-	-	-	-	-	-	-	-	0.22	82.
60	377.	-	-	-	-	-	-	-	-	0.21	79.

a(m)	2πa	R	76	R	77	R	78	R	79	R	80
1	6.	1.48	9.	15.08	95.	9.42	59.	6.73	42.	4.39	28.
2	13.	1.00	13.	8.56	108.	2.67	34.	3.45	43.	1.69	21.
3	19.	0.83	16.	5.04	95.	1.67	31.	2.54	48.	1.29	24.
4	25.	0.71	18.	3.25	82.	1.22	31.	2.14	54.	1.02	26.
5	31.	0.68	21.	2.62	82.	1.02	32.	2.29	72.	0.94	30.
6	38.	0.62	23.	2.29	86.	0.92	35.	1.91	72.	0.92	35.
7	44.	0.60	26.	2.07	91.	0.87	38.	1.62	71.	0.90	40.
8	50.	0.57	29.	1.82	91.	0.83	42.	1.45	73.	0.90	45.
9	57.	0.51	29.	1.67	94.	0.79	45.	1.26	71.	0.83	47.
10	63.	0.50	31.	1.50	94.	0.77	48.	1.16	73.	0.77	48.
11	69.	0.56	39.	1.29	89.	0.71	49.	1.04	72.	0.73	50.
12	75.	0.43	33.	1.32	99.	0.67	51.	0.89	67.	0.71	53.
13	82.	0.41	34.	1.18	96.	0.66	54.	0.71	58.	0.68	56.
14	88.	0.40	35.	1.01	89.	0.62	55.	0.76	67.	0.63	55.
15	94.	0.37	35.	1.00	94.	0.56	53.	0.75	71.	0.58	55.
16	101.	0.37	37.	1.02	103.	0.58	58.	0.73	73.	0.54	54.
17	107.	0.35	37.	0.93	99.	0.52	55.	0.69	74.	0.50	53.
18	113.	0.35	39.	0.81	92.	0.48	54.	0.68	76.	0.47	53.
19	119.	0.34	40.	0.76	90.	0.45	54.	0.64	76.	0.43	51.
20	126.	0.32	40.	0.67	84.	0.43	54.	0.62	77.	0.40	51.
22	138.	0.32	44.	0.54	75.	0.50	69.	0.57	79.	0.38	52.
24	151.	0.34	51.	0.49	74.	0.37	56.	0.51	77.	0.36	55.
26	163.	0.28	45.	0.44	71.	0.35	57.	0.46	75.	0.36	58.
28	176.	0.28	50.	0.41	73.	0.34	60.	0.44	77.	0.35	61.
30	188.	0.28	52.	0.38	71.	0.33	62.	0.41	77.	0.33	62.
32	201.	0.27	54.	0.37	74.	0.32	64.	0.40	80.	0.31	62.
34	214.	0.26	55.	0.31	66.	0.31	66.	0.38	82.	0.29	62.
36	228.	0.24	55.	0.36	82.	0.31	69.	0.37	84.	0.27	62.
38	239.	0.23	55.	0.36	86.	0.31	74.	0.36	86.	0.25	60.
40	251.	0.22	55.	0.33	84.	0.30	75.	0.35	87.	0.26	64.
42	264.	0.22	57.	0.34	89.	0.30	79.	0.34	89.	0.24	63.
44	276.	0.19	54.	0.32	88.	0.30	82.	0.31	85.	0.22	61.
46	289.	0.19	54.	0.31	91.	0.29	84.	0.31	89.	0.23	66.
48	302.	0.18	54.	0.33	98.	0.29	88.	0.29	87.	0.24	73.
50	314.	0.18	55.	0.32	99.	0.28	89.	0.30	93.	0.21	67.
52	327.	0.17	57.	0.30	98.	0.28	91.	0.27	87.	-	-
54	339.	0.16	55.	0.31	105.	0.28	94.	0.26	87.	-	-
56	352.	0.17	60.	0.30	106.	0.26	91.	0.24	84.	-	-
58	364.	0.17	62.	0.28	103.	0.26	94.	0.23	85.	-	-
60	377.	0.18	62.	0.30	113.	0.25	92.	0.23	85.	-	-

a(m)	2πa	R	81	R	82	R	83	R	84	R	85
1	6.	5.51	35.	8.37	53.	5.88	37.	1.71	11.	4.28	27.
2	13.	3.08	39.	3.32	42.	4.19	53.	0.92	12.	2.29	29.
3	19.	2.48	47.	1.95	37.	3.09	58.	0.89	17.	1.42	27.
4	25.	2.15	54.	1.49	37.	2.65	67.	0.81	20.	1.14	29.
5	31.	1.91	60.	1.31	41.	2.10	66.	0.71	22.	0.91	29.
6	38.	1.78	67.	1.00	38.	1.60	60.	0.68	26.	0.79	30.
7	44.	1.54	68.	0.90	40.	1.14	50.	0.65	29.	0.73	32.
8	50.	1.42	72.	0.83	42.	1.00	50.	0.58	29.	0.69	35.
9	57.	1.32	74.	0.79	45.	0.90	51.	0.55	31.	0.66	37.
10	63.	1.23	77.	0.78	49.	0.73	46.	0.52	33.	0.64	40.
11	69.	1.14	79.	0.70	48.	0.61	42.	0.51	35.	0.64	44.
12	75.	1.09	82.	0.63	47.	0.57	43.	0.51	38.	0.64	48.
13	82.	1.01	83.	0.59	48.	0.56	46.	0.50	41.	0.65	53.
14	88.	0.94	83.	0.57	50.	0.53	47.	0.50	44.	0.63	55.
15	94.	0.87	82.	0.53	50.	0.51	48.	0.50	47.	0.60	57.
16	101.	0.77	77.	0.50	50.	0.49	49.	0.49	49.	0.57	57.
17	107.	0.69	73.	0.47	50.	0.49	52.	0.49	52.	0.56	60.
18	113.	0.64	72.	0.44	50.	0.48	54.	0.47	53.	0.55	62.
19	119.	0.60	72.	0.43	51.	0.48	57.	0.45	54.	0.54	64.
20	126.	0.56	70.	0.41	51.	0.47	59.	0.44	56.	0.52	65.
22	138.	0.49	68.	0.36	50.	0.49	68.	0.43	59.	0.48	67.
24	151.	0.43	65.	0.34	51.	0.47	71.	0.43	65.	0.46	69.
26	163.	0.40	65.	0.31	51.	0.45	74.	0.44	71.	0.43	70.
28	176.	0.38	67.	0.31	55.	0.47	83.	0.43	76.	0.41	72.
30	188.	0.35	65.	0.29	55.	0.49	92.	0.41	77.	0.38	71.
32	201.	-	-	0.25	50.	0.50	101.	0.41	82.	0.37	75.
34	214.	-	-	0.24	51.	0.48	103.	0.40	85.	0.36	76.
36	226.	-	-	0.22	49.	0.47	106.	0.39	88.	0.33	74.
38	239.	-	-	0.21	50.	0.45	108.	0.37	87.	0.35	84.
40	251.	-	-	0.20	50.	0.43	107.	0.34	84.	0.33	83.
42	264.	-	-	0.19	51.	0.41	107.	0.33	87.	0.32	83.
44	276.	-	-	0.20	55.	0.41	113.	0.33	92.	0.30	83.
46	289.	-	-	0.20	58.	0.39	112.	0.32	93.	0.32	91.
48	302.	-	-	0.19	58.	0.36	109.	0.31	94.	0.31	93.
50	314.	-	-	0.19	60.	0.35	109.	0.31	98.	0.30	94.
52	327.	-	-	0.19	62.	0.35	114.	0.31	100.	0.28	92.
54	339.	-	-	0.19	64.	0.34	114.	0.31	104.	0.28	95.
56	352.	-	-	0.19	67.	0.33	117.	0.31	109.	0.27	95.
58	364.	-	-	0.18	65.	0.33	119.	0.31	113.	0.27	98.
60	377.	-	-	0.19	71.	0.32	122.	0.30	113.	0.27	101.

a(m)	2πa	R	86	R	87	R	101	R	102	R	103
1	6.	5.28	33.	5.41	34.	30.86	194.	41.37	260.	32.92	207.
2	13.	3.09	39.	3.02	38.	11.74	148.	14.93	188.	16.73	210.
3	19.	2.52	47.	2.66	50.	7.35	139.	8.13	153.	9.91	187.
4	25.	2.08	52.	2.50	63.	4.28	107.	4.52	114.	6.93	174.
5	31.	1.84	58.	2.20	69.	2.75	86.	2.89	91.	4.17	131.
6	38.	1.61	61.	1.90	71.	2.68	101.	2.40	91.	3.05	115.
7	44.	1.42	62.	1.64	72.	2.41	106.	1.85	81.	2.37	104.
8	50.	1.25	63.	1.42	71.	2.12	107.	1.53	77.	1.90	95.
9	57.	1.11	63.	1.26	71.	1.70	96.	1.37	77.	1.51	85.
10	63.	1.01	63.	1.11	70.	1.54	97.	1.14	72.	1.25	79.
11	69.	0.92	64.	0.97	67.	1.20	83.	1.09	75.	1.10	76.
12	75.	0.85	64.	0.85	64.	1.10	83.	0.99	75.	0.99	75.
13	82.	0.81	66.	0.79	65.	1.00	82.	0.91	74.	0.87	71.
14	88.	0.78	69.	0.74	65.	0.92	81.	0.85	75.	0.83	73.
15	94.	0.69	65.	0.69	65.	0.90	85.	0.74	70.	0.78	73.
16	101.	0.66	66.	0.58	58.	0.82	82.	0.74	74.	0.77	77.
17	107.	0.62	66.	0.63	67.	-	-	-	-	0.68	72.
18	113.	0.57	64.	0.59	67.	-	-	-	-	0.66	75.
19	119.	0.55	65.	0.56	67.	-	-	-	-	0.63	75.
20	125.	0.53	67.	0.54	68.	-	-	-	-	0.60	75.
22	138.	0.51	70.	0.52	72.	-	-	-	-	-	-
24	151.	0.48	72.	0.49	74.	-	-	-	-	-	-
26	163.	0.45	74.	0.47	77.	-	-	-	-	-	-
28	176.	0.43	75.	0.45	79.	-	-	-	-	-	-
30	188.	0.42	79.	0.44	83.	-	-	-	-	-	-
32	201.	0.41	82.	0.43	87.	-	-	-	-	-	-
34	214.	0.41	87.	0.42	90.	-	-	-	-	-	-
36	226.	0.38	87.	0.41	93.	-	-	-	-	-	-
38	239.	0.38	90.	0.39	94.	-	-	-	-	-	-
40	251.	0.36	91.	0.37	93.	-	-	-	-	-	-
42	264.	0.34	89.	0.35	93.	-	-	-	-	-	-
44	276.	0.32	88.	0.34	94.	-	-	-	-	-	-
46	289.	0.27	78.	0.33	95.	-	-	-	-	-	-
48	302.	0.30	91.	0.32	97.	-	-	-	-	-	-
50	314.	0.30	93.	0.30	94.	-	-	-	-	-	-
52	327.	0.29	95.	0.29	95.	-	-	-	-	-	-
54	339.	0.27	91.	0.29	98.	-	-	-	-	-	-
56	352.	0.27	95.	0.27	95.	-	-	-	-	-	-
58	364.	0.25	92.	0.27	98.	-	-	-	-	-	-
60	377.	0.26	98.	0.28	106.	-	-	-	-	-	-

Table C.4.1 Data of Electrical Prospecting Survey (4)

a(m)	$2\pi a$	R	104	R	106	R	108	R	107	R	109
1	6.	28.80	181.	46.45	292.	23.73	149.	37.28	234.	53.68	337.
2	13.	18.08	227.	16.35	206.	13.05	164.	15.65	197.	21.35	268.
3	19.	10.35	195.	9.32	176.	7.10	134.	7.28	137.	8.23	165.
4	25.	7.15	180.	6.38	160.	6.35	160.	4.34	109.	3.98	100.
5	31.	5.46	172.	4.67	147.	4.25	134.	2.82	89.	2.18	68.
6	38.	3.72	140.	3.53	133.	-	-	1.62	61.	1.15	43.
7	44.	3.01	132.	2.78	122.	-	-	1.37	60.	0.71	31.
8	50.	2.62	131.	2.17	109.	-	-	1.23	62.	0.55	28.
9	57.	2.18	123.	1.81	102.	-	-	1.15	65.	0.48	27.
10	63.	1.72	108.	1.51	95.	-	-	0.97	61.	0.45	28.
11	69.	1.42	98.	1.28	88.	-	-	0.78	54.	0.42	29.
12	75.	1.32	99.	1.08	81.	-	-	0.62	47.	0.39	30.
13	82.	1.14	93.	0.99	81.	-	-	0.51	42.	0.35	29.
14	88.	1.08	95.	0.94	82.	-	-	0.64	56.	0.31	27.
15	94.	0.97	91.	0.81	76.	-	-	0.42	39.	0.28	26.
16	101.	0.85	85.	0.78	78.	-	-	0.43	43.	0.24	24.
17	107.	0.76	81.	0.73	77.	-	-	0.38	39.	0.19	20.
18	113.	0.71	80.	0.67	76.	-	-	0.36	41.	0.19	22.
19	119.	0.66	79.	0.62	74.	-	-	0.32	38.	0.17	21.
20	126.	0.64	81.	0.62	78.	-	-	0.32	40.	0.16	20.
22	138.	0.56	77.	0.54	75.	-	-	0.28	39.	0.13	18.
24	151.	0.52	79.	0.50	76.	-	-	0.27	41.	0.11	16.
26	163.	0.46	75.	0.46	75.	-	-	0.25	41.	0.10	16.
28	176.	0.45	79.	0.43	75.	-	-	0.22	39.	0.10	18.
30	188.	0.41	77.	0.40	75.	-	-	0.22	42.	0.09	18.
32	201.	-	-	-	-	-	-	0.21	42.	0.08	16.
34	214.	-	-	-	-	-	-	0.19	40.	0.08	17.
36	226.	-	-	-	-	-	-	0.18	40.	0.08	18.
38	239.	-	-	-	-	-	-	0.16	38.	0.08	19.
40	251.	-	-	-	-	-	-	0.14	34.	0.08	19.
42	264.	-	-	-	-	-	-	0.14	35.	0.07	20.
44	276.	-	-	-	-	-	-	-	-	0.07	19.
46	289.	-	-	-	-	-	-	-	-	0.07	19.
48	302.	-	-	-	-	-	-	-	-	0.07	21.
50	314.	-	-	-	-	-	-	-	-	0.07	23.
52	327.	-	-	-	-	-	-	-	-	0.07	23.
54	339.	-	-	-	-	-	-	-	-	0.07	24.
56	352.	-	-	-	-	-	-	-	-	0.07	25.
58	364.	-	-	-	-	-	-	-	-	0.07	26.
60	377.	-	-	-	-	-	-	-	-	0.07	25.

a(m)	$2\pi a$	R	109	R	201	R	202	R	203	R	374
1	6.	11.90	75.	10.15	64.	19.27	121.	3.98	25.	2.86	18.
2	13.	2.15	27.	14.14	176.	11.71	147.	4.99	63.	1.22	15.
3	19.	1.13	21.	9.12	172.	6.87	129.	5.32	100.	0.73	14.
4	25.	0.80	20.	6.52	164.	4.83	121.	3.54	89.	0.52	13.
5	31.	0.48	15.	5.29	166.	-	-	3.53	111.	0.45	14.
6	38.	0.40	15.	4.18	157.	-	-	2.76	104.	0.48	18.
7	44.	0.36	16.	9.54	420.	-	-	2.23	98.	0.43	19.
8	50.	0.36	18.	2.38	119.	-	-	2.03	102.	0.41	21.
9	57.	0.25	14.	2.15	121.	-	-	1.67	94.	0.41	23.
10	63.	0.22	14.	2.41	151.	-	-	1.67	105.	0.40	25.
11	69.	0.20	14.	1.90	131.	-	-	1.63	113.	0.39	27.
12	75.	0.18	14.	1.63	123.	-	-	1.44	109.	0.38	29.
13	82.	0.17	14.	1.75	143.	-	-	1.45	118.	0.38	31.
14	88.	0.15	13.	-	-	-	-	1.48	130.	0.37	32.
15	94.	0.13	12.	-	-	-	-	1.69	160.	0.35	33.
16	101.	0.13	13.	-	-	-	-	1.23	123.	0.34	34.
17	107.	0.12	12.	-	-	-	-	-	-	0.33	35.
18	113.	0.11	12.	-	-	-	-	-	-	0.32	36.
19	119.	0.10	12.	-	-	-	-	-	-	0.31	37.
20	126.	0.10	13.	-	-	-	-	-	-	0.31	39.
22	138.	0.09	12.	-	-	-	-	-	-	0.31	42.
24	151.	0.09	13.	-	-	-	-	-	-	0.29	44.
26	163.	0.07	12.	-	-	-	-	-	-	0.29	47.
28	176.	0.07	11.	-	-	-	-	-	-	0.28	50.
30	188.	0.06	12.	-	-	-	-	-	-	0.30	56.
32	201.	0.06	12.	-	-	-	-	-	-	0.29	58.
34	214.	0.05	11.	-	-	-	-	-	-	0.28	60.
36	226.	0.04	10.	-	-	-	-	-	-	0.28	63.
38	239.	0.05	11.	-	-	-	-	-	-	0.28	68.
40	251.	0.05	13.	-	-	-	-	-	-	0.28	70.
42	264.	0.04	12.	-	-	-	-	-	-	0.27	71.
44	276.	0.04	12.	-	-	-	-	-	-	0.26	73.
46	289.	0.04	12.	-	-	-	-	-	-	0.26	76.
48	302.	0.04	12.	-	-	-	-	-	-	0.26	77.
50	314.	0.04	13.	-	-	-	-	-	-	0.26	82.
52	327.	0.04	13.	-	-	-	-	-	-	0.27	87.
54	339.	0.04	13.	-	-	-	-	-	-	0.26	89.
56	352.	0.04	13.	-	-	-	-	-	-	0.26	93.
58	364.	0.04	13.	-	-	-	-	-	-	0.26	95.
60	377.	0.04	14.	-	-	-	-	-	-	0.26	98.

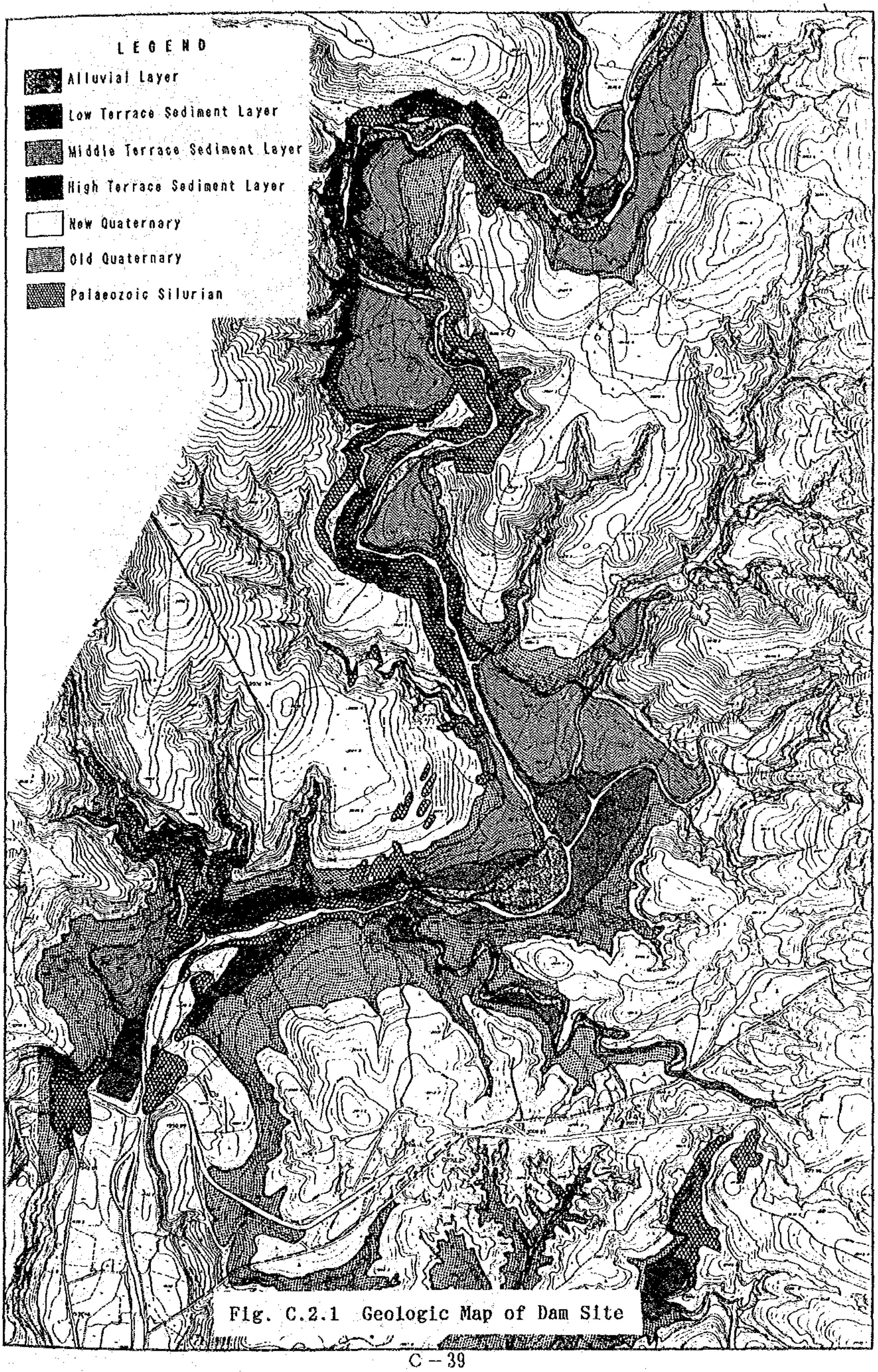


Fig. C.2.1 Geologic Map of Dam Site

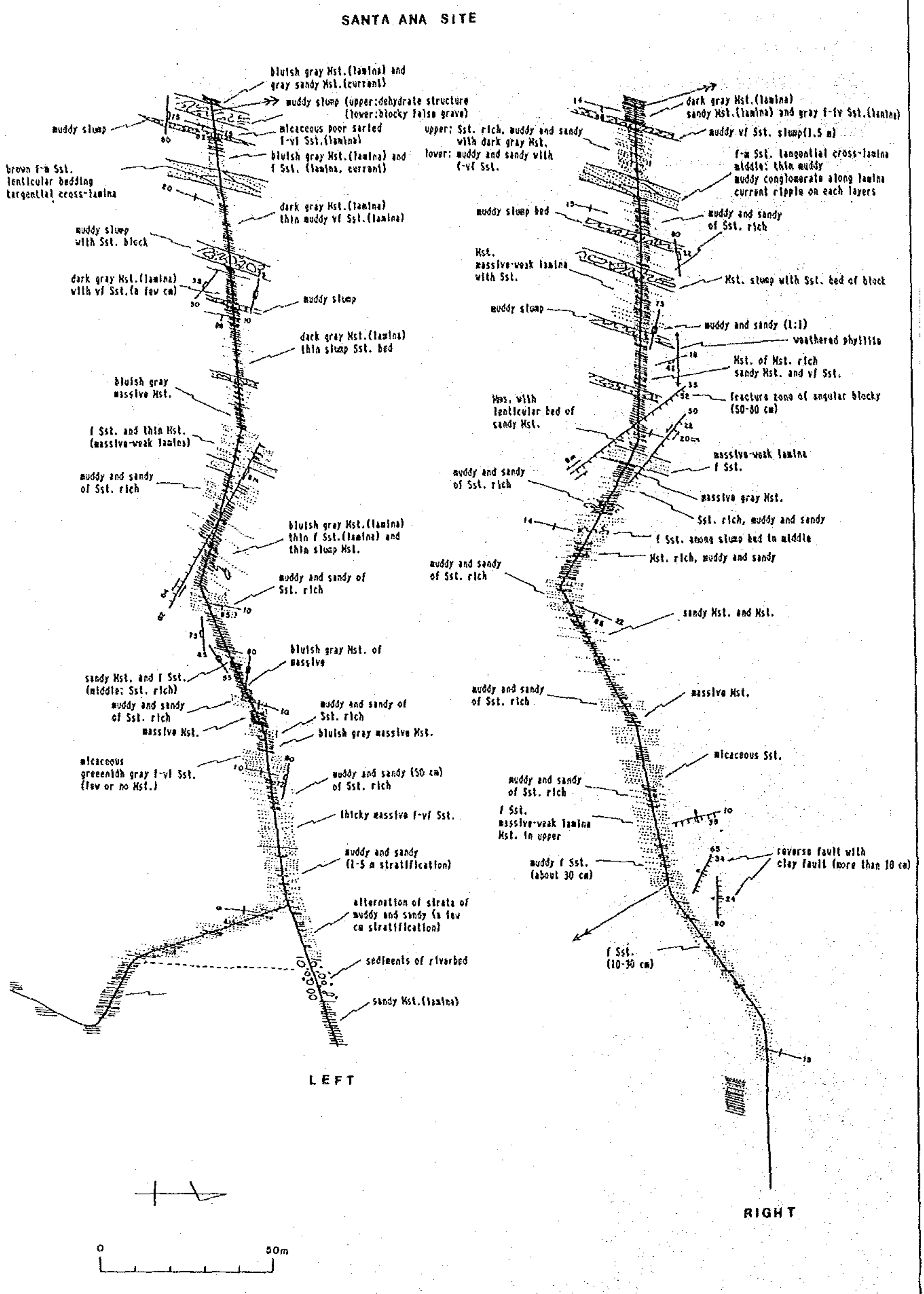


Fig. C.2.2 Map of Dam Axis (1)

LEGEND

SIZE	STONE
c : coarse	Sst. : Sand stone
m : medium	Mst. : Mudstone
f : fine	
vf: very fine	

SAN AGUSTIN SITE

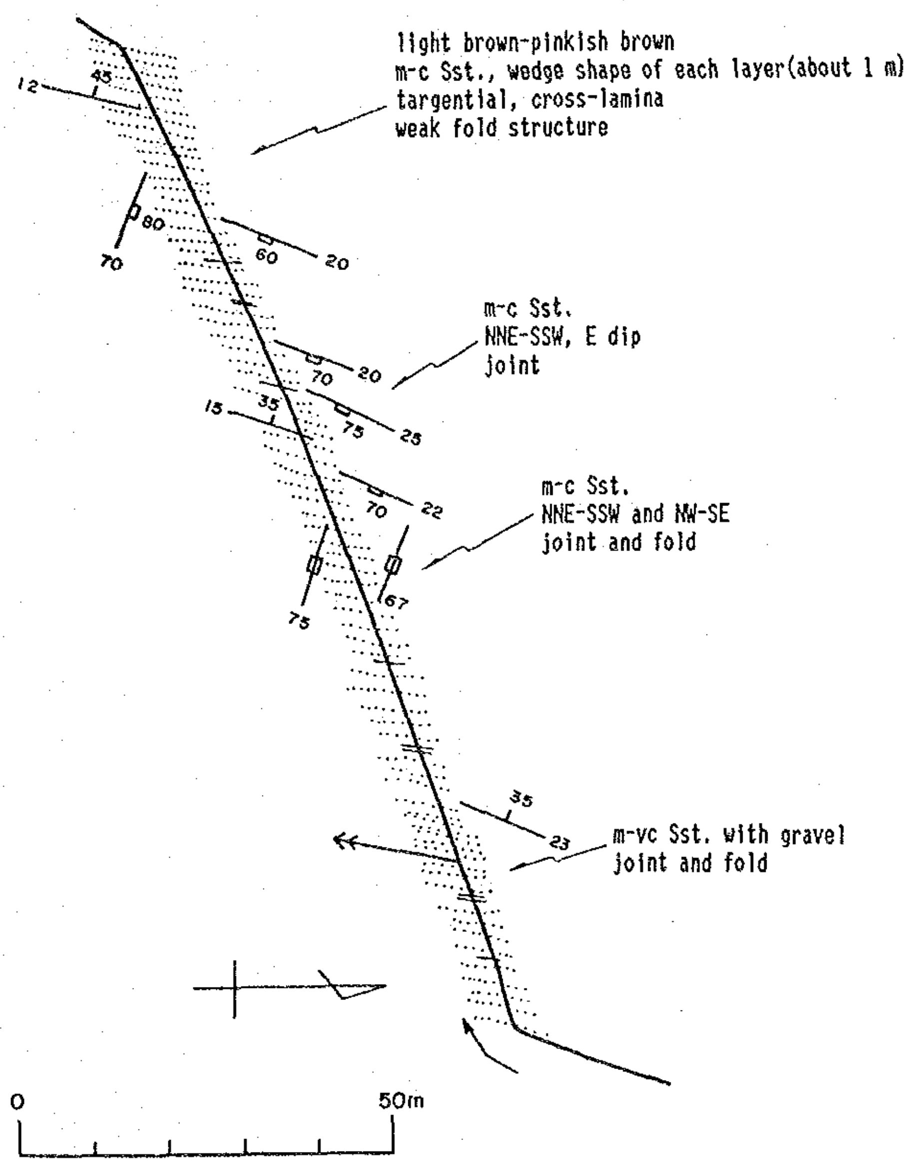


Fig. C.2.2 Map of Dam Axis (2)

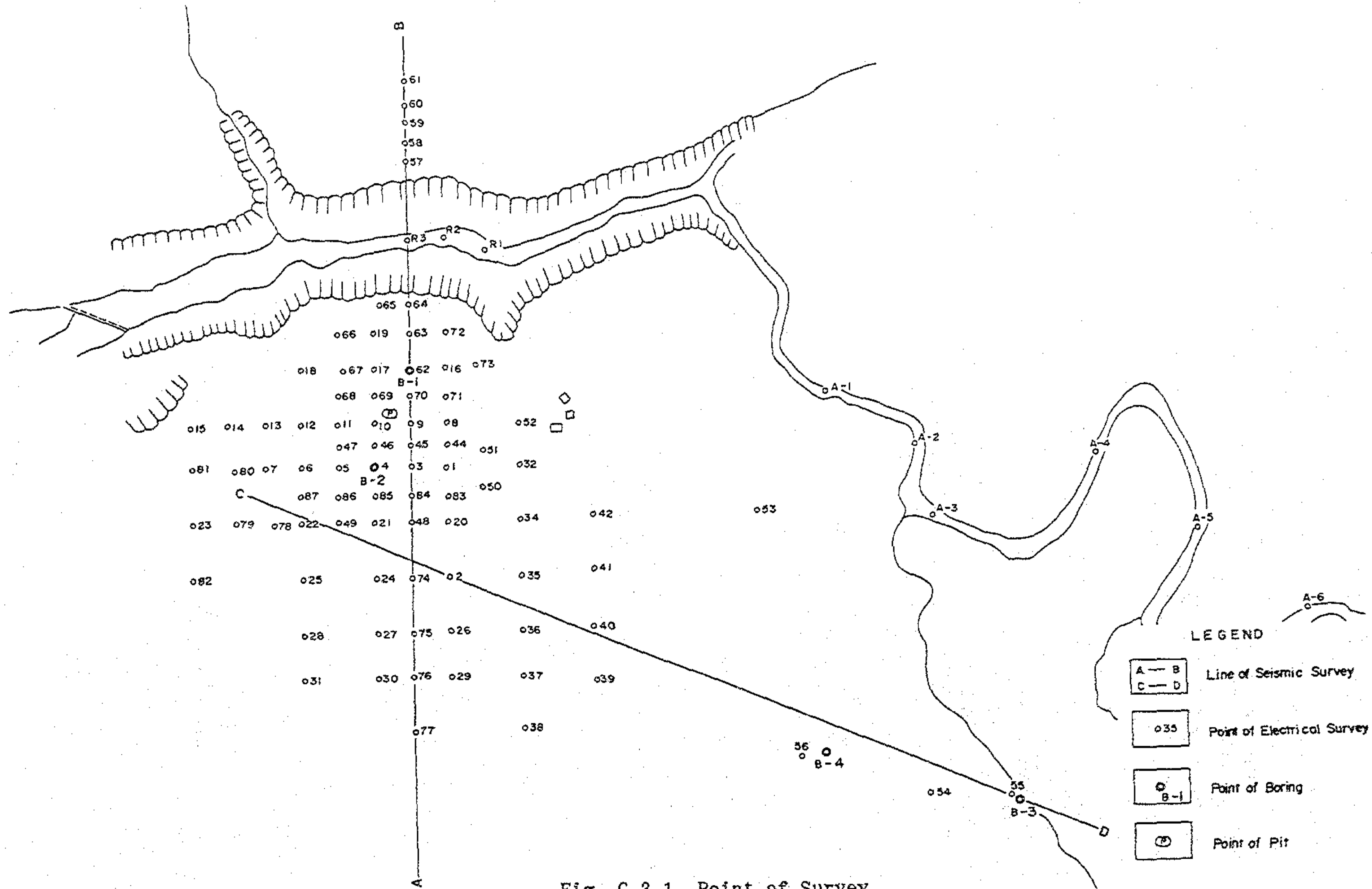


Fig. C.3.1 Point of Survey

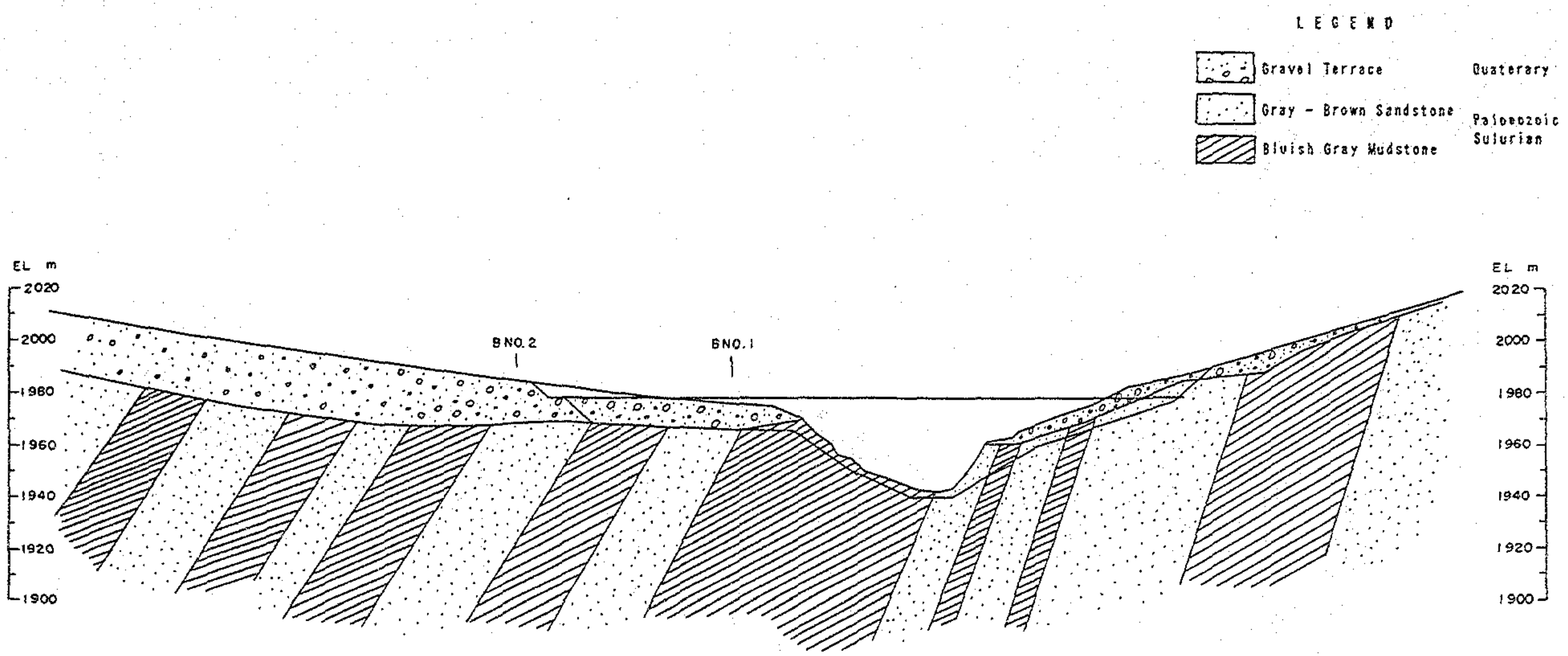


Fig. C.3.2 Geologicla Section of Santa Ana Dam (1)

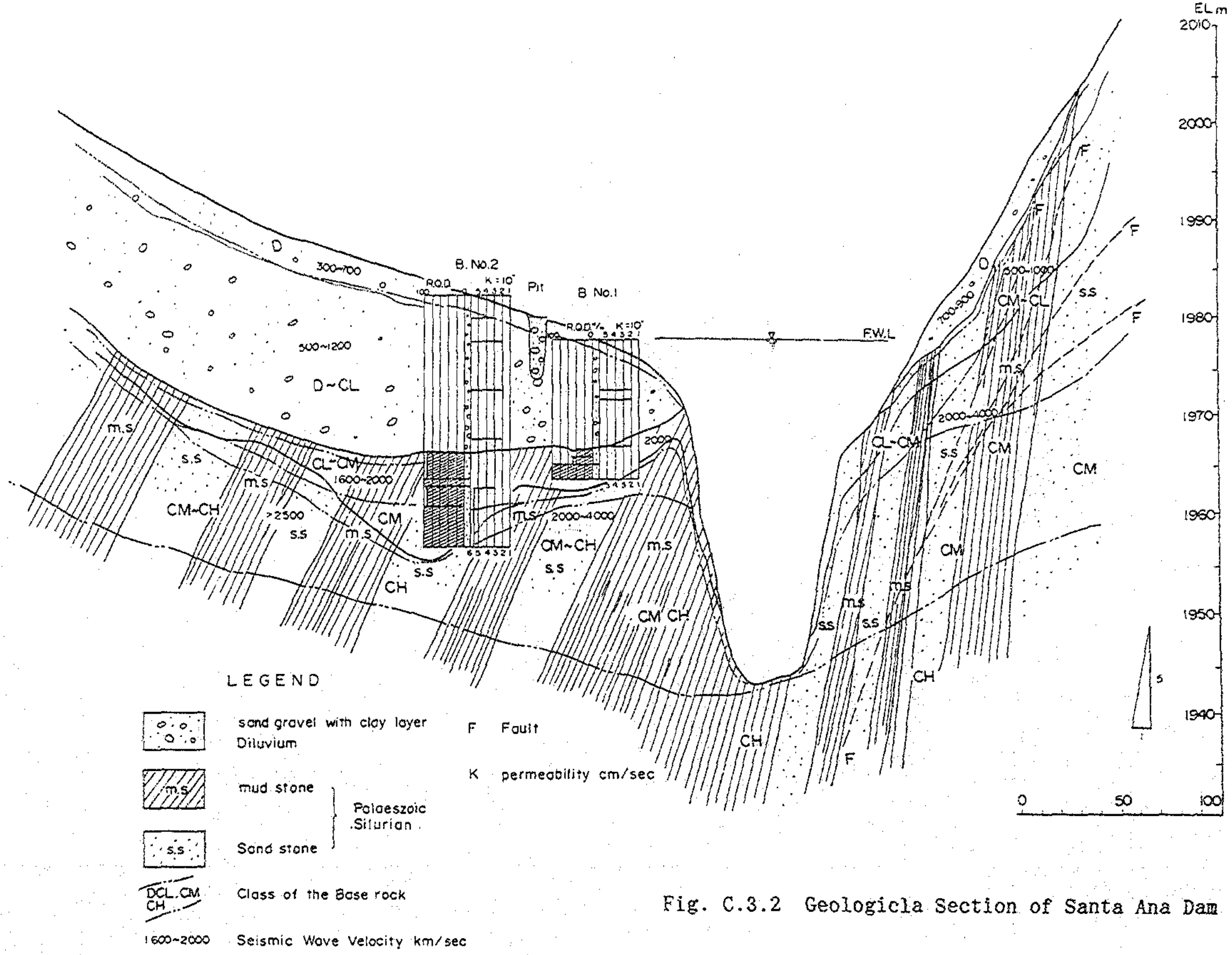


Fig. C.3.2 Geologicla Section of Santa Ana Dam (2)

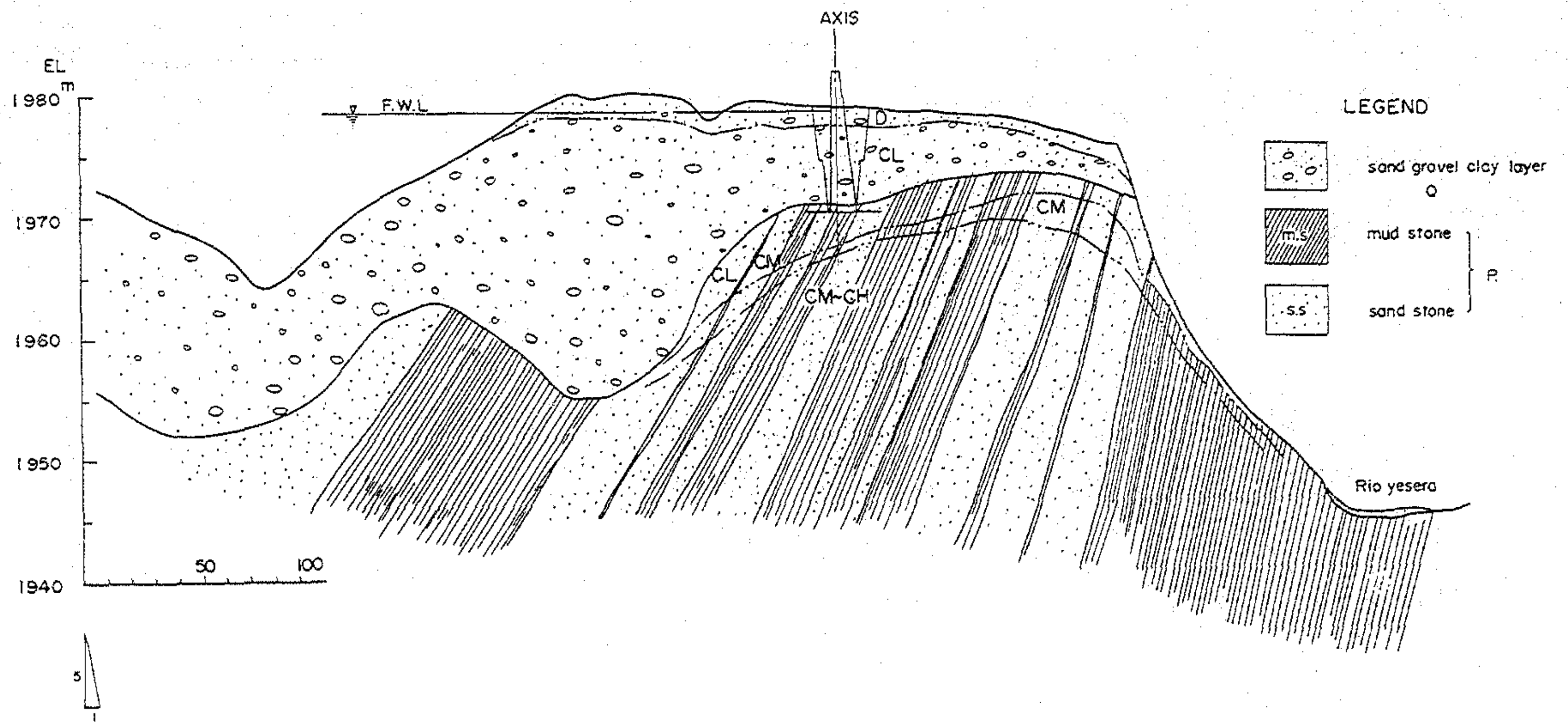


Fig. C.3.2 Geologicla Section of Santa Ana Dam (3)

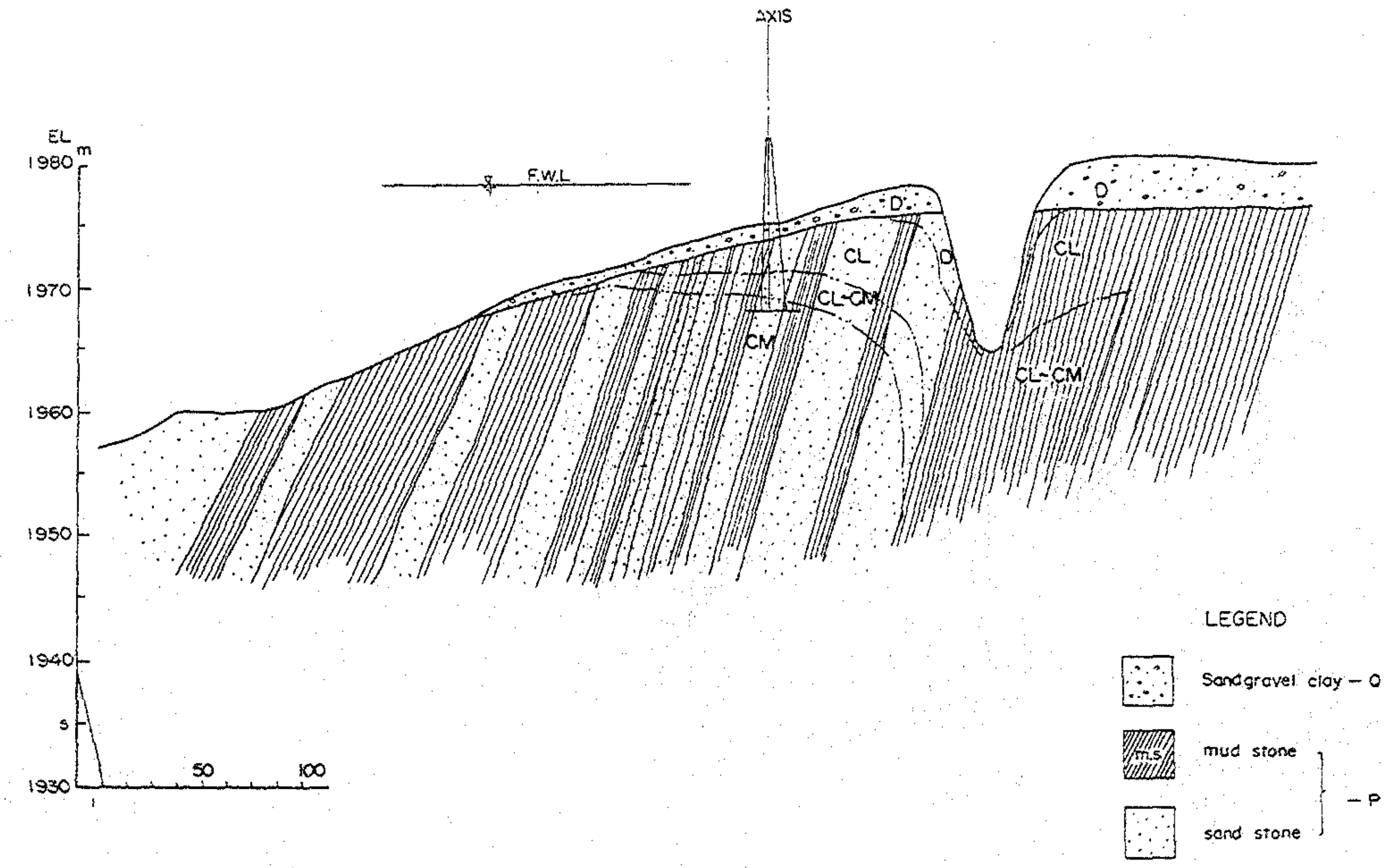


Fig. C.3.2 Geologicla Section of Santa Ana Dam (4)

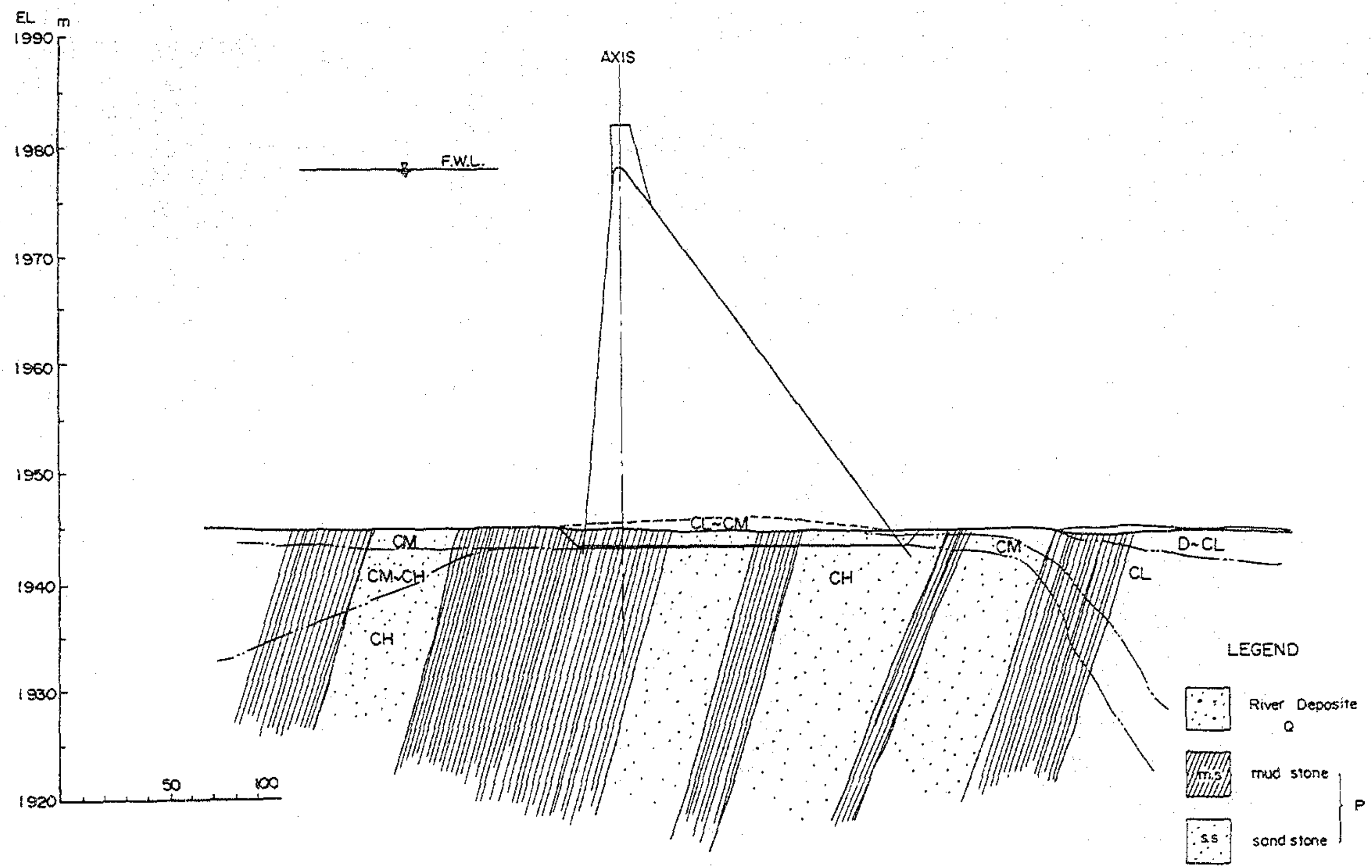


Fig. C.3.2 Geologicla Section of Santa Ana Dam (5)

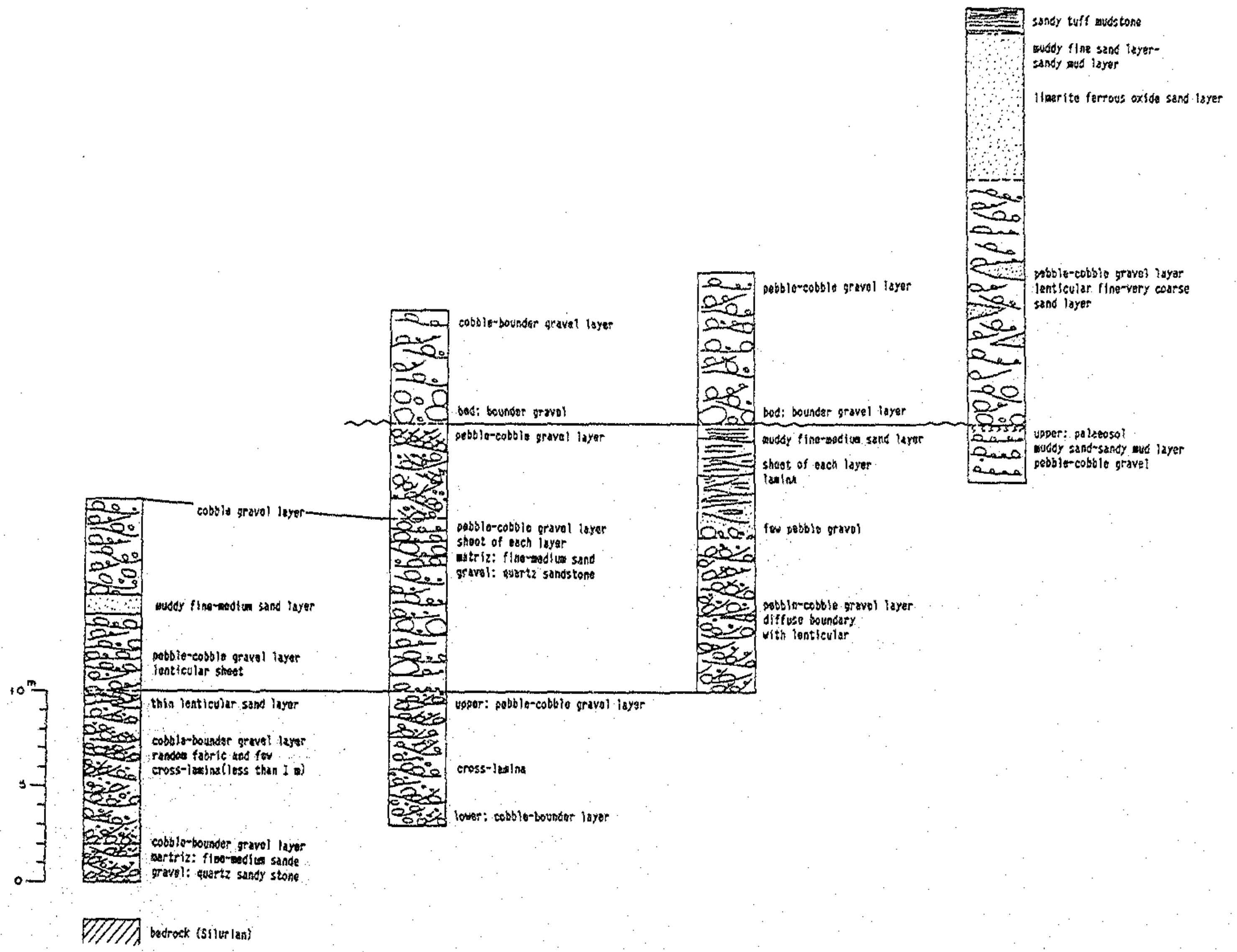


Fig. C.3.3 Comparison of Geological Profiles

Fig. C.4.1 Base Rock Contour Map (Electrical Survey)

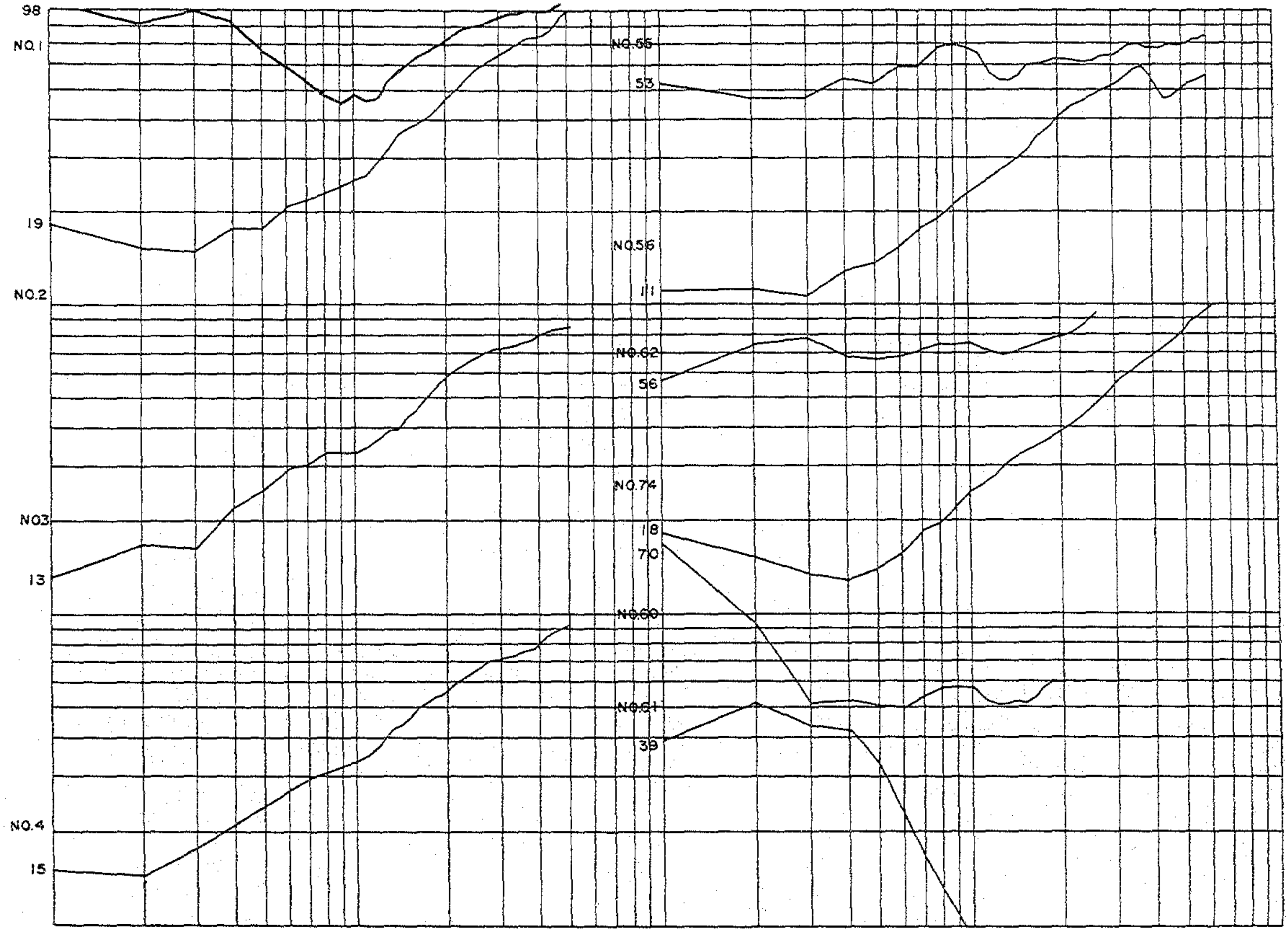


Fig. C.4.2 Electrical Survey p-a Curve

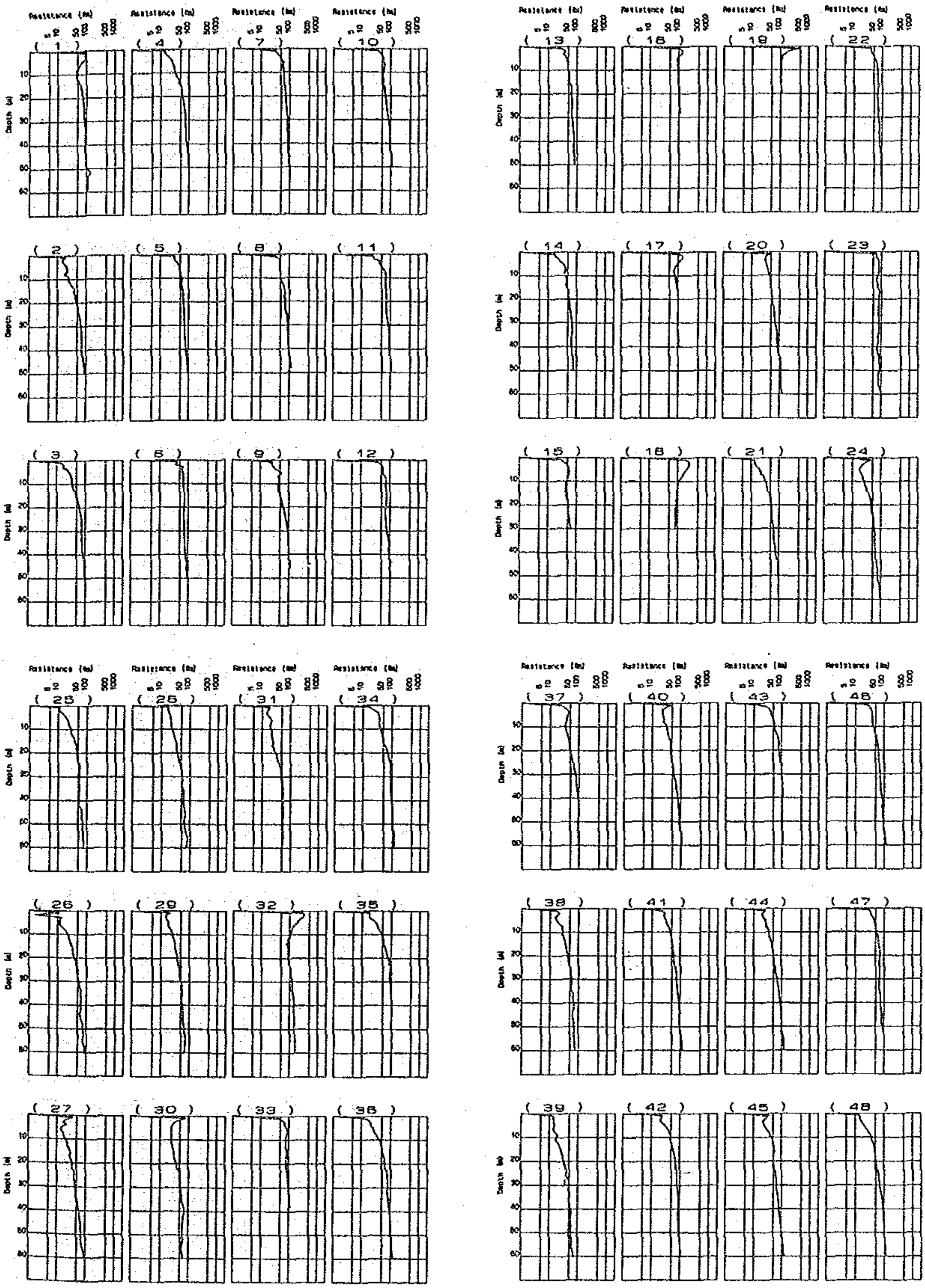
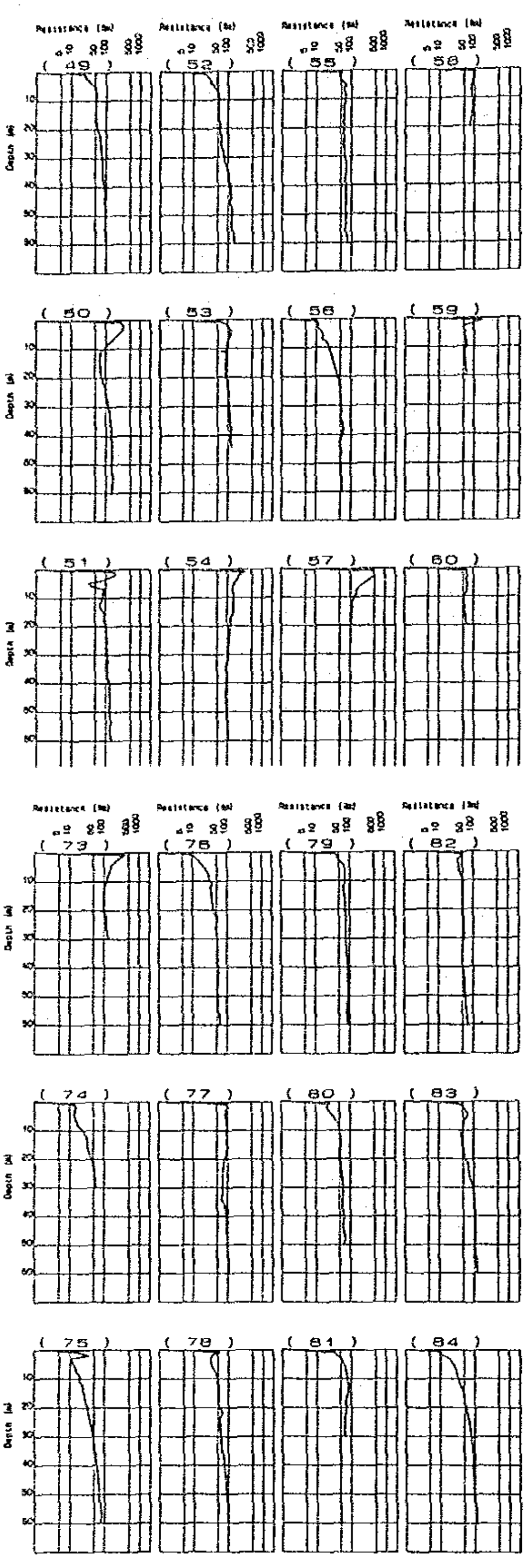


Fig. C.4.3 p-a Curve of Electric Potential (1)



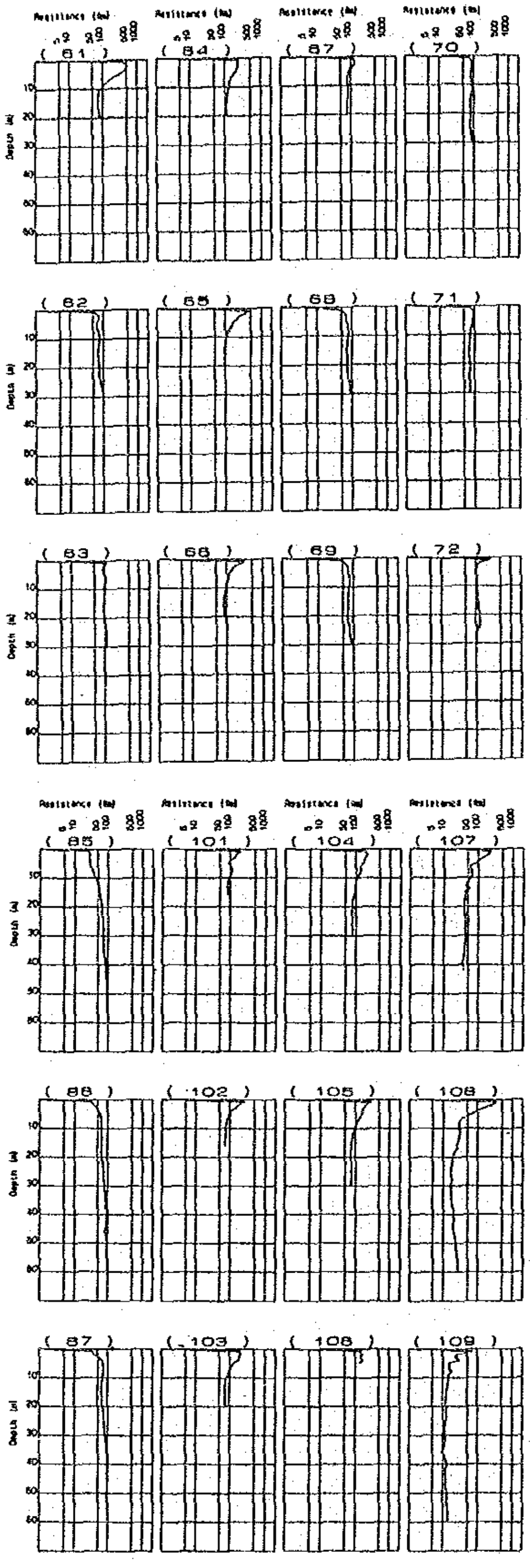


Fig. C.4.3 p-a Curve of Electric Potential (2)

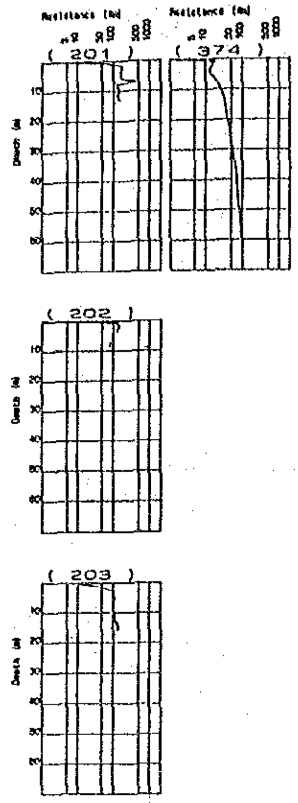


Fig. C.4.3 p-a Curve of Electric Potential (3)