OCEANOGRAPHIC SURVEY

Palau Gag, Irian Jaya

Indonesia

Report prepared for the

Ministry of Fisheries

Ministry of Mines

Republic of Indonesia

and

P. T. Pacific Nikkel

Directed by the Bechtel Corporation

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OCEANOGRAPHIC SURVEY REPORT

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SECTION 2

DESCRIPTION OF ACTIVITIES

The oceanographic survey of the area surrounding Gag Island was planned and carried out by a joint group of U. S. and Indonesian scientists supported by U. S. and Indonesian technicians. Overall coordination of the program was provided by a full-time representative of Bechtel Corporation, San Francisco, and a full-time representative was present from Pacific Nikkel. A pipeline engineer from Bechtel Corporation participated in work pertaining to selection of the pipeline route and assisted in other work.

Most of the survey was accomplished from the Research Vessel "Samudera", a 36-meter, 250 ton Oceanographic Ship of Lembaga Oceanologi Nasional (LON), the Indonesian National Institute of Oceanology. The bulk of the equipment used was leased from Intersea Research Corporation, La Jolla, California, which also provided the U. S. technicians. Bathymetric measurements were also made from a Pacific Nikkel boat, "M. V. Equator", particularly in shallow water. The current meters were set and recovered from a Pacific Nikkel barge which had been equipped with an A-frame and winch and was moved by the tug Sea Tractor.

The bathymetric survey was conducted by Dr. Pat Wilde, Professor of Marine Geology, University of California and Scripps Institute of Oceanology. Basic equipment used was an Edo Model 353 Fathometer with an Ocean Sonics 119T Transceiver/Recorder and a Motorola Mini-Ranger System. Data were analyzed roughly as the work progressed in order to permit concentration of efforts in the areas most likely to offer answers to the questions pertaining to pipeline location. All data were subsequently reduced to computer input for plotting of points and the final isobaths were drawn manually.

The physical oceanography survey was conducted by Dr. Klaus Wyrtki, Professor of Oceanography, University of Hawaii. Basic equipment used was a Plessey Environmental Systems Model 9060 Graphic Self-contained Salinity - Temperature - Depth Recorder, Nansen Bottles with reversing thermometers, and a Martek Model XMS Transmissometer. Measurements were made at a total of 67 stations, one being a 24-hour station. Data obtained were plotted to portray various phenomena pertinent to discharge of tailings in the ocean. In addition, a recording tide gauge was mounted on the Pacific Nikkel pier in Gambir Bay for continuous records throughout the survey, and Braincon Model 381 current meters were installed northeast and northwest of Gag Island in deep water and at three points on the proposed pipeline route. All current meters remained in place for at least a full lunar cycle.

The biological survey was conducted by Dr. John McGowan, Professor of Marine Biology, University of California and Scripps Institute of Oceanography. Basic equipment used was Bongo Nets, Van Dorn Bottles, A Turner Fluorometer, a Van Veen Dredge, and the STD Recorder, Transmissometer and Nansen Bottles mentioned above. It was intended to use a Mid-Water Trawl but this proved to be too heavy for the ship's winches and could not be used. Scuba diving, including visual reconnaissance, photography and hand samples was carried out in reef areas to a maximum depth of approximately 62 meters. A total of 33 stations were utilized, one of them being a 24-hour station in the vicinity of the 24-hour station mentioned above. In addition, 40 stations on the proposed pipeline route provided information for biological analysis.

The pipeline route survey was conducted by a Bechtel Corporation pipeline engineer. A tentative route was selected by Dr. Wilde as the basis for the survey. Detailed bathymetry was developed utilizing the equipment mentioned above. Scuba divers reconnoitered the route, and bottom samples were taken by hand coring and by Van Veen Dredge. A Klein 400 Side Scan Sonar was utilized to augment the bathymetry. Braincon 381 Current Meters, as mentioned above, were installed at the proposed outfall location and two intermediate points along the proposed pipeline route. Innerspace Model 406 Accoustic Releases were used with the four deepest of the five current meter installations.

The R. V. Samudera was reprovisioned from Pacific Nikkel resources at Gag Island as required during the course of the survey, including fuel, food and fresh water.

SECTION 3

BATHYMETRIC SURVEY

3.1 BATHYMETRY IN THE VICINITY OF GAG ISLAND IRIAN JAYA, INDONESIA

Dr. Pat Wilde

Regional Setting

Gag Island is a high island off the northwest coast of New Guinea in the Northern Molucca Islands. Gag lies east of the central part of the sea at 129° 30' E, 0° 26' S bounded on the west and northwest by Halmahera Island, to the northeast by Waigeo Island, to the east by the Fam Islands and New Guinea, to the south by the Jef Doif Atoll. The Halmahera Sea is the name given to the sea west of Gag. Gag is related geologically to Waigeo and to the Vogelkopf peninsula of New Guinea.

Present Work

The bathymetric survey was part of an overall environmental study of the area (see McGowan, 1973 and Wyrtki, 1973) to confirm the feasibility of submarine disposal of tailings from the projected lateritic nickel project on Gag Island.

This survey was accomplished in August-September 1973 on the "R/V Samudera", of the Indonesian Institute of Oceanology (LON) and the "M/V Equator", owned by P. T. Pacific Nikkel Indonesia. The basic sounding equipment used was the 12 KHz Edo or multiple frequency (near 3.5 KHz) O.R.E. hydrophones, received on the Gifft or O.S.R. 19-inch recorders using Alfax (wet chemically treated) paper. A 1,000 joule electronic arcing sub-bottom profiling system was available but was utilized to a limited degree. Navigation was by a Motorola Mini-Ranger interrogated transponder system. The distance to the shore transponders was recorded in real time by a digital printer for later computer processing, although in the field plots of position were made by plotting the distance to the interrogated transponder along arcs from the known shore stations. Depths were recorded by the equipment in uncorrected fathoms assuming a speed of sound in sea water of 800 fathoms per second. Full scale sweep generally was 1/3 second or 200 fathoms. On the final bathymetric charts the depths are plotted in corrected meters using in situ speed of sound values derived from Nansen and S. T. D. hydrographic data for temperature and salinity taken in August 1973 on the "R/V Samudera", (Wyrtki, 1973).

The aims of the bathymetric survey were to (1) determine the regional bathymetric features around Gag, (2) discover suitable channelized pathways by which introduced tailings might flow by gravity into the deeps of the Halmahera Sea, and (3) locate possible pipe line routes from Gag to the heads of the channelized pathways. Accordingly three separate surveys were run to realize these aims.

Regional Survey

This survey was planned as a series of ray paths similar to a star pattern with Gag at the center. Each run would be from shoal water (less than 100 meters) through the marginal deep water around Gag to the next shoal areas to the north, east, and south or to great depths (greater than 1500 meters) on the west in the Halmahera basin. Long straight runs were planned as such lines are easiest to plot and with little or no course corrections give the highest navigational precision. Unfortunately, due to time constraints and unsuitability of the "Samudera", for bathymetric surveying in reef shoal area, a complete number of rays were not run. However, enough lines were run in critical areas to determine the regional bathymetry.

For the purpose of this discussion, water shallower than 200 meters, or the approximate depth to which sea level fell during the ice ages, will be treated separately, as in this depth range coral reefs may develop, biologically modifying the bathymetry. Deeper than 200 meters the configuration of the bottom, for the most part, is governed by physical hydrologic and geologic processes.

As shown in Dwg. No. 720-C-160, Gag is totally surrounded by water deeper than 200 meters, indicating there is no direct continental connection or "land bridge" to either Waigeo or New Guinea to the east or Gebe and Halmahera to the west. The 200 meter line is closest to Gag (1) off the northeast coast and (2) near Gambir Bay. In fact both of these indentations of the 200 meter line are parallel or sub-parallel to the geologic separation on the island between andesites on the northeast and laterites on the southwest. This suggests such features are regional and produce fault zones or at least zones of weakness as seen topographically on the island as (1) the valley between the two predominate rock types and (2) the embayment of Gambir Bay. To the east of the andesitic portion of the island is a large area of relatively flat relief just shoaler than 200 meters. This 200 meter flat is bounded on the north by a steep narrow reef, which is much shoaler than the flat to the south and in places is a hazard to navigation, and on the south by a narrow rise which in turn plunges into a steep escarpment. Both these boundary features are again sub-parallel to the regional zone of weakness. The overall evenness of the surface of the 200 meter plateau with marginal narrow shoaler areas suggests the surface is an old Pleistocene back reef bounded by fringing reefs, initially formed at the lowest stand at sea level, (Kuenan, 1933 and 1950, p. 451). Thus the average depth of the flat at about 180 meters would be a reasonable estimate of the maximum sea level drop recorded in this area. The more extensive fringing reef on the north was able to maintain its growth during the subsequent rise in sea level, whereas the southern fringing reef apparently ceased to grow, indicating much better circulation, aeration, and higher nutrient content of the sea water, and that then the major surface flow was from the northeast favoring growth on the northerly reef. Wyrtki's (1973) measurements indicate the present surface flow also is from the northeast.

Around the rest of the island, the 200 meter line and even the 100 meter line are several kilometers off shore. There is no equivalent of the 200 meter surface on the northwest side of Gag, although there is a shoaler nose which is again sub-parallel to the regional trend on the andesitic side.

The bathymetric features of the areas deeper than 200 meters can be divided into (1) a steep escarpment which surrounds the island and which drops down to the regional depth on the north, east, and south onto, (2) broad relatively flat sea valleys between the islands and on the west into the depths of the Halmahera Sea. The escarpment is not everywhere a regular drop into the depths but, particularly on the west side, drops in a series of saw tooth-like peaks and basins.

A broad saddle with a minimum depth of about 500 meters is located between Gag and Waigeo. The saddle is aligned perpendicular to the trend of the northeast escarpment and has the shoalest depths of the sea valleys around Gag. From the saddle, the maximum depths increase in sea valleys around Gag (1) to the east, south, southwest and finally west; and (2) to the west and southwest. The first somewhat flat contour is at 600 meters, thus the escarpments surrounding Gag have a total drop from approximately 200 meters to a minimum of 600 meters except in the region of the saddle.

The bathymetry of the saddle is complex and not a smooth surface, with apparently unconnected depressions, troughs, and rises texturing its surface so that no regional slope can be determined here. Accordingly, there are two pathways of increasing depth into the Halmahera sea along sea valleys starting (1) east of the saddle between Gag and Waigeo, then southeast, then south between Gag and the Fam Islands, then in an arc swinging to the south between Gag and the Jef Doif Atoll, then west into the Halmahera depths; and (2) west of the saddle towards Gebe, west then southwest into the Halmahera. The sea valley east of Gag has several channels Dwg. No. 720-C-160 one of which appears to be continuous. This channel heads at a depth of about 700 meters at the mouth of a submarine canyon cut at the southern edge of the 200 meter reef surface, and can be traced at least to the 1300 meter contour and possibly to the 1400 meter contour in the Halmahera Sea. The continuous channel is joined by at least one tributary channel seen as the marginal trough just south of the southern most reef complex of Gag. The sea valley which begins west of the Gag-Waigeo saddle has no channels apparent on the fathograms, but is a broad conduit with a low slope from 600 to 900 meters and increasing slope from 900 to 1600 meters to the western edge of the surveyed area.

Intermediate Survey

The salient features of the regional survey suggested the best area to investigate for a route was the area in the vicinity of the 200 meter reef surface because:

1) The 200 meter line was closest to the shore and the plant site on Gambir Bay.

2) Its proximity to two channels that could be traced into the Halmahera Sea.

Survey lines were run in a parallel/perpendicular-to-shore pattern with either one kilometer or one-half kilometer spacing in the area immediately adjacent to the plant site. The parallel-to-the-coast lines were run from deep water north of the large fringing reef to the marginal deep south of the main reef surface. The perpendicular -to-the-coast tracks were run from the beginning of navigational control near Gag across the 200 meter surface until deep water (greater than 600 meters) was encountered on the east. Such a pattern provides tie points at each line crossing to increase the confidence in the navigation.

This survey was run on the "M/V Equator" rather than the "R/V Samudera" because the Equator has (1) higher manuverability so the turns were tighter with less drift, (2) a shallower draft so the northern fringing reef and near shore areas could be surveyed with safety, and (3) better ability to maintain and correct to relatively straight lines required for accurate controlled bathymetric surveying.

Drawing No. 720-C-162 shows the area of the 200 meter reef surface and vicinity contoured at a 50 meter contour interval. The main reef surface is separated from Gag by an escarpment from about 100 to 150 meters sub-parallel to the shore line, but complicated off the plant site by a lobate shoal standing seaward of the main escarpment. As noted above, the northern boundary of the 200 meter surface is the narrow fringing reef which at this scale is composed of two linear shoals separated by a saddle. The southern boundary is the escarpment dropping to a regional depth of from 600 to 700 meters. At the top edge of the escarpment is a small fringing reef. The reef flat surface is on the average at about 170 to 180 meters, decreasing eastward from the base of the 100 to 150 meter escarpment which suggests either (a) gradual tilting to the east of the platform underlying the reef or (b) ramp formation against Gag during a gradual rise in sea level from the 200 meter level. There is a triangular shaped depression oriented with its apex to the south, just south of the northern fringing reef and east of the 100 to 150 meter escarpment. The maximum depths in the depression are about 300 meters. Spill-over points from the depression occur (1) at the saddle between the two lobes of the northern fringing reef, (2) along a channel system at the southern margin of the northern fringing reef, and (3) along a discrete channel system crossing the southern apex of the depression. The southernmost channel system can be traced with confidence to the base of the 100 to 150 meter escarpment to about 170 meters north of the lobate shoal off the plant site. Both these channels have apparent high points along their downstream profiles of 140 meters for the northern channel and 90 meters for the southern channel. (These figures would be the apparent thickness of subsequent fill which prevents the channels from having a continuous downslope profile and are not water depths). However, in the sounding of channels, as pointed out by Krause (1962), THE REAL DEPTH AT THE BOTTOM OF A CHANNEL IS ALWAYS GREATER THAN THE DEPTH ON THE FATHOGRAMS BECAUSE THE SONIC SIGNAL REFLECTS OFF THE WALLS RATHER THAN THE BOTTOM OF THE CHANNEL IF THE DEPTH OF WATER IS SIGNIFICANTLY GREATER THAN THE WIDTH OF THE CHANNEL. Sometimes the true depth or an apparent true depth can be seen as a sub bottom reflection beneath the "vee" crossings representing the walls of the channel. Thus the spill-over depth from the depression could be reduced, particularly where the channel width is narrow. The continuity of the channels certainly implies they either initially had a continuous down slope profile or they represent a downdropped zone of weakness such as a fault graben. The present blockage may be debris swept in after formation initially as solution channels or subaerial drainage when the platform was near sea level during the 200 meter low stand. The northern channel terminates in a broad submarine canyon eventually debouching out to 600 meters. The southern channel empties into the west wall of the northerly incised canyon that in turn empties into the deep sea channel which may be traced (Dwg. No. 720-C-160) to the 1300 meter contour west of Gag in the Halmahera deeps.

Pipe Line Route Survey

The location of the heads of the two channels cutting the 200 meter platform, near the plant site on Gambir Bay suggested these may be ideal transport routes for the tailings. The next survey was run in the area between the plant site and the heads of the two channels at the base of the 100 to 150 meter escarpment. Initially, the survey was planned to be run as a parallel/perpendicular-to-shore pattern centered on the line extending seaward of the plant site along which three current meters had been set. However, the time alloted for the survey was limited by other commitments of the "Equator" and the need to transfer both gear and the Intersea personnel to the "Samudera" for the biological survey. Accordingly, the pipe line route survey was run on a modified ray path/parellel-to-shore pattern, based on the restriction of the echo sounding system used such that the survey line spacing cannot be less than the depth of water to avoid ambiguous results such as plotting a pinnacle as a ridge. A detailed explanation of this technique is given in Appendix I.

The pipe line survey essentially detailed the generalized bathymetric picture of the near shore gained from the survey of the 200 meter platform; that is, it substantiated the outline and orientation of the 100 to 150 meter escarpment and reef patch just seaward of it near the mouth of Gambir Bay. However, because of the increased density of surveyed points, subtle features now could be discerned as seen in Dwg. 720-C-164 contoured at 10 meter intervals.

The head of the northern channel is seen as landward indentations in the 180 and 190 meter contours at the northeast edge of the map. The head of the southern channel can be traced further landward just north of the reef patch seen as an outlayer from the 100 to 150 meter escarpment. The head of the southern channel possibly may be as shoal as 150 meters between the escarpment and the reef patch. In any case it can be traced to at least 170 meters. In general the bottom, seaward of the 100 to 150 meter escarpment, slopes as a ramp towards the depression and the regular surface of the 200 meter platform.

The major escarpment at 100 to 150 meters broadens somewhat to the south and actually is separate from the reef patch, although both features have a top at 100 meters where the slopes become very gentle. This flat surface suggests a still stand of sea level at about 100 meters planing both the active reef of the escarpment and reef outlayer. Landward of the 100 to 150 meter escarpment to about 70 meters is a relatively flat ramp surface gently sloping seaward. This surface is textured with pinnacles and depressions characteristic of back reef areas, as seen in the irregularity in orientation of the 80 meter contour.

Another escarpment sub-parallel to the coast is at 50 to 70 meters, increasing from 50 to 80 meters. The reef front is cut by an outlet which reduces the elevation of the escarpment to 20 meters. This feature is probably a drowned former entrance or surge passage through the reef. Landward of this escarpment the bathymetry is generally slightly dipping seaward with irregular back reef patchy growth.

Diver observations off the plant site indicate a recent reef front dropping from sea level to about 5 meters with the bottom sloping seaward to the escarpment, presumably to the next escarpment break in slope at 50 meters. The area between the 0 to 5 meter and the 50 to 70 meter escarpment again is relatively flat with gently sloping bottom dimpled with patch reefs, pinnacles and depressions of a back reef area.

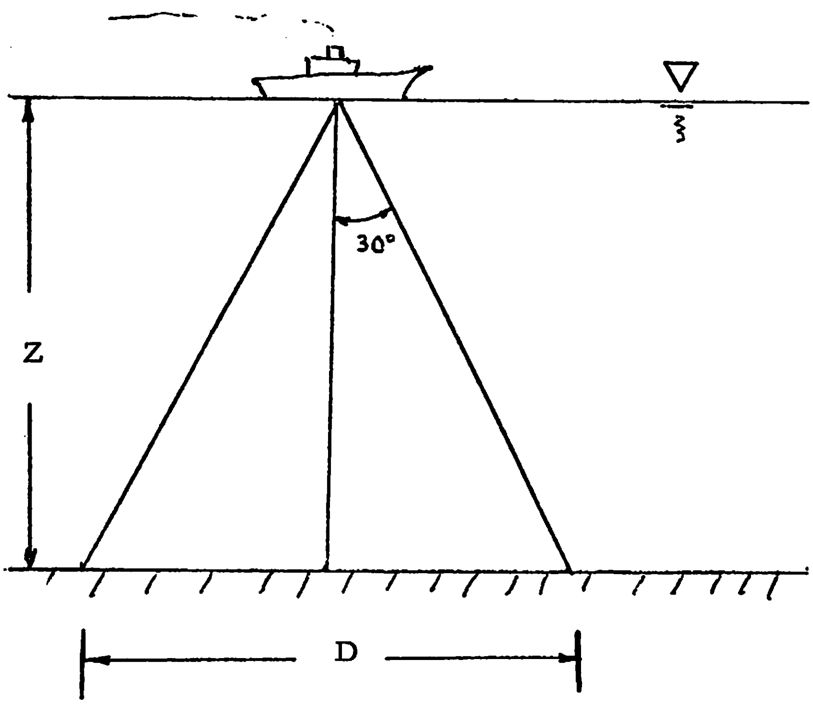
In summary, the bathymetry in the area east of the plant site on Gambir Bay may be visualized as a series of parallel steps at 5 meters, 50 to 70 meters, and 100 to 150 meters, with .75 kilometer wide relatively flat ramps sloping gently seaward between the steps. Seaward of the 100 to 150 meter escarpment the bottom surface merges with the 200 meter platform which extends at least 9 kilometers east of the 100 to 150 meter escarpment.

APPENDIX 1

SURVEY PATTERNS

FOR A 12 KH TRANSDUCER

The spacing between survey lines should not be governed strictly by the precision of the navigation but also should reflect the characteristics of the sounding system. Most modern bathymetric surveys are run using a 12 KH echo sounder which produces with each sonic ping a sound cone with a half angle of 30°. As shown the diameter of conic section produced by the intersection of the bottom with the sound cone is approximately equal to the depth, if the bottom is relatively flat.



SEA LEVEL

Z = DEPTH

D = DIAMETER OF SOUND CONE

$\tan 30^\circ = \frac{D}{2} / Z$

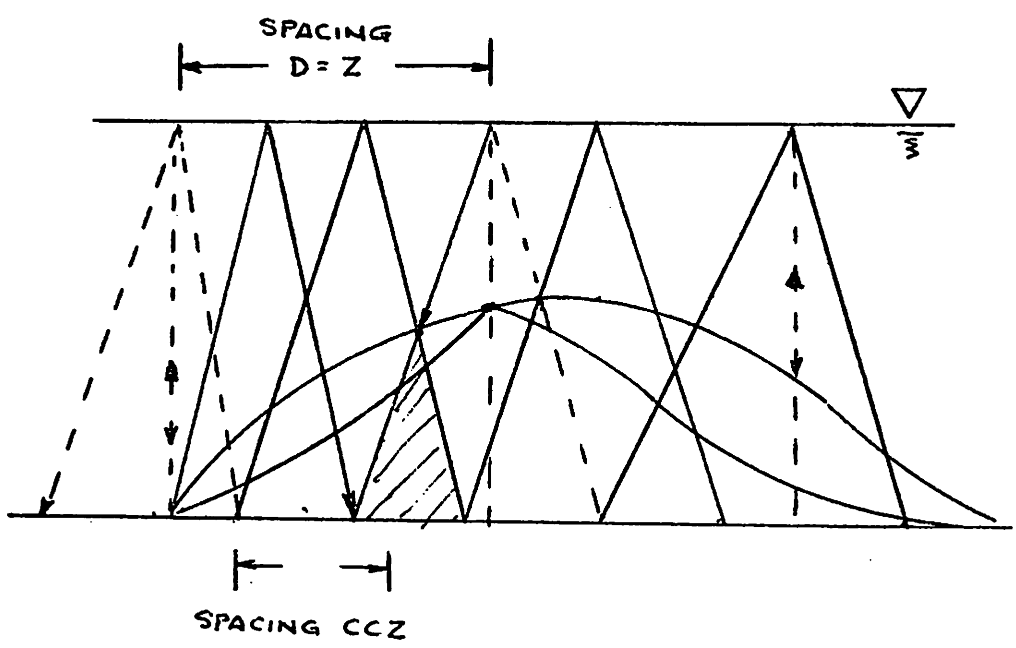
$D = 2Z \tan 30^\circ$

$D = 2\ (.58)\ Z$

$D = 1.16\ Z$

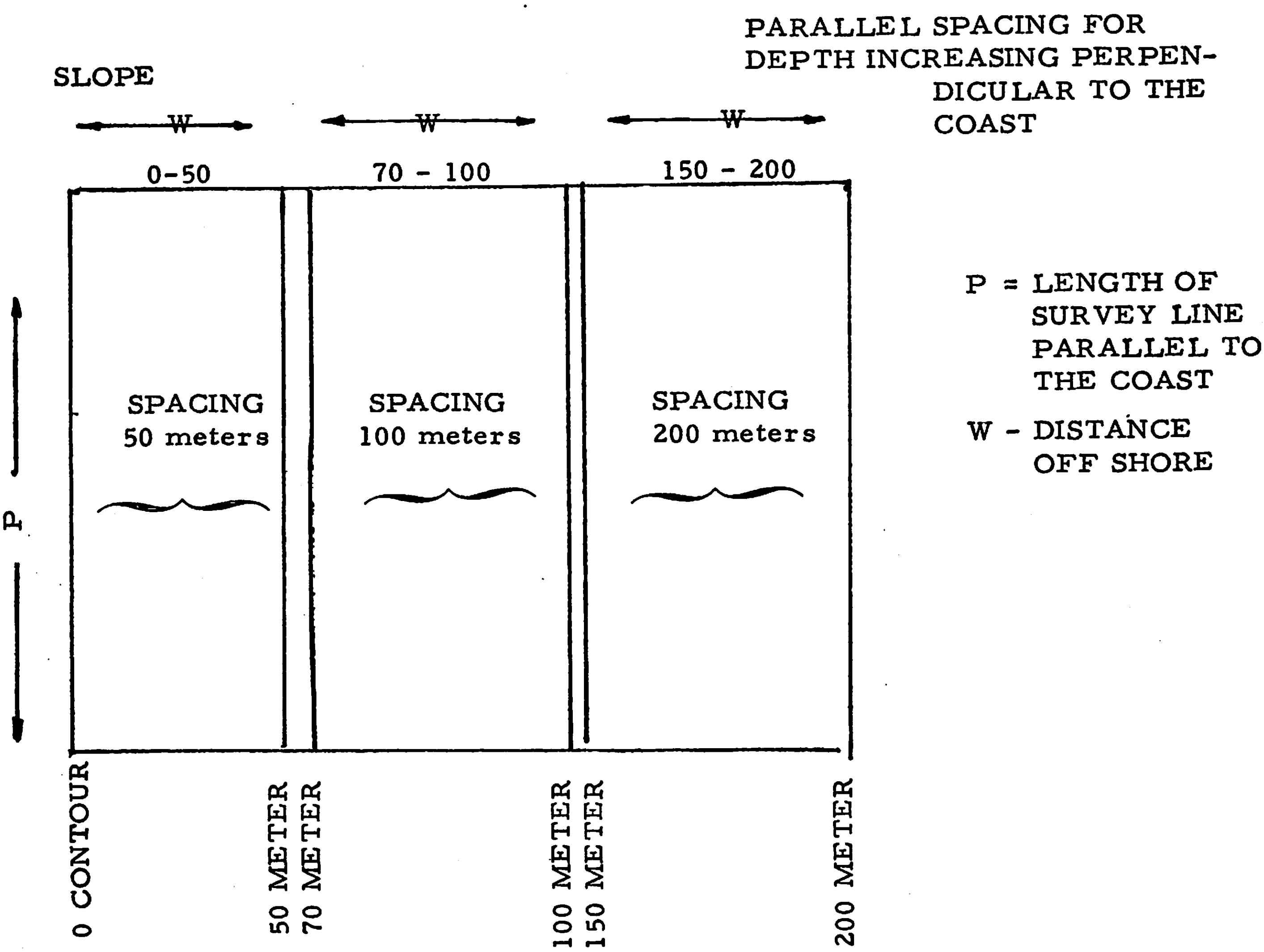
$D \approx Z$

As (1) usually the first arrivals back to the ship conservatively are plotted as the depth, and (2) there is no way to position any given first arrival more precisely except some where in the sound cone, it is apparent that a line spacing less than the depth can produce bottom records which are either ambiguous or give an erroneous impression of the actual bottom configuration.



As shown on page A-2 given a simple flat surface with a pinnacle, the survey line spacing where D=Z gives a much more accurate picture of the bottom than the spacing which is less than the depth. In other words, because of the sound cone, any line spacing less than the depth tends to exaggerate or broaden the dimensions of any bottom figure, in this case converting a pinnacle into a broad ridge. On the other hand, sounding on any line spacing much greater than the depth could miss a really small but significant feature such as pinnacles. Thus a line spacing approximately equal to the depth would be optimal in producing a bathymetric chart within the irreducible errors of position governed by the sound cone, regardless of how precise the navigation might be.

However the sea floor is not a simple surface, so allowance must be made for more complex geometries. The regional survey, for example, showed in the area around Gag the bathymetry could be generalized as a series of steps. Thus a parallel to shore pattern could be designed by dividing the area at the breaks in slope and using a line spacing equal to the depth in the area between the breaks in slope.



Thus: For Z = regional or deepest depth in individual survey cell

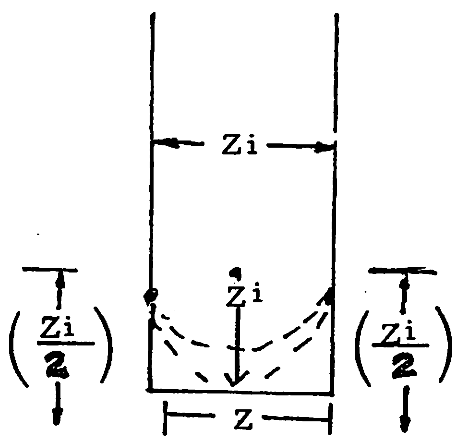
$\frac{Wi}{Zi}$ = Number of lines in Cell of Length P

AND

$\sum \frac{Wi}{Zi}$ = Total number of lines run in survey

For $\bar{V}$ = average speed of survey ship

Assume turns can be made in a distance = 2 Zi, for Zi shoal



The number of turns = $\left(\sum \frac{Wi}{Zi}\right) - 1$

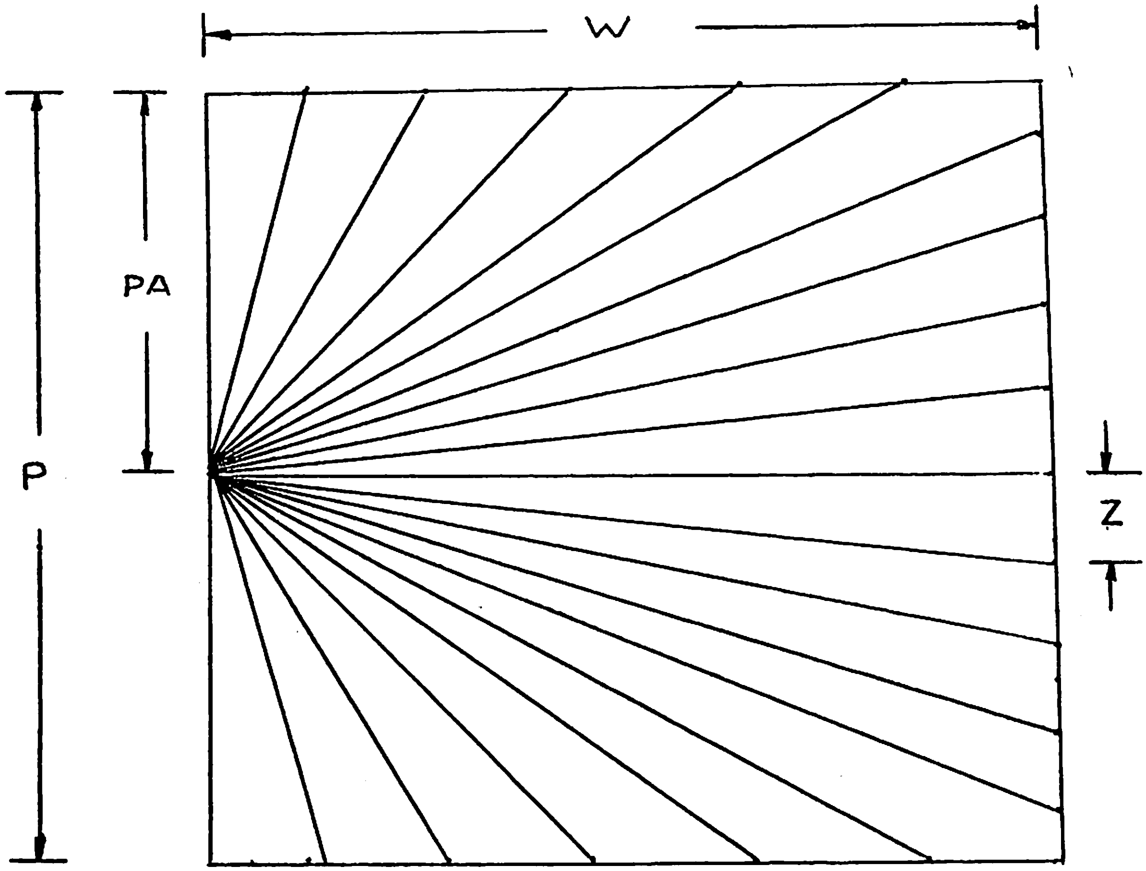
Therefore the survey run time is approximately

$$Ts = \frac{P\left(\sum \frac{Wi}{Zi}\right)}{\bar{V}} + \frac{2\,Zi}{\bar{V}}\left[\left(\sum \frac{Wi}{Zi}\right) - 1\right]$$

RAY SURVEY

For survey around a point such as an island the parallel pattern would be modified into some box pattern. However an efficient pattern also would be as straight course rays emanating from some known survey point, located visually or electronically or as a transponder interrogated from the ship. Here the control of the spacing would be either the deepest depths encountered or the depths at the edge of the survey area. A ray survey also can be used to tie points of a parallel survey. The example on page A-7 shows the use of ray survey lines along a linear coast line.

A-7



P	=	PARALLEL TO COAST DIMENSION OF THE SURVEY AREA
PA	=	DISTANCE ALONG P TO STATION A FROM ONE CORNER OF SURVEY AREA
P-PA	=	DISTANCE ALONG P FROM STATION A TO OPPOSITE CORNER
Z	=	DEPTH AT SEAWARD EDGE OF SURVEY AREA
W	=	OFFSHORE DIMENSION OF SURVEY AREA
θ	=	OPTIMAL ANGLE BETWEEN RAYS

$\tan \theta = \frac{Z}{W}$

n = NUMBER OF RAY STARTING WITH n=1 ORIENTED θ^{o} FROM A LINE PERPENDICULAR TO THE COAST AT THE STATION AND PARALLEL TO W.

$n\theta$ = ORIENTATION IN DEGREES WITH O^{o} A LINE PERPENDICULAR TO THE COAST AT THE STATION AND PARALLEL TO W.

Lo = LENGTH OF RAY AT n=O

Ln = W
= LENGTH OF RAY OF SURVEY LINE n

FOR $n\theta$ FROM O^{o} TO $\pm$ 45^{o}

Ln = n Z SIN $(n\theta)$

FOR $n\theta$ FROM + 45^{o} TO + $(90-O)^{o}$

Ln = PA/SIN $[(n-1)\ \theta]$

FOR $n\theta$ FROM - 45^{o} TO - $(90\theta)^{o}$

Ln = (P-PA) / SIN $[(n-1)\ \theta]$

ASSUMING THE LINES $n\theta = \pm\ 90^{o}$ ARE TOO CLOSE TO SHORE TO BE RUN SAFELY

$Lo + \Sigma Ln$ + TOTAL LENGTH OF SURVEY RAYS

Σn = TOTAL NUMBER OF USABLE RAYS FROM A STATION

$$= \left(\frac{180^{\circ}}{\theta} - 1 \right)$$ FOR LINEAR COAST

$$= \frac{360^{\circ}}{\theta}$$ FOR SURVEY AROUND AN ISLAND FROM ONE STATION WHERE THE ISLAND IS SMALL COMPARED TO THE LENGTH OF THE SURVEY LINES.

FOR $\overline{V}$ = AVERAGE SPEED OF SHIP

T_R = TIME OF RAY SURVEY NEGLECTING TURNS

$$= \frac{Lo + \Sigma Ln}{\overline{V}}$$ FOR BLOCK SURVEY OF LINEAR COAST

In general some practical compromise must be made to combine a ray and a parallel survey pattern, to maximize the useable run time and to reduce dead time in turns or coming on a survey line. However, the advantage of a geometrical analysis of a bathymetric survey is that (1) the optimal line orientation, line distance and survey time can be estimated so that (2) some evaluation, for example in percent, of the completeness of the survey can be made from the actual line spacing and orientation, line distance, and run time available.

APPENDIX I

MARINE SEDIMENTS

Dr. Pat Wilde

The extensive program of sampling the bottom sediments in the vicinity of Gag Island to investigate both the benthic organisms and the physical properties of the sediment was not carried out as the winch system on the R/V Samudera failed after the first lowering of the grab sampler. Thus during the marine operations in 1973 only 34 bottom samples were obtained, 33 of which were shallow water samples from 10 to 200 meters depth along the proposed pipeline route taken from the barge, and one was from deep water taken from the Samudera. Accordingly, no real conclusions can be drawn on the susceptibility of the deep water sediment seaward of the outfall to be entrained by the turbidity current formed by the plant tailings flowing from the outfall; or possible interactions among the plant tailings and the marine sediments in the regions of transport or deposition of the plant tailings.

SHALLOW SAMPLES

The 33 samples taken along the proposed pipeline route just east of Gag were all coral and reef debris, essentially medium to fine sand with little change in grain size with depth to just over 200 meters. Table A gives the grain size for nine representative samples. Appendix G shows bottom photographs along the pipeline route. These samples were taken chiefly to determine the trafficability of the sediments for the pipeline, although such samples would be typical of the deposits on the submerged reef flats on the eastern side of Gag.

DEEP SAMPLES

Most of the information on samples from deeper water regions must be derived from data from previous expeditions to the area. Five samples from the Siboga Expediton (Boggild, 1916) are described in Table C. A detailed description of the Snellius samples from the Halmahera Sea is quoted as follows:

> "At St. 352, between the S. E. arm of Halmahera and the island of Gebee, fragments of coral rock were brought up, to which Foraminifera and other organisms were attached. There was no clay and very few minerals. It appears, thus, that strong bottom currents run over this sill. As minerals chlorite or serpentine, with little green hornblende and plagioclase, and traces of distinctly pleochroitic hypersthene were identified. They may be derived both from the S. E. arm of Halmaheira, where Verbeek found besides low coral sandbanks, limestone and serpentine conglomerates

at a higher level in the most easterly part; and they may contain detritus from Gabee, where Verbeek found partially serpentinised periodotite and gabbro".

"At St. 353 in the Halmehera basin the sampled sediment consisted of hard, very much dried up lumps of Globigerina Ooze, which contained a great deal of clay and little sandy minerals. The minerals as in 353, were principally chlorite and serpentine, with more plagioclase, as well as a little green hornblends and actinolite and traces of pale green augite. This material also is detritus of serpentine, gabbro, and diabase, which rocks Veebeek reports in the mountains around the Weda bay, while peridotite and gabbro are reported from Gebee and Fau". (Neeb, 1943, p. 193)

The physical properties, as determined by Dames and Moore, of the sample #140 taken by the Samudera in the trough south of Gag Island is given in Table D and Figure E (see figure 1 of the McGowan report for location). The sample upon examination by hand lens is a green mud with fine sand particles consisting chiefly of foraminifera tests. It has close affinities to Siboga sample number 151 taken north of Gag. The green color and relatively high organic content of almost 5 percent suggest slightly reduced conditions and a possible terrestrial origin similar to green hemipelagic muds found on deep-sea sediment fans. However, the muds have a high lime content as shown by treatment with dilute hydrochloric acid. Thus it probably is a green globigerina ooze with a significant terrestrial silt-clay content. This substantiates the view that there is transport of material from east to west towards the Halmahera Basin.

APPENDIX 1

MARINE SEDIMENTS

REFERENCES:

Boggild, O. B., 1916, Meeresgrundenproben der Siboga-Expedition: Siboga-Expeditie Monograph 65, Brill, Leiden, 50p.

Neeb, G. A., 1943, the composition and distribution of the samples: The Snellius - Expedition, Vol. 5., Part 3, Section II, Brill, Leiden, 268 p.

TABLE A

MECHANICAL ANALYSIS SUMMARY

OCEAN BOTTOM SOIL SAMPLES

PROPOSED TAILINGS DISPOSAL PIPELINE

DAMES AND MOORE

	PASSING								
	PIPE LINE ROUTE								
SAMPLE NUMBER	80	83	84	85	87	92	96	107	115
SIEVE SIZE									
3/4"		100	100	100	100			100	
3/8"	100	99	98	99	97			98	
No. 4	99	93	92	96	91	100		97	
No. 10	98	74	77	87	73	97	100	94	100
No. 40	70	30	31	44	32	51	88	80	87
No. 200	3	4	4	4	5	5	12	10	12

TABLE B

SEDIMENT SAMPLES
FROM PREVIOUS EXPEDITION

SIBOGA (BOGGILD, 1916, p. 4-5)

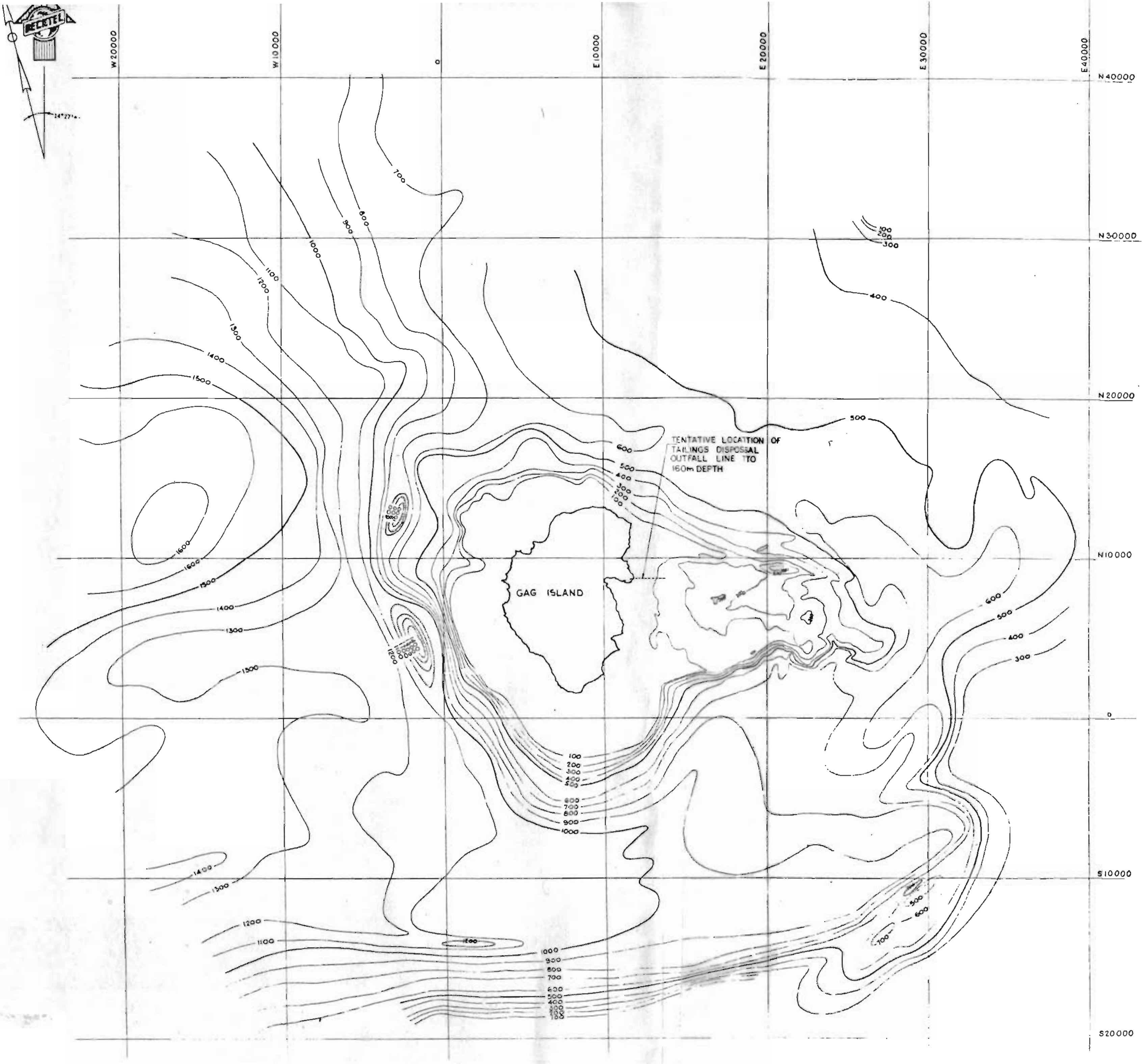
# SAMPLE	DEPTH METERS	LOCATION	o/o Ca CO_3	DESCRIPTION
147	2039	0° 22.7' s 129° 52.7' E (West of Gag)	32.7	Gray Globigerina Ooze
148	1855	0° 17.6' s 129° 14.5 E (West of Gag)	36.9	Gray Globigerina Ooze
151	845	0° 12.6' s 129° 48' E (North of Gag)	69.2	Greenish Globigerina Ooze
156	469	0° 29.2' s 130° 5.3' E (East of Gag)	88.8	Coral Sand
159	411	0° 59.1 s 129° 48.8' E (South of Gag)	64.8	Gray Globigerina Ooze

TABLE C

SEDIMENT SAMPLES

SNELLIUS (NEEB, 1943, p. 82-83, & 193)

# SAMPLE	DEPTH METERS	LOCATION	o/o $CaCO_3$	DESCRIPTION
352	1050	East of Halmahera Island	-	Coral and other Rock Fragments
353	1900	East of Halmahera in Basin	42.6	Globigerina Ooze with Clay



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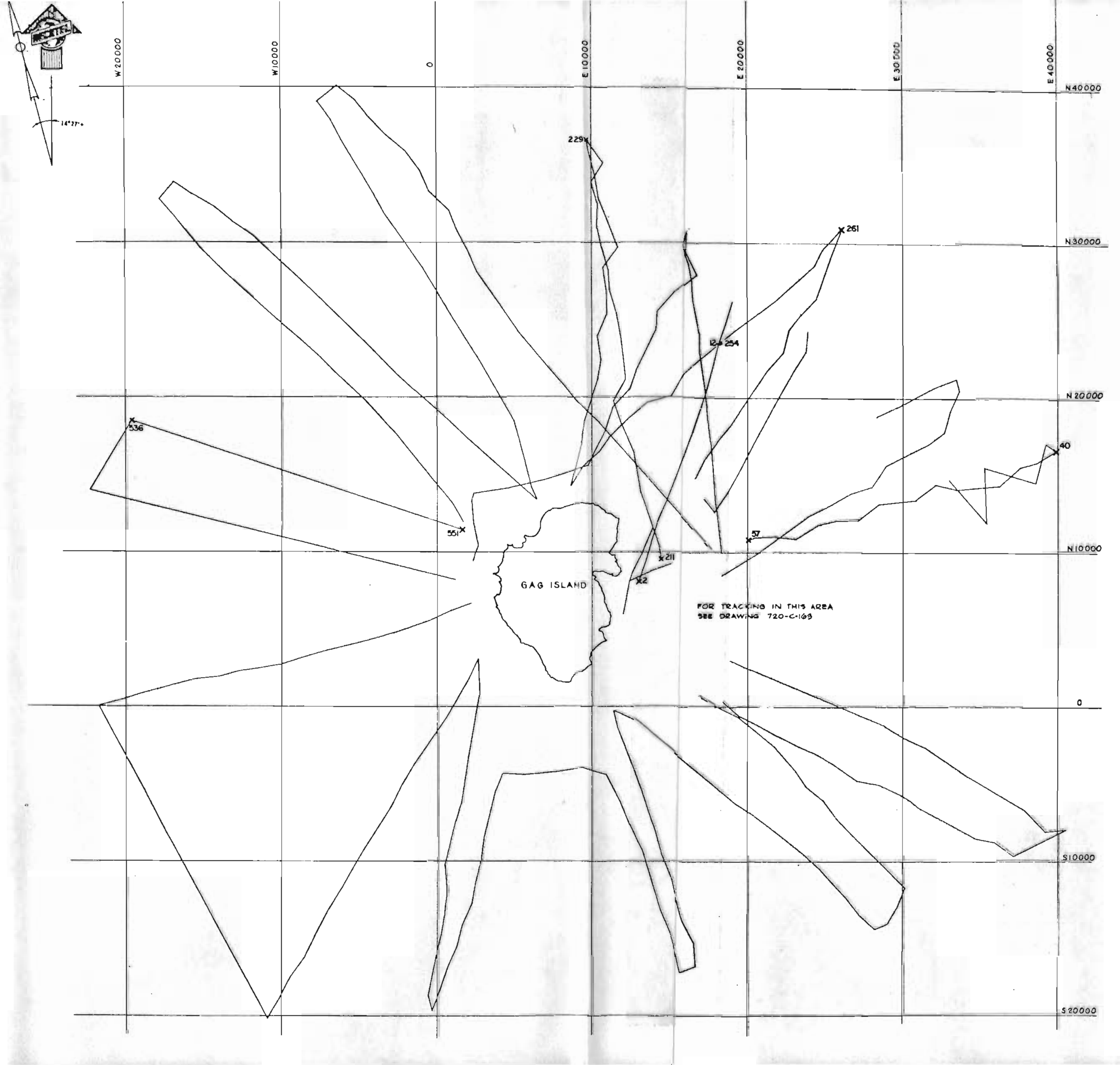
W10000
0
E10000
E20000
E30000
E40000
N40000
N30000
N20000
N10000
0
S10000
S20000
TENTATIVE LOCATION OF TAILINGS DISPOSAL OUTFALL LINE TO 160m DEPTH
GAG ISLAND



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N10000
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S10000
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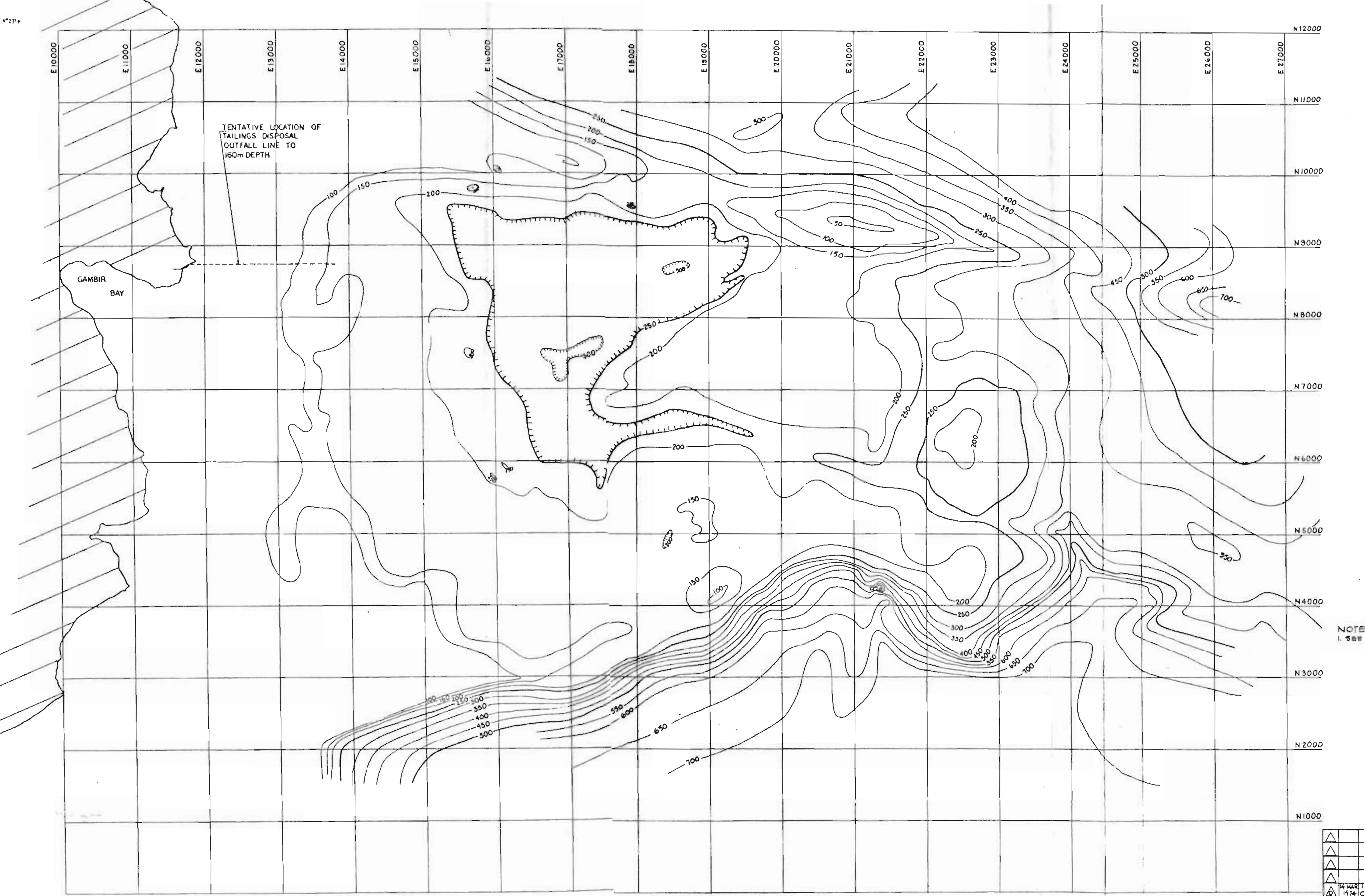
229
261
12
254
536
551
40
57
211
2
GAG ISLAND
FOR TRACKING IN THIS AREA
SEE DRAWING 720-C-163



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E 26000
E 27000
N 12000
N 11000
N 10000
N 9000
N 8000
N 7000
N 6000
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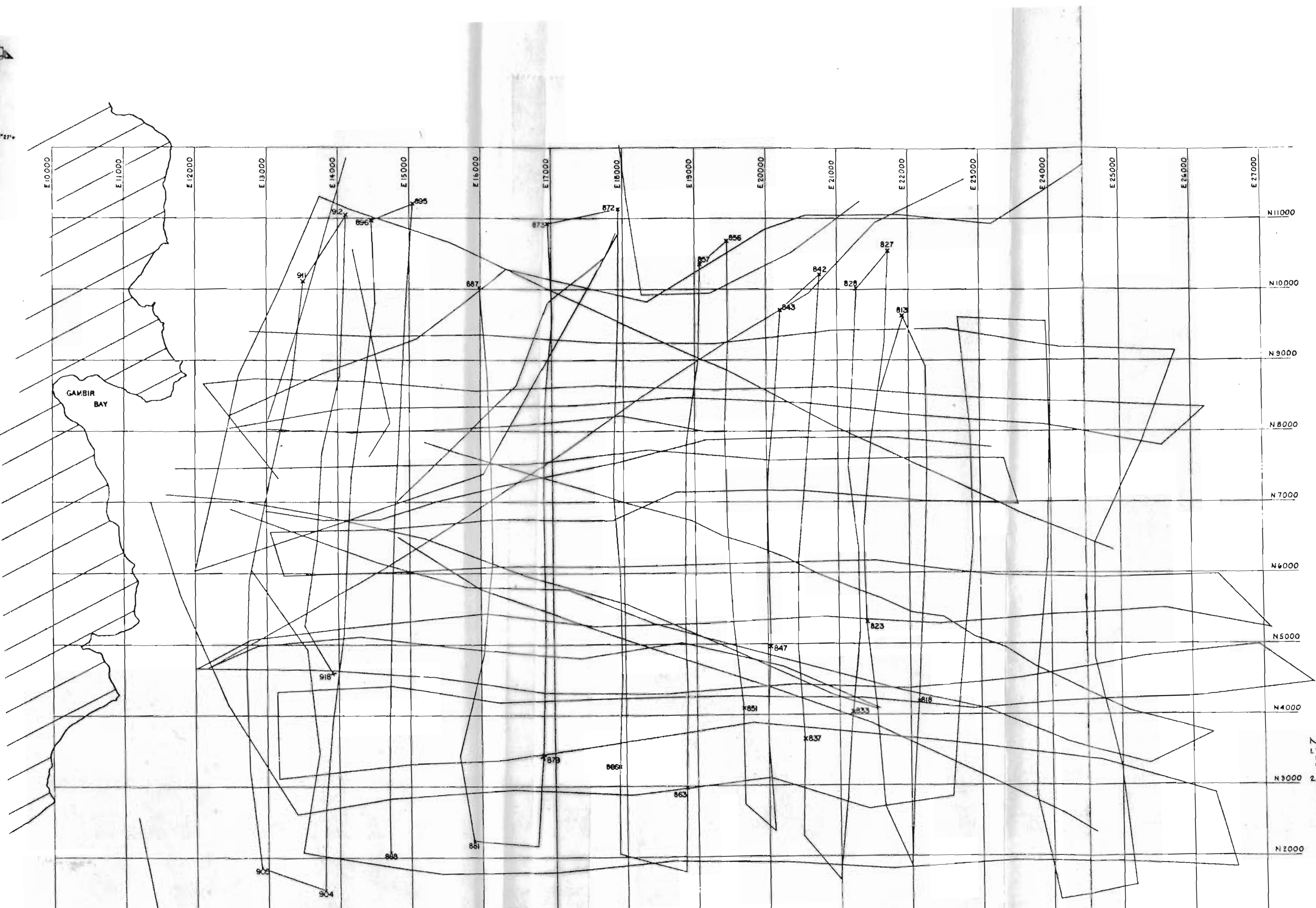
N 1000
TENTATIVE LOCATION OF TAILINGS DISPOSAL OUTFALL LINE TO 160m DEPTH
GAMBIR BAY
NOTE
1. SEE



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E 24000
E 25000
E 26000
E 27000
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N 10000
N 9000
N 8000
N 7000
N 6000
N 5000
N 4000
N 3000
N 2000
GAMBIR
BAY
912
895
896
872
873
856
857
827
842
828
911
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865
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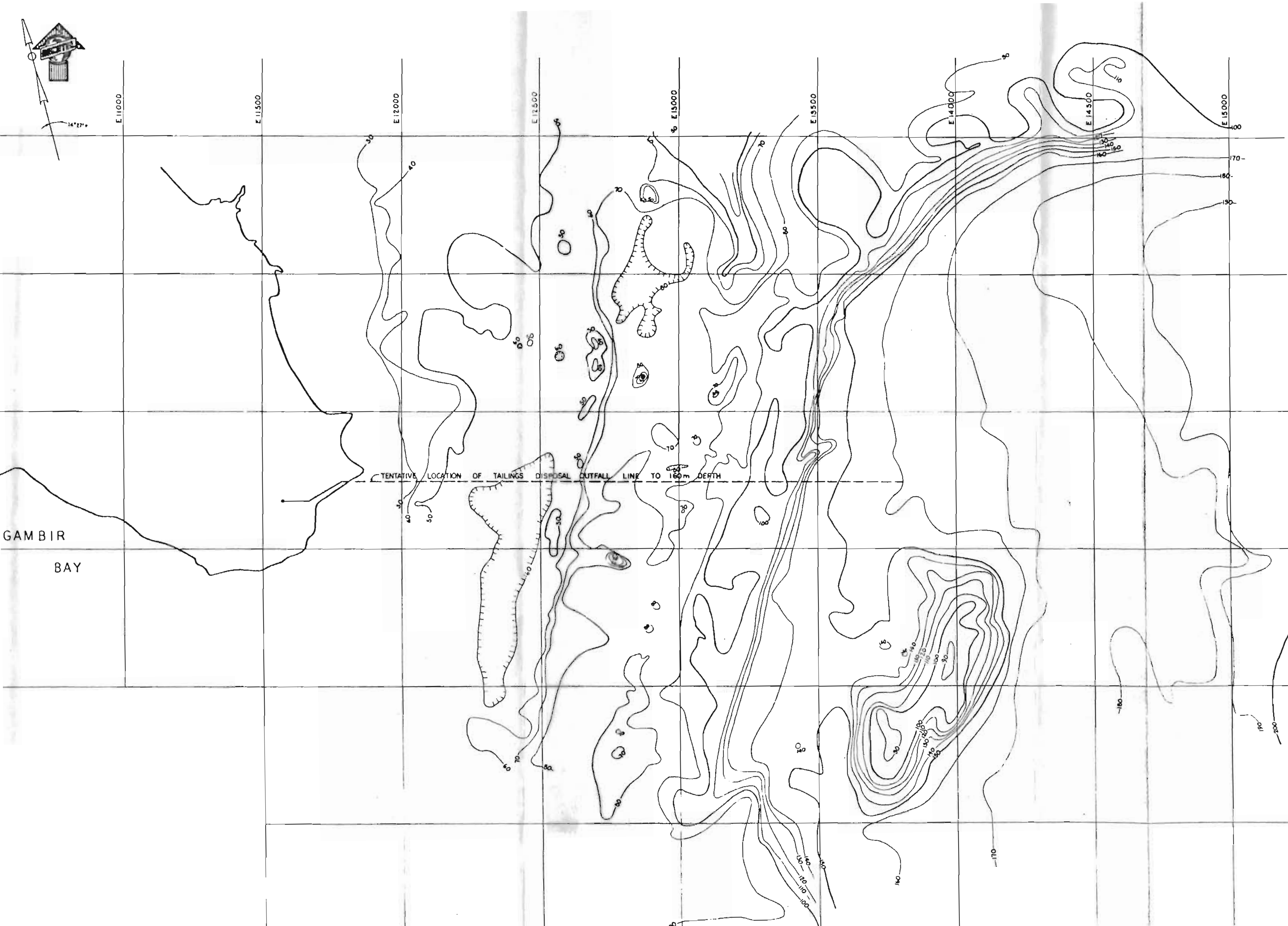
868
905
904



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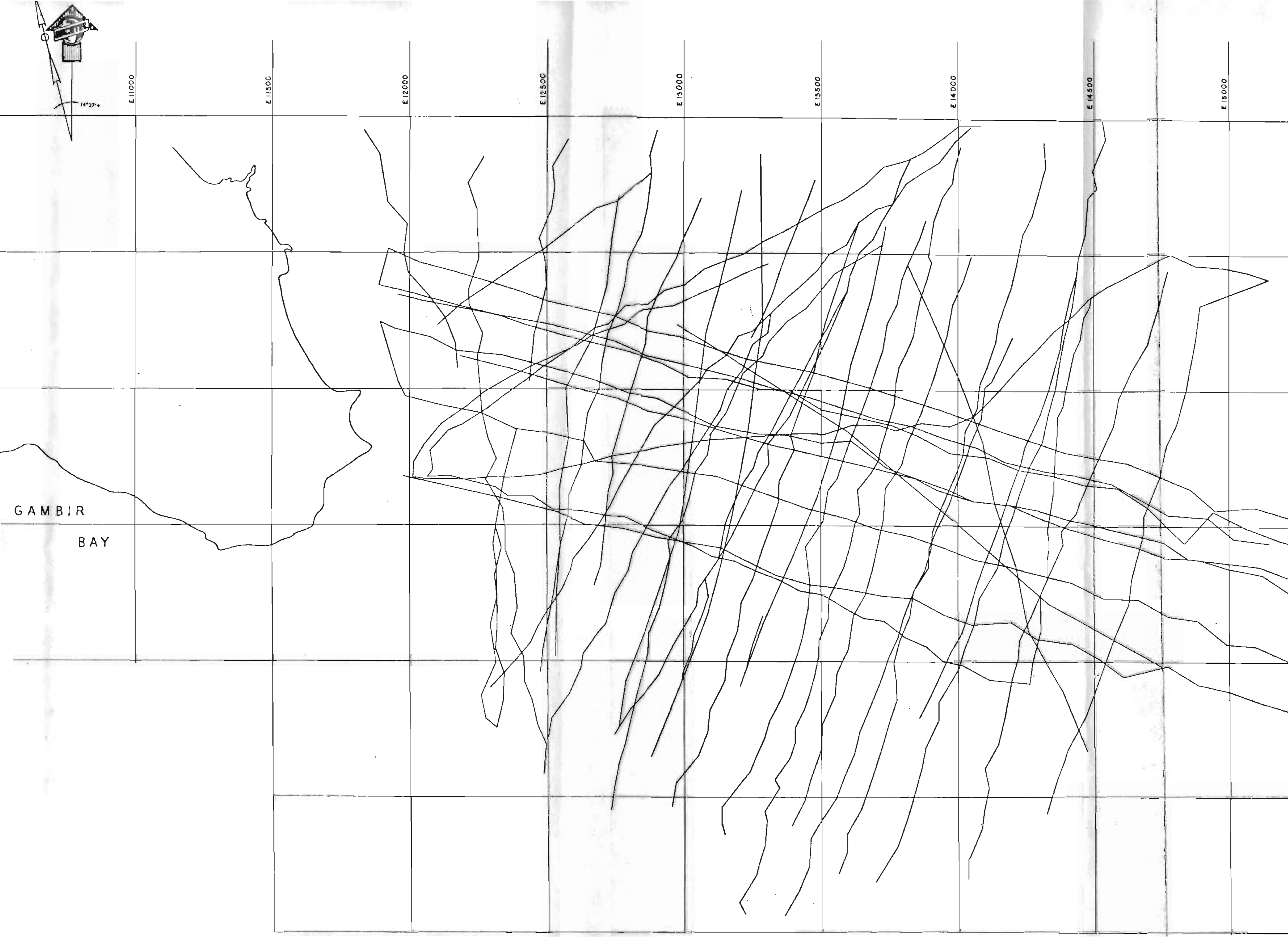
TENTATIVE LOCATION OF TAILINGS DISPOSAL OUTFALL LINE TO 160m DEPTH
GAMBIR
BAY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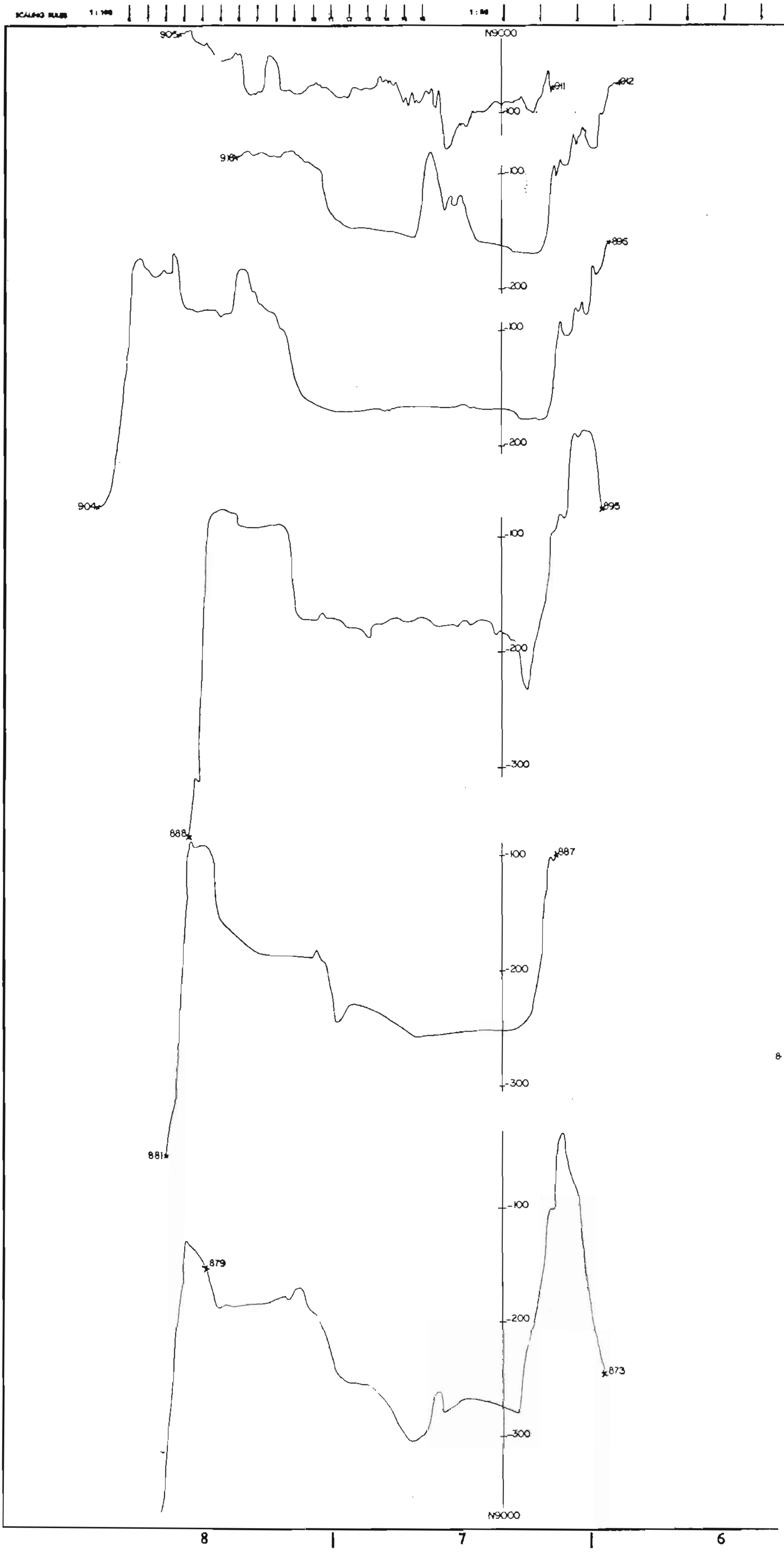
E 14500
E 15000
GAMBIR
BAY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916
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-100
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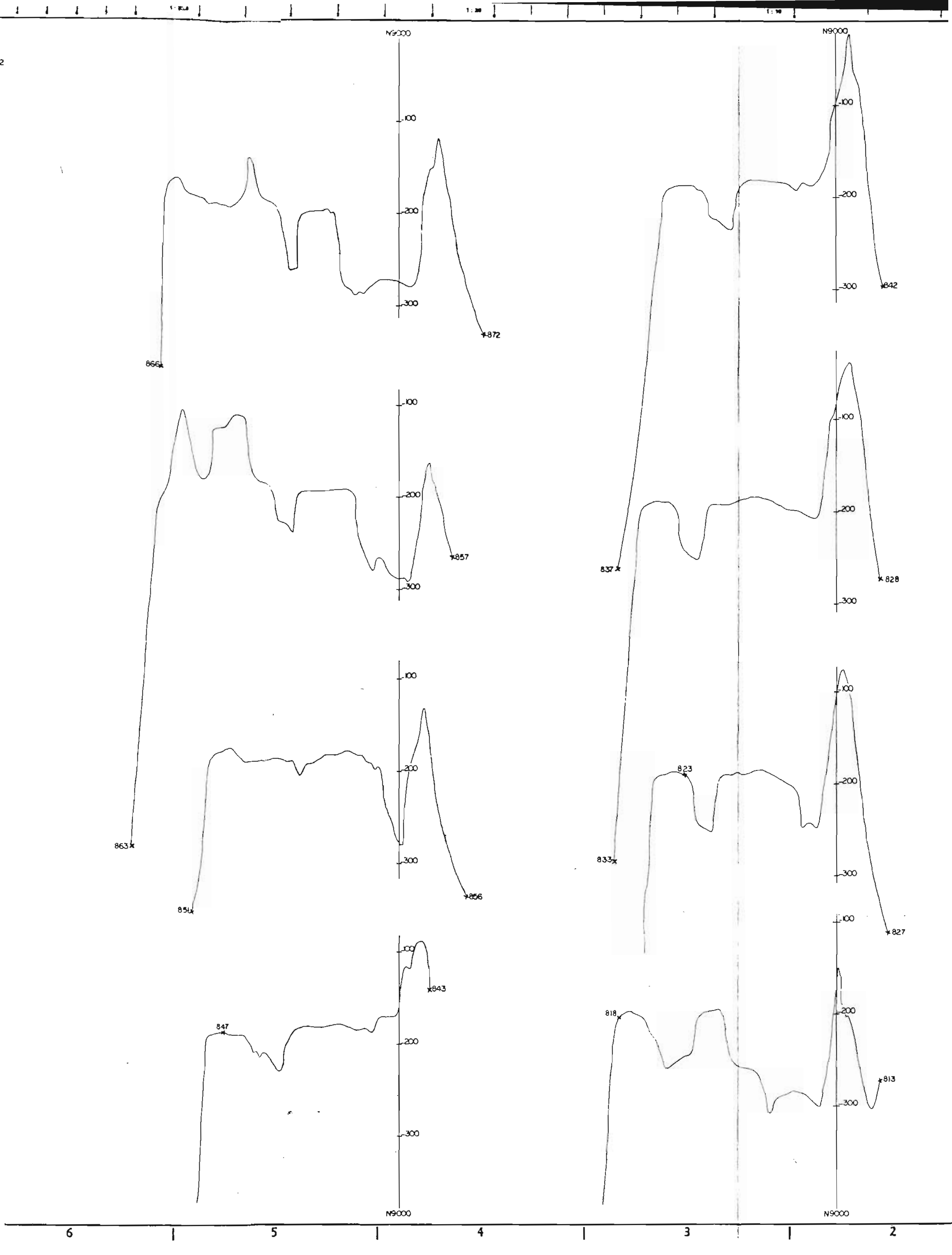
N9000
8
7
6



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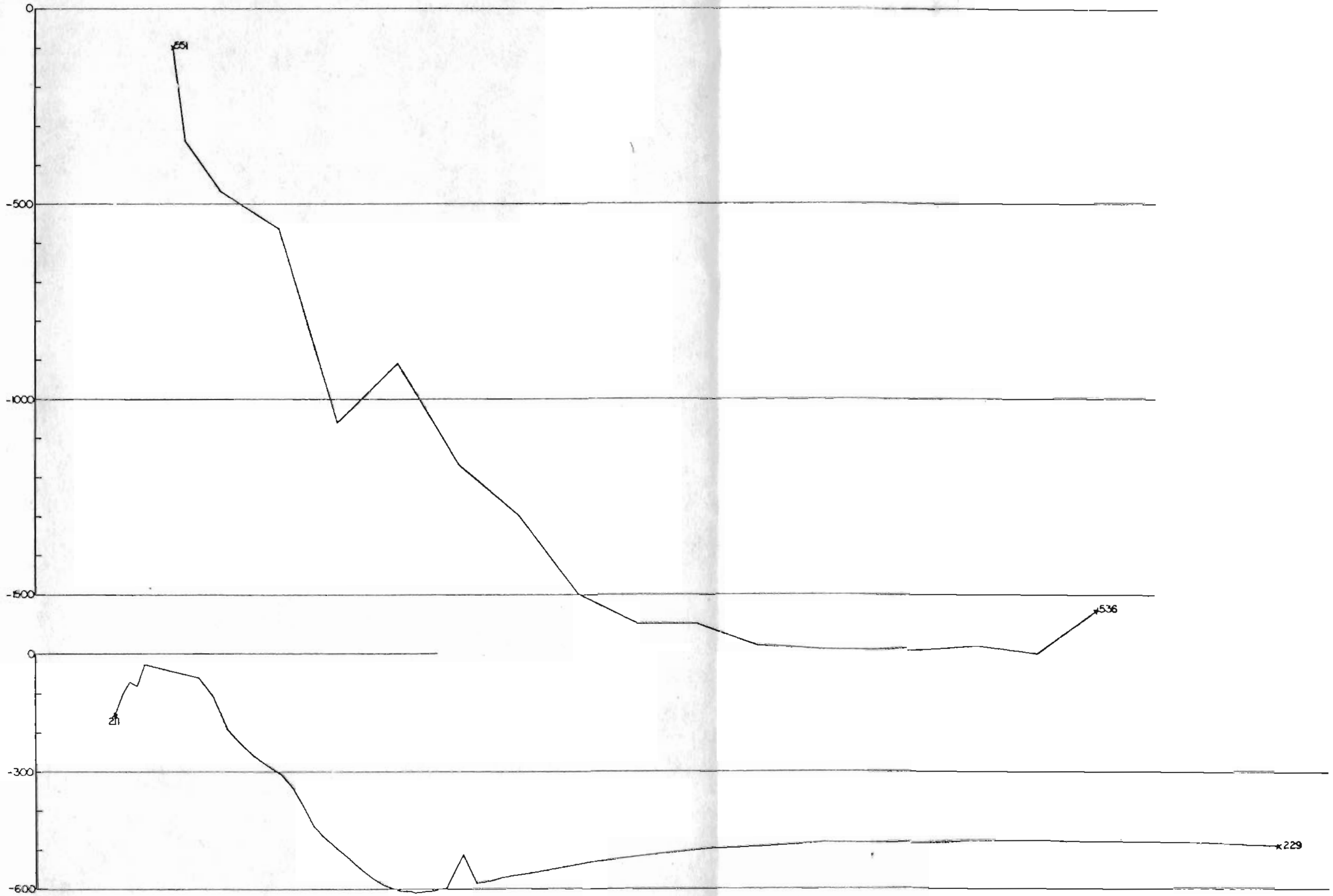
6
5
4
3
2



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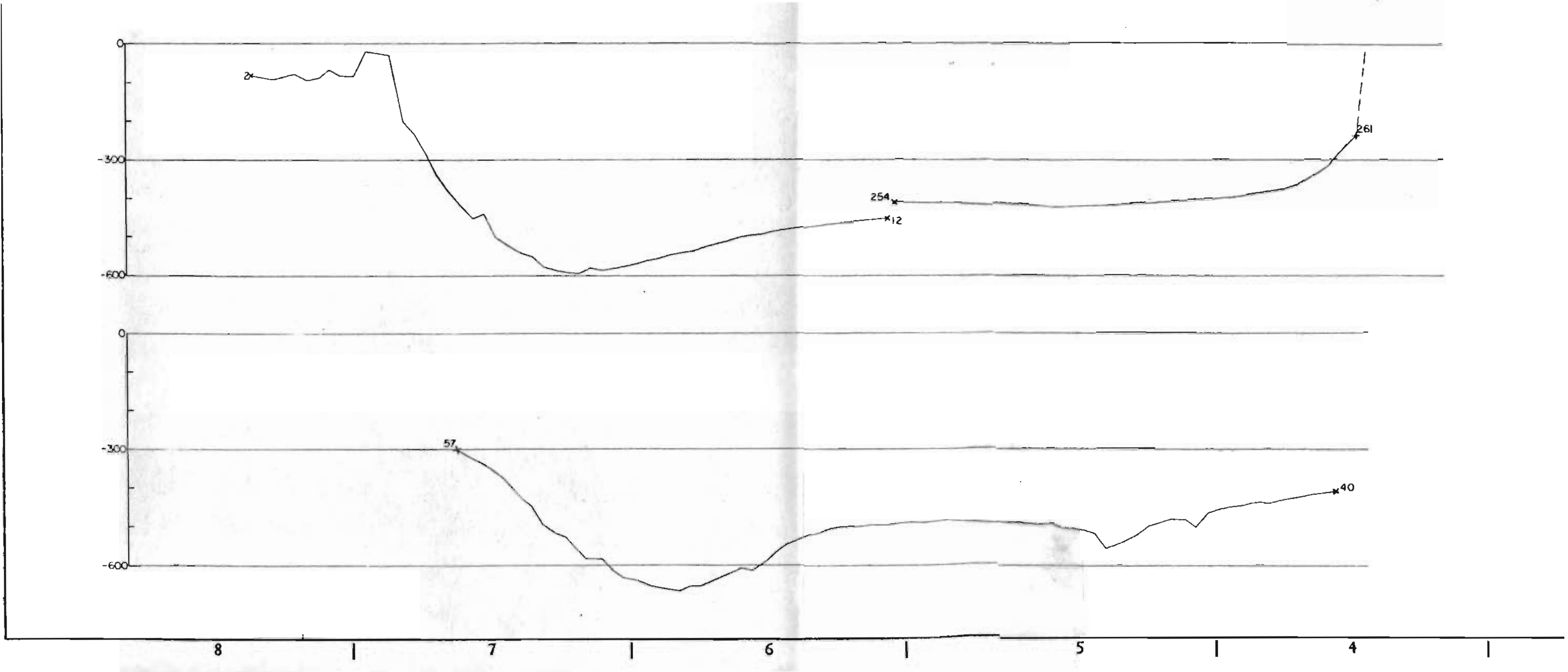
-500
-1000
-1500
551
536
0
-300
-600
211
229



0
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12
261
0
-300
-600
57
40
8
7
6
5
4