MISIMA MINES

TAILINGS LINE
RECONSTRUCTION PROJECT

NEVILLE MILENG

MISIMA MINES

TAILINGS LINE RECONSTRUCTION PROJECT

WRITTEN BY: NEVILLE MILENG **JULY 1998**

CONTENTS

Page

Introduction.......... i

Bathymetric seabed surveys.......... 1

Remote Operating Vehicle (R.O.V) runs on proposed routes.......... 2

Major control surveys for oncoming construction.......... 3

Additional seabed profile surveys on proposed routes.......... 5

Pipeline railway earthworks and construction.......... 8

Mix tank site layout and offshore trench cut earthworks.......... 9

Onshore tailings line setouts and bundwall earth works.......... 16

Placing the deep-sea tailings outfall and seawater intake lines into position.......... 19

Conclusion.......... 22

Diagrams

Diagram(1).......... 4

Diagram(2).......... 6

Diagram(3).......... 7

Diagram(4).......... 10

Diagram(5).......... 11

Diagram(6).......... 12

Diagram(7).......... 14

Diagram(8).......... 17

Diagram(9).......... 18

Diagram(10).......... 21

INTRODUCTION

The Misima Mines tailings line reconstruction project was a major construction project undertaken by Placer Pacific's project development team in Sydney Australia to replace the existing tailings disposal system. The old disposal system consisted of a mixing/deaeration tank, which sits on the seashore and two very long poly pipelines, which are connected to it. These two pipelines differ in length and consist of a salt-water intake pipeline (shorter pipe) and tailings discharge pipeline (longer pipe). Both pipelines run of into the ocean on the seabed with the end of the discharge pipeline sitting on the ocean floor at approximately 200m offshore and 1000m below sea level.

Basically the system works as follows; discharged tailings from the mill is pumped through an on shore tailings pipeline to the mix tank on the seashore for final dilution. Simultaneously, saltwater is drawn into the mix tank from the ocean lying saltwater intake pipe, which dilutes the incoming tailings discharge from the mill, before discharging the diluted tailings onto the ocean floor. The discharged tailings from the mill is therefore totally diluted and environmentally safe before it is discharged into the ocean. The tailings disposal system meets very stringent government environmental policies in place and operates within environmental protection guidelines. The system is kept in check by ongoing environmental monitoring carried out by the Misima Mines environmental section on site.

Unfortunately, the above system was partially damaged by naturally occurring causes, and therefore an executive decision was made to replace the entire system. It was discovered that the area around the tailing discharge line and the saltwater intake line, which together form the Misima submarine tailings disposal system, had been subjected to an underwater landslide. Apparently the underwater landslide was in fact a failure of a submarine canyon which ran west of the tailing lines. This formed an underwater cliff from approximately 55metres below sea level. It was at this point that a segment of the tailing outfall line was wrenched apart. The detached section was then dragged down the cliffside to a depth of 1500m along with all the other rubble. The detached segment of the saltwater intakeline had freed itself from its anchoring system amid the underwater turmoil and floated up to the surface. It was on discovery of the detached segment that sparked off the investigations on where, how and why the pipeline came about. The above information was gathered by carrying out underwater surveys utilizing some of the most advanced and sophisticated equipment available in the world today, including a submersible remote-controlled video camera.

The new tailing disposal system was a replica of the first system and would generally operate in the same way as the original system. The only main significant difference would have been the site and location of the new system itself. The reconstruction project of the new system comprised three major areas in which Misima Mines survey section would be fully involved in from day one to completion of the project. The three main areas were seawater mix tank, submarine pipelines and the land-based (onshore) pipeline. Survey involvement in the three main areas was important and vital to the project, as any other major construction project, to ensure the new system was installed according to design requirements, enabling it to operate as planned.

With the technical challenges that come with any major construction project in the mining industry, there has to be technically minded surveyors to take on the job head on, and display the professionalism of the survey profession through the quality work produced. Modern day surveyors today must take the initiative to bring this profession out into the forefront of all the fields we serve in, to establish our importance and integrity. If we continue to take the back seat all the time this profession will never evolve to be future project managers. If project surveyors are also project managers in Israel and other countries known; isn't it time we took the survey profession in P.N.G to greater heights in the coming future, after all we are the new generation.

1. BATHYMETRIC SEABED SURVEY

On discovery and inspection of the displaced segment of the salt-water intake pipeline, it was first thought that the pipeline was left over from construction. This theory was discarded as on closer inspection of the pipeline it was noted that the pipe had "Made in Canada" stamped all over it. It was obvious that it was part of the tailing system, but why it was found floating on the sea surface was an unanswered question that needed answers fast.

What happened was determined by many diving expeditions and bathymetric surveys carried out by specialist consultants over the following weeks. Its was discovered that the area around the tailing lines had been subjected to an underwater landslide. During the underwater landslide, segments of the salt-water intake line and the tailings outfall line, had been severed and wrenched of from the rest of the line. It was discovered that the landslide was a failure of an underwater canyon in the area where the pipelines were situated on the seabed.

The mill was shut down temporarily as the pipelines were inspected and the amount of damaged assessed. Plans for repair and other remedial work required for the damaged line were then formulated and carried out immediately. PDG's project and development teams along with their experience and expertise were called in to assist in formulating long and short-term plans for repair and replacement of the system. After immediate repairs were carried out to the tailings discharge line, the company sought government permission to test run the repaired system under very stringent environment controls and monitoring program. The monitoring program was developed and conducted by NSR Environmental Consultants Pty. Ltd. of Australia, whose expertise in submarine tailing disposal and ocean sampling is world renowned. Tests proved the system could still operate as per design requirements and still meet environmental compliance requirements.

The PNG government then allowed the mine to continue normal operations under a temporary exemption, but required the company to design and install a replacement system by March 1998. The task of designing and installing the duplicate system was assigned to Placer Pacific's project development team in Sydney, Australia.

Misima Mines survey section were then required to carry out a detail topographic survey of the foreshore and surrounding areas where the existing mix tank was and beyond. A set5F and SDR33 data recorder was used for the detail survey as it had the speed needed to obtain the data in the short time it was required. Detail plans of the survey were then sent off to the Sydney office for further evaluation. This data along with the bathymetric survey data would be used to identify possible locations for the new mix tank and possible routes for the new tailings line to be installed. Utilizing the bathymetric survey data would enable design engineers to design proposed routes for the submarine tailing line and salt-water intake line, well away from the failure zone

Design engineers proposed two coordinated possible sites for the mix tank and approximately 11 proposed tailing line routes from the two proposed mix tank sites. These routes were given as horizontal bearings (radiation's) from the two possible mix tank sites. This information was then sent by the Sydney office via cc-mail to Misima Mines survey section to set out on the foreshore. Using a Set4A total station for the job, standard iron pins were used to mark out these two locations and were then surveyed in as per normal survey requirements. The given proposed tailings line routes were to be set out so further hydrographic surveys of the sea floor along the proposed routes could be carried out by using a Remote Operating Vehicle (ROV). This additional data would enable design engineers to select the most suitable route for the new tailings pipeline to be installed. Ideally the best route would have to be free from huge outcrops of reef, steep underwater cliffs, and gorges and well away from the existing failure zone. Surveying the seabed along the proposed routes was due to commence as soon as the contract divers engaged to do the job arrived on site.

2. REMOTE OPERATING VEHICLE (R.O.V) RUNS ON PROPOSED ROUTES

On completion of the bathymetric seabed survey, all the survey data was compiled and looked at by those involved in the survey and the Placer office in Sydney.

From this, contour plans of the seabed surface were produced and proposed tailings line routes were designed from two coordinated reference points. This data was then sent from Placer Pacific's Sydney office to Misima Mines to be set out and surveyed as required.

From existing survey control in the area the two coordinated reference points were established using iron pins as standard survey marks. Both of these reference marks were on the shoreline and would act as control marks to set out proposed tailings line routes to be surveyed underwater by the Remote Operating Vehicle (R.O.V).

With the two reference marks setout and surveyed in, project surveyors were ready to set out the proposed tailings line routes. Initially this survey was done using a SET4A Sokkia total station and a triple prism. With the two reference marks set out, proposed routes were set out from these marks from on-shore. Design bearings of these proposed routes were set out and the surveyor on shore guided a tugboat out at sea on the correct line of direction. With the tugboat on line it continued out to sea on the given bearing and sunk markers on the seabed so as to mark out a path for the R.O.V. Once the proposed routes were set out and marked on the seabed the R.O.V was lowered into the water and guided along the marked out route to survey the seabed to identify the most suitable route for the tailings line. A total of ten proposed routes were set out and surveyed using the R.O.V. From the ten proposed routes four of them were identified as being ideal and required further survey work on them to define long sections along each of the four routes chosen.

Problems faced in the set out were significant, such as continuous movement of the prism being held on board the tugboat, and the time it took for a good fix on the prism before a reading could be taken and recorded using the Set4A total station. On a calm day with calm seas the use of a triple prism was ideal, but this was never the case at most times, therefore a bank of ten prisms was the only option. This unfortunately reduced the accuracy of positioning to within three meters horizontally at the most, bringing the relative accuracy to about 1:100. This however was acceptable to what was required in this survey given the circumstances and requirements involved doing the job.

Good communications skills was required by the surveyor involved as it was his job to be able to guide and keep on line a tugboat out at sea with only a theodolite and two way radio. The minimum distance between the surveyor on shore and the tugboat would have been between 50 to 70 meters at the most. While the maximum distance ever recorded would have been up to approximately 300 meters out to sea, giving the surveyor a working range of up to 50 to 300 meters at the time.

3. MAJOR CONTROL SURVEY FOR ONCOMING CONSTRUCTION

With the oncoming construction and earthworks to take place for the project, a major control survey had to be planned and carried out bearing in mind an accuracy of 1:10,000 or above would be desired. This being the case as construction setout requirements for the project could demand setout accuracy to the nearest 5 to 10 millimeters.

The control survey was planned to be completed within week at the most if need be. The theodolite used was a Sokkia Set 5F total station one-second instrument, which was ideal and good for the job at hand. Single prisms were used for backsights and foresights as the Set 5F has a range of up to 1.5-km utilizing single prisms. Measured distances in between stations did not exceed instrument range limits as per instrument limitations.

A total of three established trig stations in the area were used to tie the control survey in and to check, improve and obtain the required accuracy of 1:10,000 at the most. The datum adopted was a calculated bearing and distance between Parkers and Patgenu trig stations, with a check observation taken to Quartz Mountain trig station.

Instrument station one was Parkers trig station with the backsight being Patgenu trig station. From this datum a total of five other control stations were established as the major control. The closed control survey ran through the proposed construction sight area with at least three of the control stations ideal for any construction surveys required in the near future. Angular observations were done with three arcs per station, while distance observations were observed three times for both left and right face observations. The spread of mean angles of each arc of both left and right faces was kept to a minimum of three seconds per station. Marks used for the new control stations were either star iron pickets in concrete for the more permanent control marks, or iron pins for marks that could be disturbed or destroyed during the construction stages. Control stations were labeled and identified with a standard white wooden survey peg showing 3-D coordinates (E, N, RL), and backsite bearings to various control stations. This enables the surveyor to do quick engineering survey calculations on the spot for the construction and engineering survey setouts to come.

On completion of the fieldwork the reduced traverse was downloaded using Geocomp software for a Bowditch adjustment, misclose and accuracy calculations. Final achieved accuracy was 1:14,000. Adjusted coordinates of each control station were then adopted and would be used for the construction survey setouts.

(See traverse diagram overleaf)

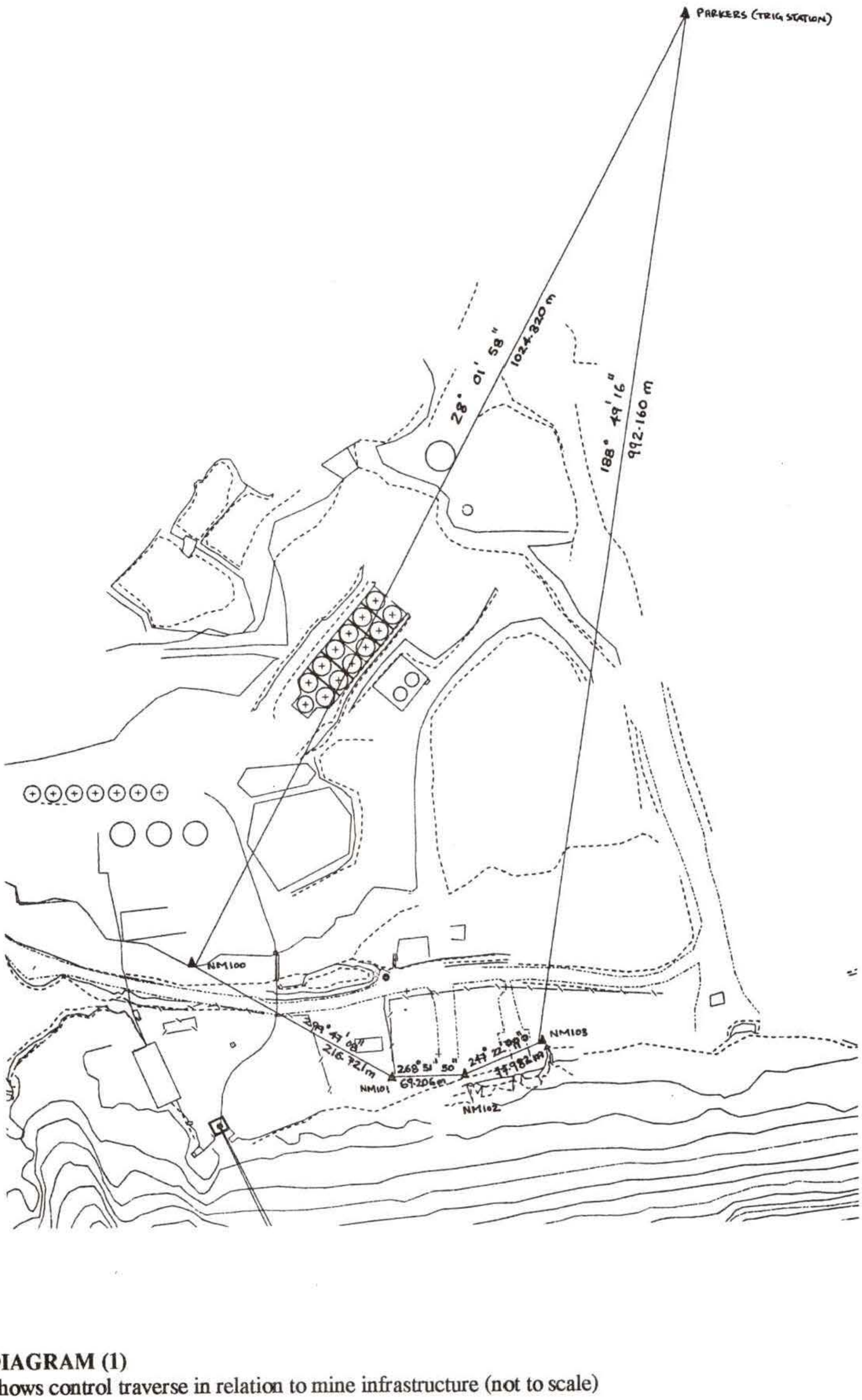

DIAGRAM (1)
Shows control traverse in relation to mine infrastructure (not to scale)

4. ADDITIONAL SEABED PROFILE SURVEYS ON PROPOSED ROUTES

On completion of the R.O.V runs additional detail of what the profile of several of these routes looked like in long-section was required despite the information provided by the R.O.V runs. Misima mines Survey section was then faced with the daunting task of providing reasonably accurate profile surveys of the seabed along the proposed tailings line routes. Discussions on the most appropriate way of tackling this technical problem were held between the surveyor's involved and key personal with the construction team. The construction team comprised Placer Dome Technical Services, Queensland Construction Diving Services Pty, Ltd, Ausenco Pty, Ltd, and Misima Mines surface construction crew. Other local contractors were utilized when required for engineering earthworks.

The agreed method of doing the profiles was to coordinate positions out at sea where depth measurements of the seabed were taken, adopting the surface of the sea as 0.000 RL, with an allowable variation of 0.5m. The depths were to be measured using a weighted 5mm steel cable with 1m graduations marked at every meter and wound around a reel with a locking mechanism. This was then mounted on the side of an aluminum outboard motor powered dinghy. In theory the surveyor on shore would guide the dinghy on line and simultaneously a depth would be measured. This information was relayed the surveyor on shore to by two-way radio to be recorded and simultaneously a bearing and distance was observed to where the depth reading was taken. For a distance to be read and recorded to the dinghy's position, a bank of ten single prisms put together was held by a crew member and faced back towards the surveyor on shore. The major problem faced with this approach was the continuous movement of the dinghy making the it very hard for the surveyor on shore to get a good fix on the moving prism. This in term reduced the positioning accuracy to within two to three meters at the most but was acceptable for what was required. Taking multiple observations, and depth measurements, in any one area at a time compensated this, derived a good mean in observations and depth measurement. Due to the problem of continuous movement of the prism, it often took 2 to 3 minutes per observation. At times more than a hundred observations were done per proposed tails line routes thus making it a whole days job just to do two lines. Above all the job required a lot of patience and persistence by those involved in order for it to get done.

On completion of the fieldwork carried out, detailed long-section profile plans of the seabed were required from the survey field data. The field data was downloaded on computer using Geocomp software to produce the required long-sections of the seabed.

The construction manager and other technical personal then looked at the long-section plans of several proposed routes to decide on the most appropriate route for the tailing line. From the long-sections the project engineer could see where there were large outcrops or steep drop-offs which could present a problem when laying the tails line on the seabed on a particular route. The ideal route would have to have a consistent sloping gradient with no major outcrops of rock or reef formations. This was to avoid the tails-pipe from bending over the allowable bending radius, which could cause the pipe to break.

Once the final tails route was chosen the design engineers then used the longsection profile to design cable lengths for each pontoon that would carry segments of the tails pipe out to sea. This would allow for the correct length of cable needed when lowering various segments of the tails pipe onto the seabed from under each pontoon.

(See diagrams 2 and 3 overleaf)

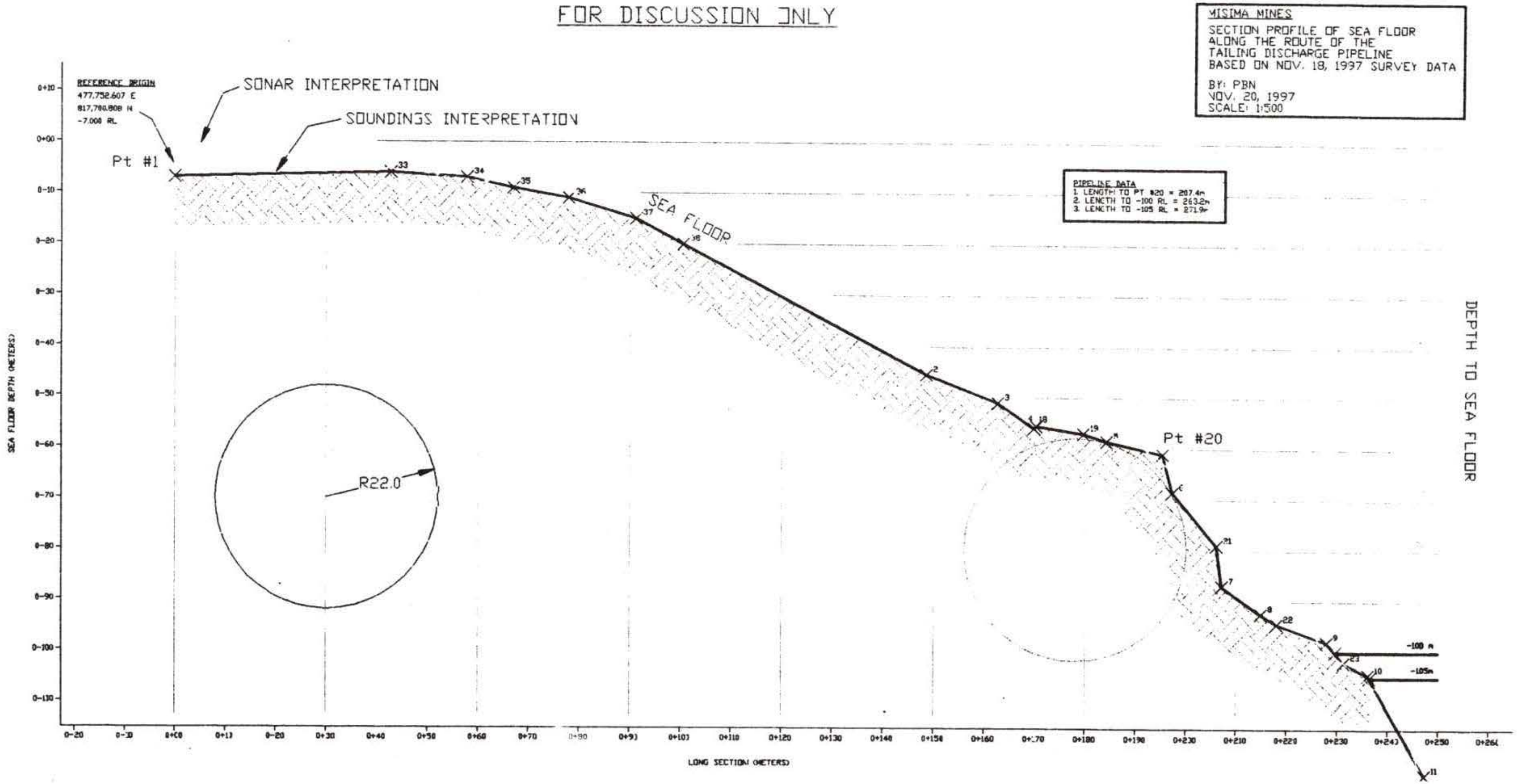

DIAGRAM (2)
Shows profile of seabed along the chosen tails pipeline route, plotted from survey data using Geocomp.

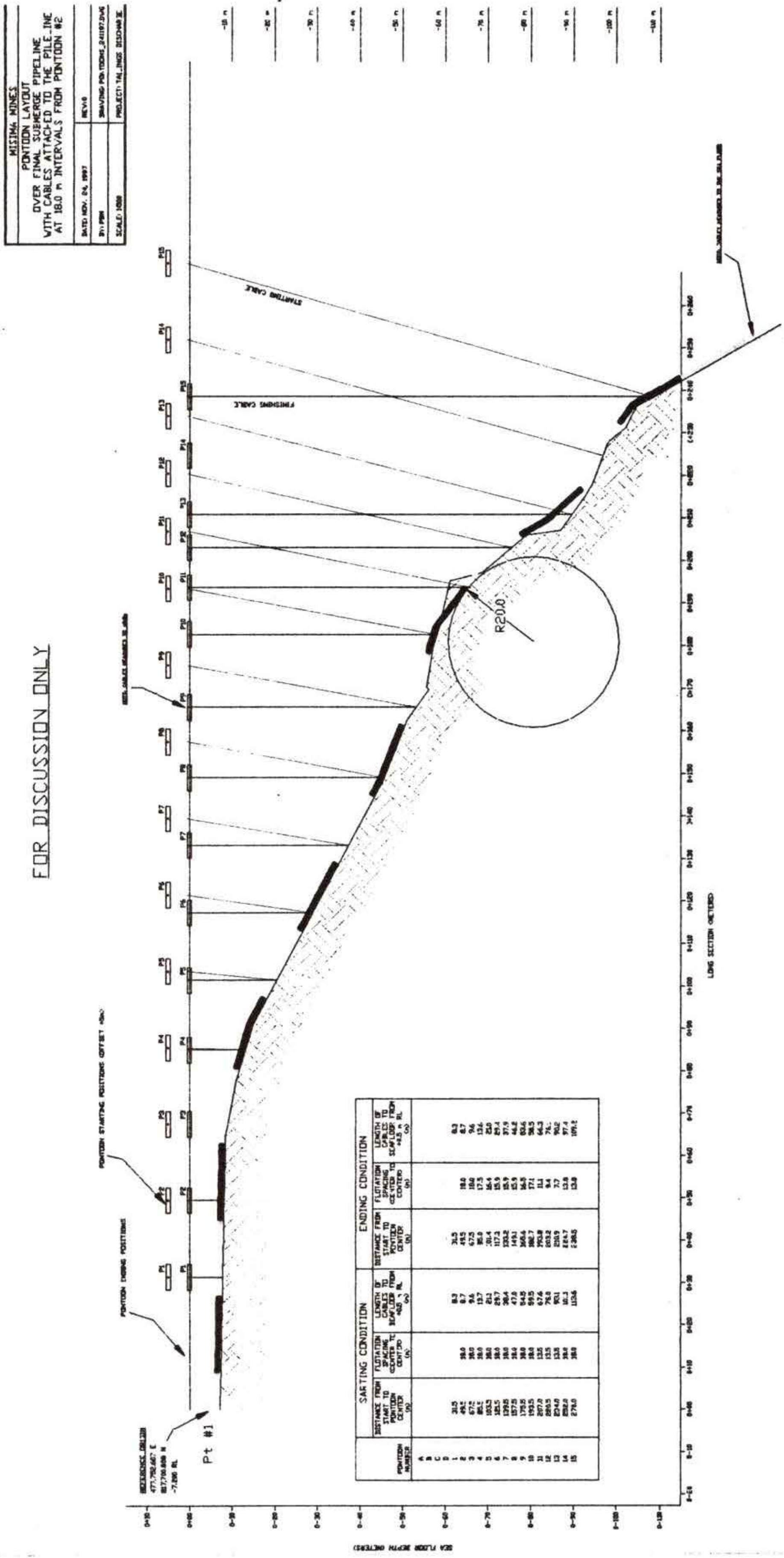

DIAGRAM (3)

Shows seabed profile along the chosen route with pontoon and cable length design for segments along the tails pipeline to be lowered onto the seabed.

5. PIPELINE RAILWAY EARTHWORKS AND CONSTRUCTION

In order for the tails line to be dragged out to sea so it could be lowered down on to the seabed, a slip-way with a railway had to be constructed. The slip way site chosen had to have a cleared area of up to 300m long and would start at the sea shoreline and go inland along a fairly straight line. The railway to be constructed was very similar to the normal train railways used for transport in other countries. In this case the railway tracks were brought in from Australia of which were used as tracks for sugarcane trolleys to transport sugarcane in the cane fields.

The engineering behind all this was to have the tails line all connected up on dry land and on top of the trolleys sitting on the railway ready to roll out to sea.

Surveys involvement in this particular job was as follows. The centerline of the proposed railway route, had to be pegged out so initial clearing for the slipway itself could begin. With the clearing completed, survey was asked to calculate a grade to suit (approximately 1: 40 down) from a given position where the slip way was to slope down to the mean sea level along the shore line. The start point where the railway would start to slope down to the sea on a gentle gradient was approximately 80m to the shore-line.

Using a Sokkia set 4A which was good enough for the job, level shots were taken to where the start of the actual slipway was to start and to the shoreline. A horizontal distance between the two points was calculated using coordinates of the two shots taken. With the difference in reduced level (RL) over the calculated horizontal distance, the grade to suit was then calculated in the field so calculations for cut pegs could be done and pegged out for earthworks to begin.

The design centerline along the actual slipway itself was repegged at 10m intervals with cut pegs placed in along those intervals, but at offsets of, 9m to the left and 5m to the right of the centerline pegs. This gave the total width of the slipway 14m wide, thus ensuring adequate space for other heavy equipment and light vehicles to move around the slipway when construction was completed. The rail-way track itself was only a meter wide, but adequate space was needed to accommodate a 30 ton crane to be seated along side the track come the time when the tails line was to be launched.

Calculated cut depths for each cut peg were written on each peg and different colored flagging tape was used for each different cut depth as per standard engineering earth works cut and fill marking methods. Once all the cut pegs and centerline pegs were in, the dozer operator was then given the go ahead to begin cutting the ramp as per engineering survey setouts. On completion of the earthworks for the slipway, the actual 300m railway still had to be constructed so assembling of the tailings discharge pipeline and the saltwater intake pipeline could begin simultaneously.

The centerline of the of the railway line starting from the shoreline up to about 200m had to be set out again so construction of the railway could get underway as scheduled. This time centerline pegs were placed in at 25m intervals along a straight line. Construction of the railway line started immediately after the railway centerline pegs were setout.

On completing the construction of the 300m railway the next difficult and time-consuming task for the construction crew was to assemble all the trolleys on the railway with the tails pipelines on the trolleys in place. Once the trolleys were in place, the tailings discharge pipeline were then joined together on the trolleys and put in place as per construction requirements.

6. MIX TANK SITE LAYOUT AND OFFSHORE TRENCH CUT EARTHWORKS

The earthworks and construction phase of the mix tank site and the underwater tails pipeline trench was probably the most crucial and time-consuming part of the whole project. The mix tank is a large cylindrical steel tank with a diameter of 5.0m and length of 14.1m, which serves to dilute tailings discharge with saltwater before being discharged into the ocean. This enables the tails discharge to be environmentally safe and acceptable by stringent government environmental policies in place, by which Misima Mines strictly adheres to as required.

Survey involvement in this phase of construction was almost on a daily basis, starting from day one when survey was required to set out the design center position of the mix tank. For most of the engineering survey work to be described and elaborated about, a Sokkia Set4 or Set4A total station was used.

Initially a detail topographic survey of the shoreline and surrounding areas to be affected by construction works was done for compensation purposes and design work. All topographic survey data was recorded and stored using a Sokkia SDR33 data recorder. Using the established survey control near the site, the mix tank center position and trench centerline were set out on the shoreline so the loose sandy material could be blown of using compressed air. Clearing and blowing of the sand would expose the hard rocky reef surface below to enable drilling of the mix tank site and trench cut to proceed. The cleared area was then picked up to establish surface RL'S which were then compared with design depths of the mix tank site and underwater pipe trench. The trench was to be cut so the tails line would lie safely in it when finally connected to the mix tank itself. Given the design depths and gradient of the trench cut and mix tank, drill depths were calculated and set out in the field for drilling to begin immediately (see diagrams 4 and 5). Holes were drilled within the set out mix tank site perimeter and within the set out design toe line of the trench.

On completion of the required drilling, all the drill holes were then charged and blasted to enable earthworks to begin without delay. All the blasted material had to be dug out to establish the required trench at design floor RL'S and mix tank design floor RL. Utilizing an excavator and dragline (crane with bucket attached), the momentous task of digging out the blasted material began. The construction crew involved in the earthworks had to put up with waves and huge swells, which kept depositing material back into the trench. This natural environmental obstacle adversely put the project behind schedule, of which nothing much could really be done about it.

Survey was required to check on the asbuilt floor RL'S on request to see if the required design depth of the mix tank site trench were achieved. These surveys were done similarly to how the profile surveys of the tails line route were carried out. Once again bearings and distances were observed to different positions where construction crewmembers on board a dinghy took depth soundings. Each depth measured was relayed back to the surveyor to be booked against the observed bearing and distance to each particular position. This field information was then taken back to the office to be downloaded using Geocomp and processed. Once the observations were downloaded and reduced, contours of the surveyed sea floor were created at 0.5m contour intervals. Detailed plans showing contours, spot levels and outlines of the mix tank area and trench were created and plotted to compare with design. From the first survey done, it was found that more material had to be dug out from the mix tank area and pipe trench itself. With the ongoing excavation work, two more of these surveys were done to check and confirm if the required floor RL'S were achieved as per design RL'S. It was later found that the mix tank site floor levels were down to design and acceptable, but the trench had to be drilled and blasted again as design depths were not achieved in the first drill, blast and digging phase.

The following diagrams illustrate the mix tank and trench cut design plans in both plan view and section view, and also contour plans produced from the depth sounding surveys.

(See diagrams 4, 5, and 6).

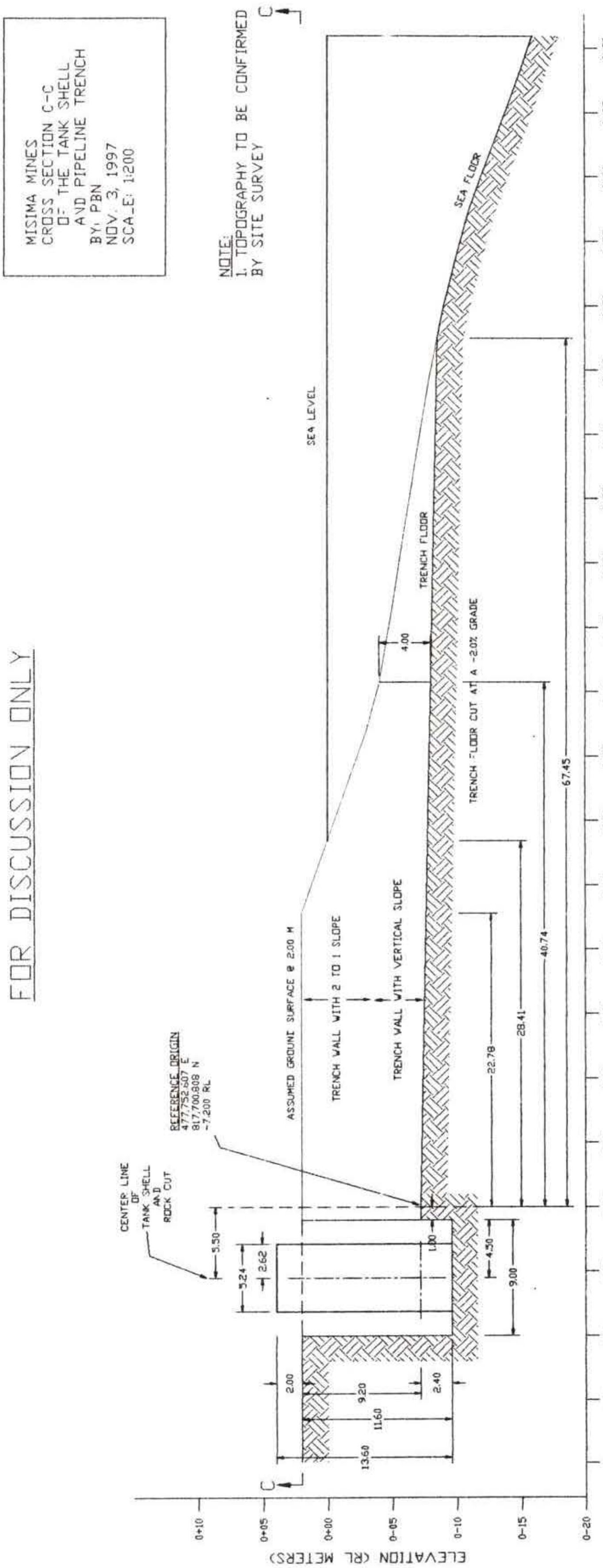

DIAGRAM (4)
Shows design plans of section view of the mix tank and trench cut for the tails outlet and saltwater inlet pipelines.

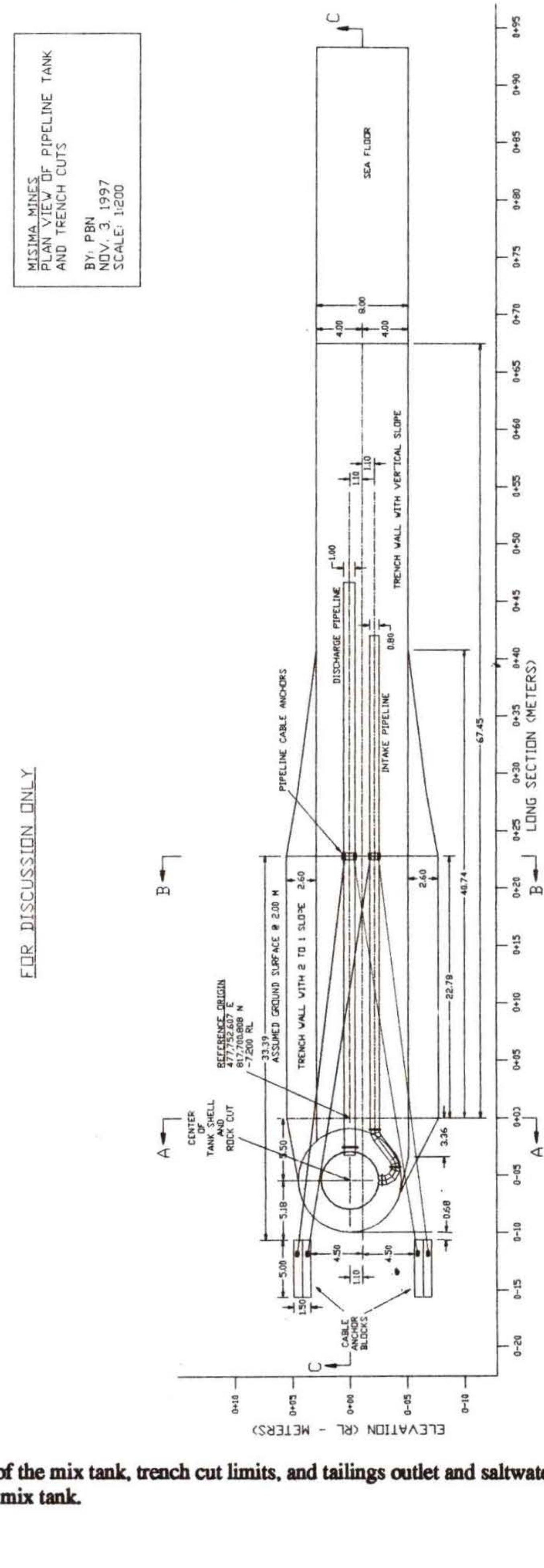

DIAGRAM (5)
Shows design plan view of the mix tank, trench cut limits, and tailings outlet and saltwater inlet pipelines connected up to the mix tank.

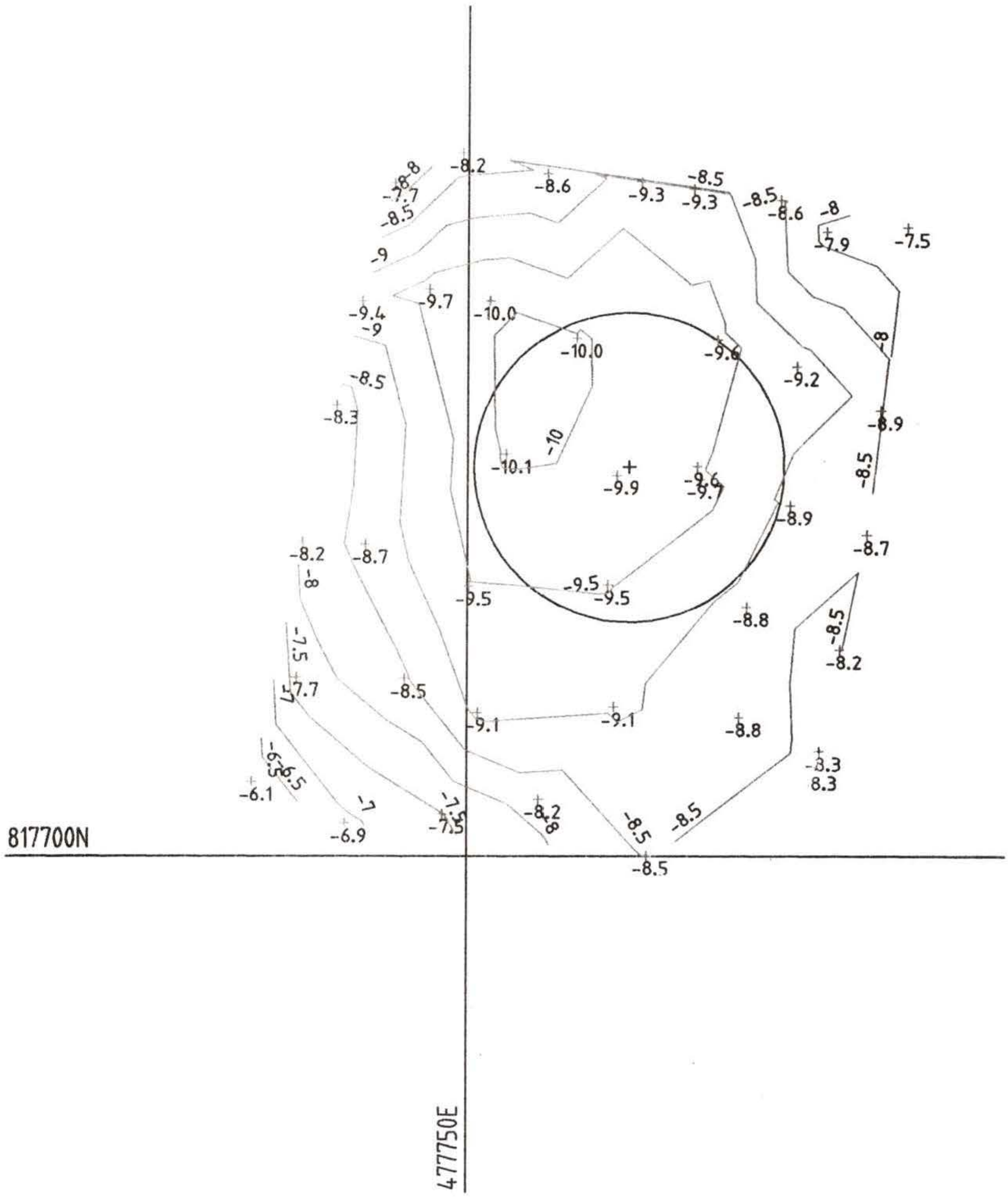

DIAGRAM (6)
Shows contour plan produced from depth sounding survey data of the excavated area where the mix tank would be positioned. Spot levels of the floor are also shown.

With the coming survey task off sinking the mix tank into design position and at the correct RL, it was decided within the survey crew that two additional survey stations (star pickets) were to be set out from the existing survey control stations. The two stations had to be at least 90 degrees apart from each other and perpendicular to the design tank center position, and at a desirable distance away from the design tank center itself. Positioning and surveying in the two additional stations like this would enable survey to have total control in positioning the mix tank into design position when the time came. Survey would be able to control its shift in both east-west and north-south directions, and be able to guide the tank into design position to within 0.050m (50mm) at the most. Controlling the RL of the top of the tank was just as important, as getting the top of the tank leveled in at the designed RL was another challenge for the survey crew involved.

Temp3 and Temp4 were the two additional survey control stations put in, with Temp4 being established at 25.0m from the design tank center and on the centerline brg of the tails line. The most suitable route for the tails line was at 187 degrees and therefore Temp4's position was at 25.0m from the design tank center on a bearing of 7 degrees. This put Temp4 directly behind the tank, and on line with the bearing of the tails line. This obviously enabled survey complete control in positioning the tank when the time came (see diagram 7, which illustrates this).

Excavation of loose materials in the trench and the mix tank area went on for a long while yet before survey could actually sink the tank. Once all the loose material had been dug out another depth sounding survey of the mix tank area and trench was done to confirm if the required design floor had been achieved. From the survey data collected and contour plans drawn it was found that the required floor RL's had been achieved around the mix tank site, but not the trench cut area. Additional drilling in the trench cut area then had to be done, but this time using an underwater air-track drill and diver to operate it fully submerged underwater. On completion of drilling in the trench, all the holes were charged with high explosive and blasted. Without delay an excavator and dragline were then utilized to dig out the blasted material so the required trench floor RL's could be established. Further depth sounding surveys were done in the trench cut area when excavation was complete, and survey results showed that final trench cut floor RL's and slope gradient achieved were acceptable as per design requirements. This was a great relief to all the construction personal involved as this particular phase of the project was both time consuming and frustrating, which put the entire project behind schedule.

With the earthworks for the mix tank site area and the trench cut area completed, sinking the mix tank into position was the next challenging task to be carried out. With the survey control needed to do the job already in place, the survey crew wasted no time in setting up a Total Station on Temp3 and another one on Temp4 (refer to diagram 7). With two instruments set up on both sides of where the tank would finally be positioned, and a surveyor manning each one, the surveyors would have total control in positioning it to designed position and RL. Good communication between the two surveyors, the crane operator and the construction manager was vital to enable the job to run smoothly. Once the surveyors were in place, the go ahead was given to the crane operator to lift up the mix tank and slowly carry it over to the mix tank site. Four thin pencil lines were marked on four sides of the tank so as to give the surveyors two targets each on either side to line up the tank into position. Joining the marks opposite to each other would pass through the tank center forming two diagonal lines. Theoretically If both pencil marks coincided into each of the surveyors set line of site on both sides, it would place the tank center to exact design position. Practically this was achievable, but would require a great deal of patience, time and skill on behalf of the crane operator; who would have to move the tank in a number of directions as directed by the two surveyors. Two other heavy-duty ropes were tied to the sides of the tank and would be used to pull, drag and steady the mix tank into position using manpower. An additional crane with a man basket attached to it was moved into position to lower a rigger on top of the tank when it was in position. The rigger was to hold a single prism reflector (without prism pole) on the top of the tank in line with the four pencil marks, so level shots could be taken for vertical control. The top of the mix tank had to be at an even 4.00 RL on all sides and not slanting or sloping. The tolerable difference in levels allowed was not more than 10mm.

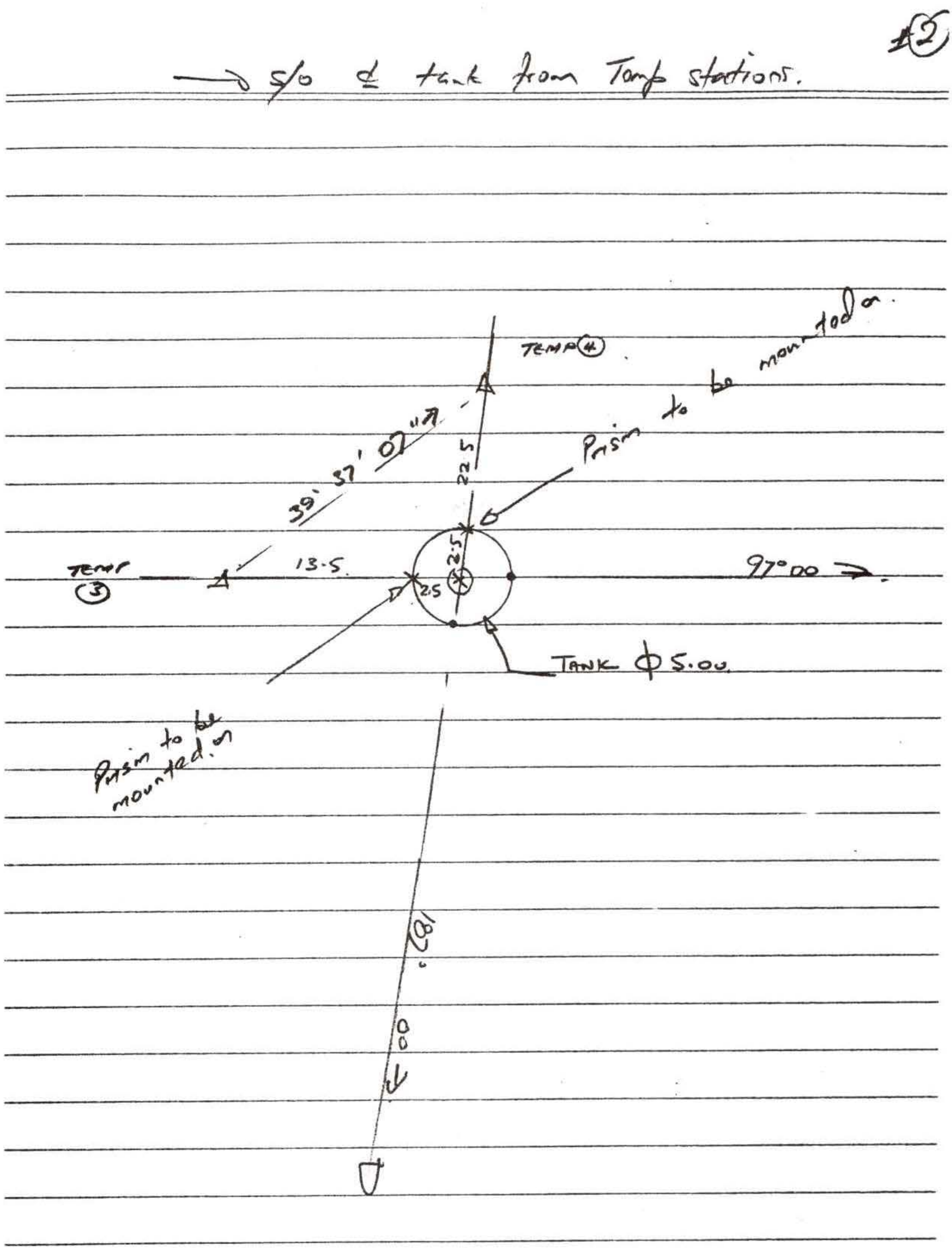

DIAGRAM (7)
Shows field sketch of additional control stations Temp3 and Temp4 in relation to mix tank center.

With all the required heavy equipment and construction personal in place, the task of sinking and positioning of the mix tank began. The mix tank was lifted and carried over to designated location and lowered into position under the simultaneous directions from both surveyors on either sides. The crane operator was then directed to stop the lowering and maintain its position once it was within approximate design position, so we could survey and calculate the tanks current position against its design position. It was found that the tank still needed to be shifted to design position on a bearing of 137°38'40" and distance of 0.705m. This was calculated by, observing a bearing and distance to two of the pencil marks on opposite sides of the tank and then calculating coordinates of the two opposite sides. Using the calculated coordinates of the two points a bearing and distance between these two points was then calculated, the calculated distance was then halved to give the distance to the center from either point. Coordinates of the tanks current center position were then calculated, using the calculated bearing between the two points and the halved distance. These actual tank center coordinates were then compared to design tank center coordinates to give the required shift in bearing and distance required to bring it onto design position.

This information was calculated in the field and relayed to the construction manager and the contract design engineer before continuing. After quick discussions and visible observations of the tanks current position, (by the construction manager and the design engineer) it was decided that the current position would be the final position. Despite the fact that the surveyors were able to continue guiding the tank into design position, the construction manager was more than satisfied with the current position and wanted to start grouting the tank bottom immediately. Level shots were taken to the top of the tank on the four marks to check if the tank was level and on design RL. The asbuilt level of the top of the tank was 3.93RL, 70mm below design RL. This was acceptable and would have minimal or no effect at all on the pipelines to be connected to mix tank.

With the tank still suspended from the crane in position, grouting the base of the tank with concrete began immediately. Utilising another crane with a cement bucket attached to it, a rigger would hang on to the bucket and guide it over to the top of the tank where another rigger would be positioned. Both riggers would then pour the concrete down an 800mm diameter steel tube, which was submerged in the water down to the sea floor and the base of the mix tank. This continued over a period of days until the base of the tank was totally cemented and stabilized to the sea floor, and only then did the crane detach itself from the tank. While this was happening, survey was required to check levels on the top of the tank to check if it was level and had not sloped to one side. From levels observed, the top of the tank was found to be on level and maintained an average RL of 3.93m with a spread of 3mm difference in level observations taken.

Due to the mix tanks asbuilt center being off design by an average of 0.500m in eastings and northings, the design position of the left onshore anchor block had to be shifted. This adjustment was done in the field after the design engineer consulted the project surveyor on site. Pegs marking the corners of the anchor block were then shifted by 0.700m to the east to cater for the tank centre position. Other minor design changes were also done according to the mix tanks new position.

For this particular phase of the project, the main difficulties faced would have been the weather and equipment availability to do the job. Large swells caused by the cyclone weather at the time made it very difficult in excavation of loose material in the trench and mix tank site areas. Not having the right kind of heavy equipment available at times for the job also caused further delays, but by sheer determination and cooperation by everyone involved, the mix tank was finally put into position.

After a few days, project surveyors involved were required to align and position six offshore anchor blocks before they were lowered onto the seabed. These anchor blocks would provide further anchorage and stability to the tailings discharge and salt-water intake pipelines to be lowered onto the seabed. Using a Set 4A total station set up in the centre position on top of the mix tank, one surveyor would be the instrument man whilst other would use a two-way radio to relay information to the tugboat captain to position the anchor blocks before lowering onto the seabed. Each anchor block was attached underneath a pontoon and towed out to sea individually by a tugboat. Once out at sea the surveyors on shore would then start issuing instructions to the tugboat captain in order to bring the pontoon on to the required position. A bank of ten prisms was held by a crewmember on board the pontoon to enable bearing and distance measurements to each pontoon so as to confirm positions before lowering. Despite the difficulties involved all anchors were lowered in position within 3 to 4 meters of design position, which was acceptable as per job requirements.

7. ONSHORE TAILINGS LINE SETOUTS AND BUNDWALL EARTHWORKS

Even prior to the mix tank being put into position, preliminary engineering surveys (setouts) were being carried out for the land based tailing pipeline and safety bundwalls. Designs for the land-based pipeline were given to the project surveyors involved for setting out purposes. The original designs were sent from the Sydney office as AutoCAD dxf files and were then converted to Geocomp files for interpretation and setting out purposes. (See diagram 8 overleaf)

The centerline route of the on-shore pipeline was initially set out for clearing purposes and establishing where it was in relation to features in the area. Once the initial clearing was done, the centerline was repegged and levels were taken at each wooden peg used to mark out the centerline. The actual surface RL'S were then compared with design RL'S to calculate cut and fill depths for the required earthworks. The design needed to achieve a design slope gradient of -2% (1 in 50 down) for the pipeline base surface. Offset pegs to establish the pipeline centerline were put in instead, as actual centerline pegs would inevitably be destroyed by heavy machinery. This saved the survey crew a lot of extra work in establishing the centerline pegs every time they got dozed down or damaged by ongoing earthworks. (See diagram 9 overleaf)

A Set4A Sokkia total station was used for all the engineering earthworks setouts, along with a single prism and pole. Set out plans and radiation's for the jobs were done in the office at most times, prior to the fieldwork, using Geocomp software. Established survey control in the area were used for all the engineering surveys required for the pipeline route and safety bundwalls.

On completion of the earthworks, a survey pickup was done to check asbuilt against design. This then allowed the construction crew to begin installing the land-based tailing line, which connected from the existing one, and followed the new route down to the new mix tank. The onshore tailing pipeline was made up of 750mm diameter poly pipes.

Safety catchment bundwalls were constructed to contain any spillage's in the event that the pipeline ruptured or broke under extreme external force. Constructing the bundwalls to design was important, as the mine would be held responsible for any leaks or spills that might happen. By constructing the bundwalls it shows that Misima Mines continues to adhere to the stringent government environmental policies in place as per company to government obligations.

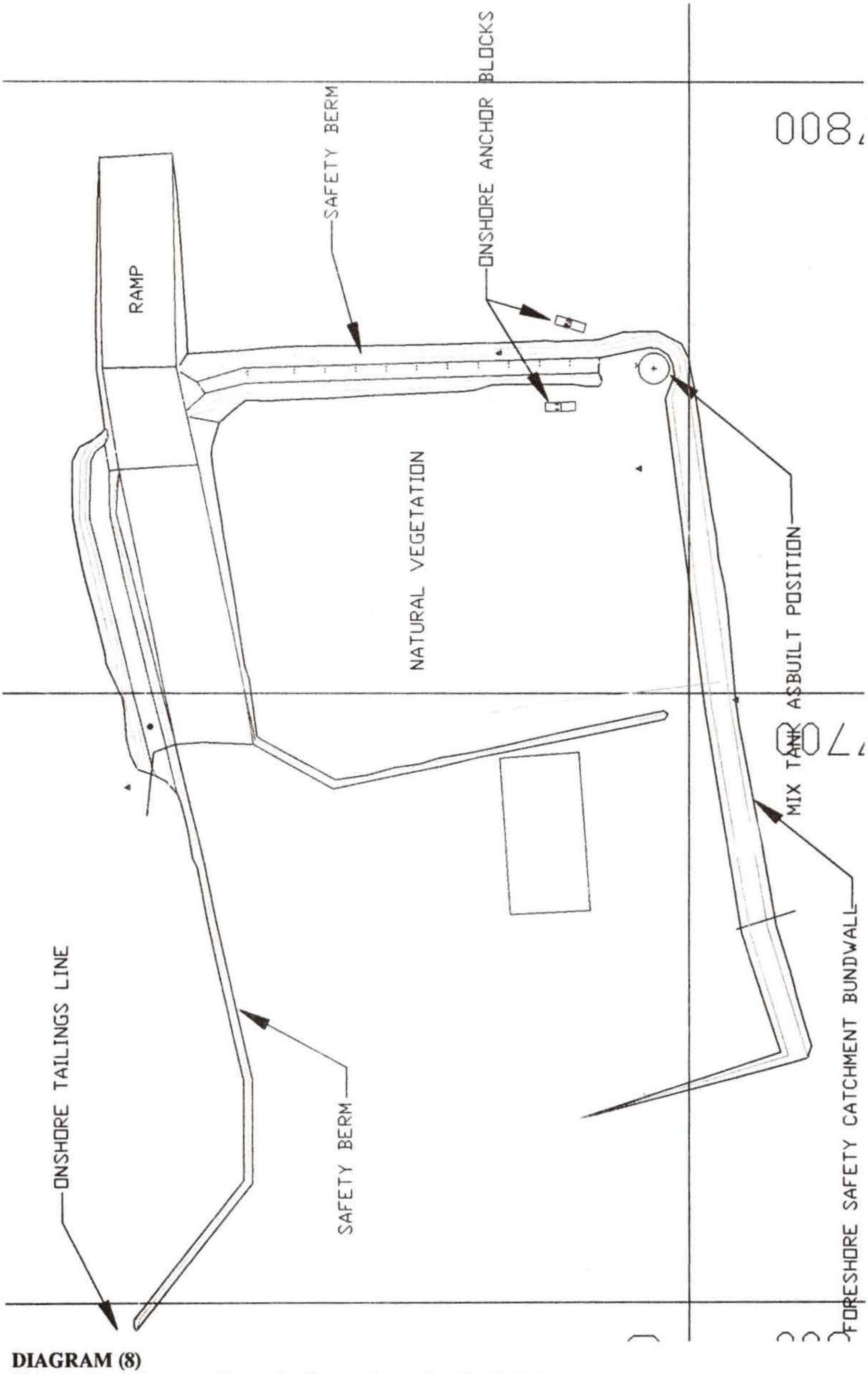

DIAGRAM (8)
Shows tailings line centerline and safety catchment bundwall design.

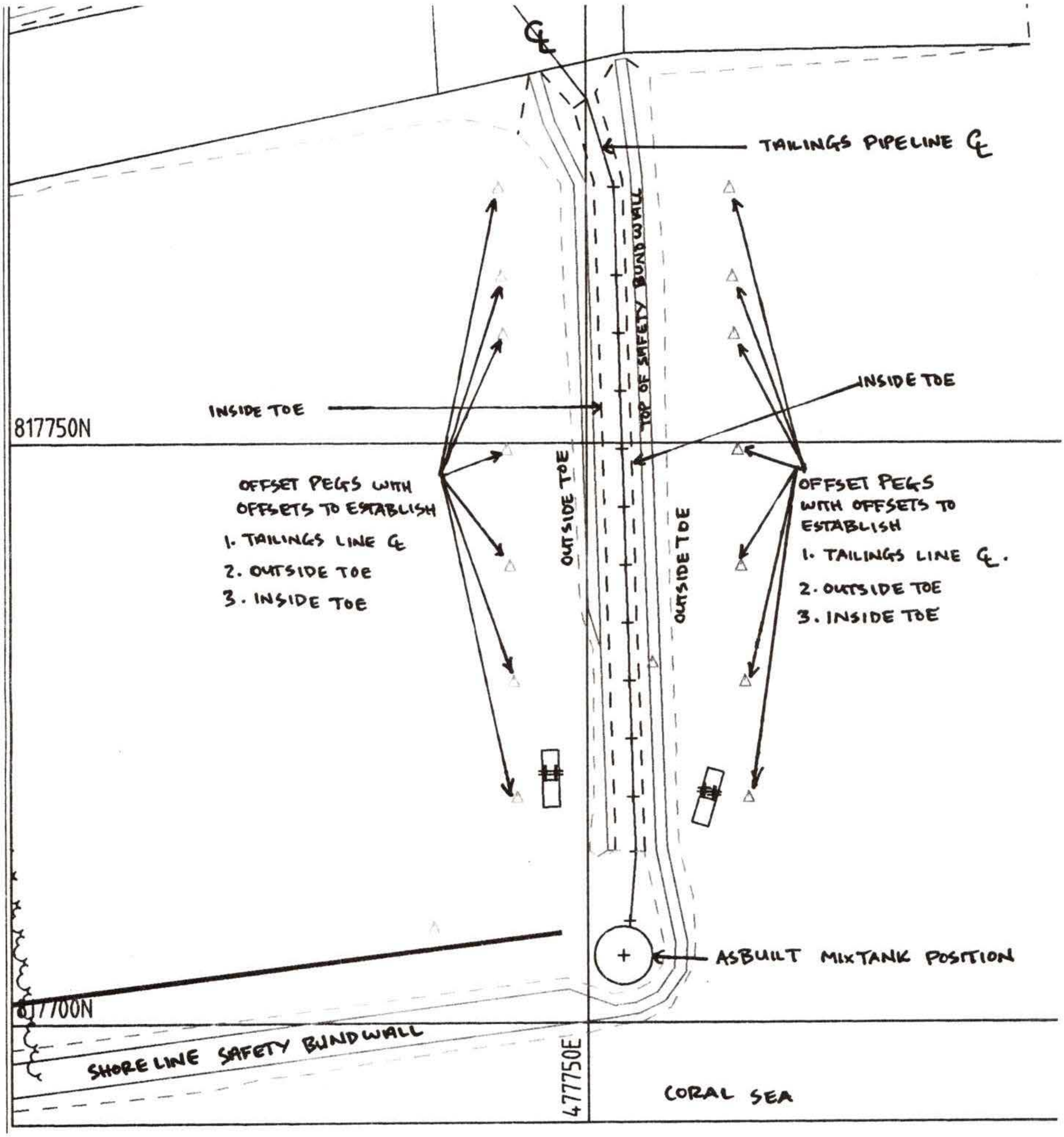

DIAGRAM (9)
Shows survey plan of offset pegs placed in to enable the construction crew to relocate the tailings pipeline centerline on completion of the required earthworks for the pipeline base.

8. PLACING THE TAILINGS OUTFALL AND SEAWATER INTAKE LINES IN POSITION

The most challenging phase of the project would have been this phase, where the two pipelines were to be laid along the steeply sloping ocean floor. This would make the project 95% complete with the other 5% to complete, being the remaining safety catchment bundwalls along the seashore.

A prerequisite to this phase of the project, were very calm seas, to enable the pipelines to be sunk into position without too much movement by the pontoons carrying the pipelines underneath. Of the two pipelines the first pipeline to be placed into position on the ocean floor, was the tailings outfall pipe. Following that the inlet pipe would then be put into position. This part of the project involved a significantly large number of Misima Mines personal and local villagers, apart from the contractors engaged to do the job. Good communications between the project surveyor and all other personal involved was vital to the success of this phase of the project. Ten or more motorised dinghies owned by villagers were hired along with the owners to be on hand to help with this phase of the project. Placing the first pipeline into position was anticipated to take up to a whole day's work, starting as early as 6:00 am in the morning.

The pontoons to be used to float the pipelines out to sea before lowering them were constructed out of steel cylindrical drums welded together. Each drum had an approximate diameter of 0.800m and a length of approximately 5.00m, of which four of these were welded side by side with a platform on top. A generator driven cable winch sat bolted down on the platform, whereby the cable was then hooked up to the pipeline floating underneath the platform. At the centre of each pontoon an iron rod with a spearhead shaped plaque with a number was bolted into position. The number shown on the spearhead shaped plaque identified the pontoon and the tip of the plaque itself would act as a target for lining up the pontoons. There were a total of 15 pontoons and each pontoon had the correct calculated length of cable per winch on board, to lower a particular segment of the pipeline down onto the seabed. (Refer back to diagram 3)

The project surveyor's role in this phase of the project was to guide all these pontoons into design alignment before the pipeline could be lowered into position on the seabed. As early as 6:00am that morning the project surveyor involved had set up the instrument in the centre on top of the mix tank. Meanwhile over where the track and pipelines were situated a great deal of activity was going on in getting various segments of the pipeline hooked up under the correct pontoons, before being lowered into the sea. Utilising two cranes, of which each one of the cranes would pick up a pontoon and lower it onto the corresponding segment of the pipeline, to be hooked up underneath it, and then slowly lowered into the sea. The first pontoon lowered into the sea was obviously hooked up to a waiting tug boat which would eventually drag the whole lot of pontoons out to sea once they were all lowered into the water. This phase took up most of the morning to complete as there were a total of fifteen pontoons to hook up to approximately 280m of pipeline. Once all the pontoons were in the water, they were then dragged out to sea and over to where the mix tank was; to be aligned and positioned before the pipeline was actually lowered onto the seabed.

The first pontoon hooked up to the tugboat had the discharge outlet end of the pipeline, whilst the last pontoon lowered into the water had the flange end to be connected to the mix tank. The flange end was then towed in towards the mix tank and simultaneously lined up by the surveyor set up on top of the mix tank. The surveyor on top of the mix tank was able to tell which pontoon was drifting offline and thus issue instructions to motorised dinghies on hand to pull or tug the individual pontoons on line. Before the actual pipeline could be lowered, the flange end was bolted to the mix tank by underwater construction divers and then hooked up to the onshore anchor blocks. Once this was complete and the rest of the pontoons were brought into line, the go ahead to sink the pipeline was given. Pontoon No.1 was the first pontoon to begin lowering its segment of the pipeline (flanged end) then pontoon No.2 followed consecutively and so forth. This enabled the whole pipeline to be lowered into position without putting too much strain onto different segments of the pipeline during the lowering process. All up the whole episode took one approximately 10 hours to complete.

This whole process was going to be repeated in a couple of day's time, but this time it was anticipated to be less time consuming than the first time. The whole process would be repeated for the positioning of the salt-water inlet pipeline, which formed part of the tailings disposal system. The salt-water inlet pipeline is shorter in length and would not require as many pontoons to float it out to sea, as was the case with the tailings discharge pipeline. Two days after the discharge pipeline was lowered into position, it was time to lower the salt-water inlet pipeline into position. This time an offset position of ssecond pipeline. The surveyor was to set up on the offset position to give line and position the pontoons, and still maintain the same bearing of 187°00'00" for alignment. In theory this would position the salt-water pipeline parallel to the outlet discharge pipeline when lowered onto the seabed. With the project surveyor set up on top of the tank, the whole process started again for the second time round. As anticipated this phase took less time and was a success just like the first time.

During this phase of the project everyone involved displayed a great deal of patience, professionalism and commitment to ensure success, despite the problems and difficulties faced in this phase of the project.

On completion of this phase of the project in order to ensure 100% completion, the construction of the seashore safety bund wall and backfilling around the mix tank had to be completed. Once again the project surveyor involved was asked to set out the inside toe limits for earthworks to begin and to do check levels on the height of the of the bund walls. A Sokkia Set 4A total station was used for the setouts and an automatic level and staff to do levelchecks on the bund walls.

On completion of all onshore earthworks, a topographic survey of the whole area was carried out so a plan showing earthworks, the whole tailings disposal system, and surrounding infrastructure could be drawn. This plan was to be made available to the government department of Mines and Petroleum and Placer Pacific's Sydney office. (See diagram 10 overleaf)

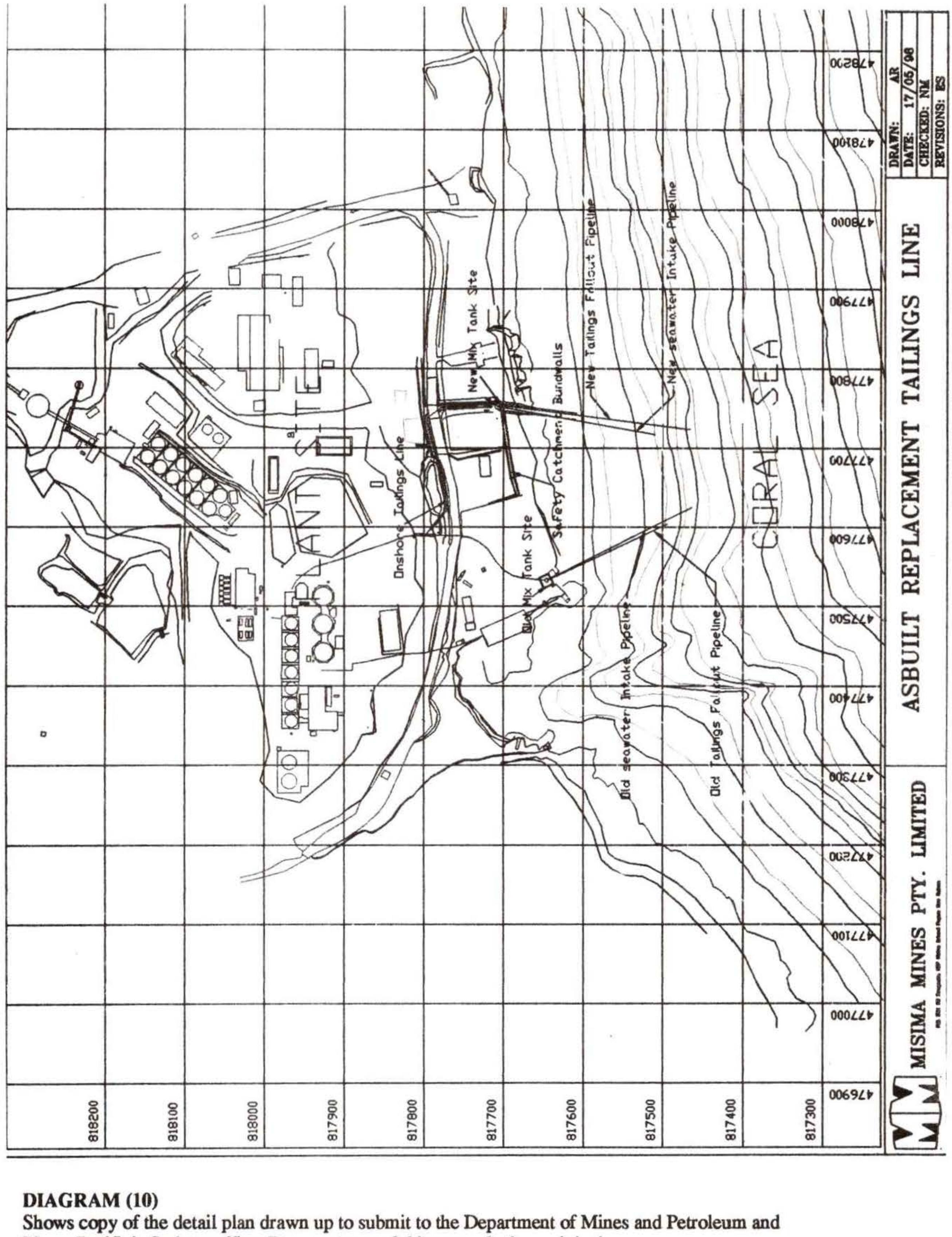

DIAGRAM (10)
Shows copy of the detail plan drawn up to submit to the Department of Mines and Petroleum and Placer Pacific's Sydney office. Drawn at a much bigger scale than original.

CONCLUSION

In conclusion to the whole project, one can see that this was unique and definitely had its challenges and fair share of problems, as any other construction project that could be undertaken and completed successfully. From the survey point of view, it was a demanding project for the Misima Mines survey crew, as a surveyor was required on a daily basis for all the engineering surveys involved with the project from day one to project completion. Despite the constant workload and demand for survey in the pit on a day to day basis, the Misima Mines survey section was always there for the construction crew when required. Once again the surveying profession has proved itself to be an important part of the team in any construction project whether it be big or small.

I as a national surveyor engaged on the job from the start to the finish is proud to be one of the three national surveyors to have worked on this project and have shown and proven our professionalism of the survey profession in Papua New Guinea. Finally, although it has been challenging at times it has also been a learning experience for myself.