University of Southern Queensland

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Impact of tailings subsidence on rehabilitated landform erosional stability

A dissertation submitted by

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Abstract

As a mine gets closer to the end of its productive life, rehabilitation of the site for its release back into the surrounding environment involves disposal of toxic, saturated fine grained tailings derive from ore processing. Tailings disposal back into the excavated pit and capping the site with a landform to isolate them from the environment is an accepted method of mine rehabilitation. The predicted long term stability of the landform due to the influence of tailings compression is a key factor to be considered in the design of the landform. The project investigates the settlement that had occurred at a mine site that was rehabilitated using this method of rehabilitation. The total settlement of the landform is quantified by comparing historical surface information to the existing surface level as determined by conducting a topographic survey. Current griding and mapping technology were also used to assist in the quantifying process. Using historic mine, landform design and construction information a consolidation model is presented base on Terzaghis one dimesional consolidation theory. This model is then calibrated to the landforms maximum recorded settlement. The findings presented provide a basis for further development towards designing capped tailings landforms with long term stability

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Certification

I certify that the ideas, designs and experimental work, results, analyses and conclusions set out in this dissertation are entirely of my own effort, except where otherwise indicated and acknowledged.

I further crtify that the work is original and has not previously been submitted for assessment in any other course or institution, except where specifically stated

Richard John Houghton

Student Number: 0019821368

Signature

Date

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Chapter 1 – Introduction

1.1 Project Description

This research project forms part of a larger project being established at the Environmental Research Institute of the Supervising Scientist (ERISS). The waste bi-products produced as a concequence of mining and ore milling operations are required to be disposed of with minimal risk of polutent release to the surrounding environment (mine rehabilitation). Mine tailings derived from the processing of extracted ore and unprocessed rock (low grade ore or overburden rock) constitute the bulk of wastes to be managed at mine closure. The land effected by the mining operation needs to be rehabilitated for its return back the environment in which these contaminanted materials are forever isolated.

One method of contained disposal at Pit excavation sites is to dispose of the tailings material within the excavation. Further, constructing a landform above the pit (and contents) to provide a cap, effectively isolating the wastes from adversely affecting the immediate and surrounding environment is employed.

These tailings material are generally saturated and highly compressive. The consolidation of the tailings material due to the load pressures generated by the above landform cause surface sudsidence. This subsidence may cause breaching of the the cap and release of contaminants to the environment. The long term stability of the landform and cap is of primary concern with regard to mine rehabilitation.

This project (part of the overall project) investigates the settlement that has occurred at a rehabilitated former mine site (of similar characteristics to that described above) to aquire the knowelge to better predict the settlement magnitudes that are likely to occur at similar type sites to which rehabilitation is yet to be implemented.

At the completion of mining at the Ranger Uranium mine (for details refer to Backgroun following) Pits 1 and 3 will be capped with waste rock and laterite and surcharged to accommodate tailings consolidation. As the landform matures, slope angles and elevations may change as a result of consolidation. Currently landform evolution modelling simulates change in elevation and slope resulting from erosion and deposition only. Information is available to estimate consolidation rate i.e. (i) results of tailings consolidation studies at Ranger, and (ii) through measurement of consolidation and settlement that has occurred at the rehabilitated Dyson's pit at Rum Jungle. Once consolidation rate is estimated the rates of elevation change will be incorporated in landform evolution model simulations of the Ranger landform focusing on development in the first 20 *years* after construction.These results will be compared to simulations which do not incorporate tailings consolidation to assess if there is an increased erosion risk from cap settlement.

1.2 Aims

To estimate the likely extent of post-rehabilitation waste rock dump settlement as a result of tailings consolidation/subsidence for use in simulating the effects of settlement on long term erosion using landform evolution modelling.

1.3 Specific Objectives

This project part seaks to compare the predicted consolidation settlement to the measured actual long term subsidence of the rehabilitated, Dysons Open Cut at Rum Jungle Mining Lease. If the predicted and actual subsidence rates do not agree, an investigation into modifying the prediction model parameters and apply for an agreement with actual measured subsidence will be performed.

1.4 Background

1.4.1 Rum Jungle Mine

The Rum Jungle Mine is a former Uranium, Copper, Manganese, Lead and Zinc mining lease that was operational between 1952 & 1971. It is located 85 km South of Darwin in the headwaters of the East Branch of the Finniss River (Appendix B). The site was left in a heavily contaminated state causing significant environmental damage downstream in the catchment. A degree of rehabilitation of the site was completed over a period between 1982 and 1986 (Allen & Verhoeven, 1986).

Of particular interest at the site, is the Dysons Open Cut to which rehabilitation was completed in late 1984. The Cut was used as the receptor of untreated tailings prior to rehabilitation. As part of the rehabilitation of Dysons Open Cut it was further filled with the tailings and contaminated subsoil from the leases heavily polluted old tailings dam. On top of the tailings waste, a low grade copper ore and its associated contaminated subsurface soils, from a failed experimental leach pad trial were placed to form the bulk of the above ground landform. The Dysons fill was then capped, above which a series of drainage and plant growth mediums were laid. The landform was shaped with a gentle slope, continuous longitudinal grade and a transverse concave grade that converged to a central diversion channel consisting of a rock mat stabilised by wire mesh (Pidsley, 2002). Appendix B contains various diagrams and images of Dysons open cut. The containment of contaminated materials, collection, and shedding of excess water with minimal surface erosion, pooling of water and infiltration were the main functional criteria to be met in rehabilitating Dysons open cut pit. Settlement of the surface was recorded to have occurred as early as 1986 (Allen & Verhoven, 1986). Further investigations in 1988 (Kraatz & Applegate, 1992) reported considerable site settlement including a large area along the channel approximately 20m in length subsiding to the degree that pooling of water during the monsoonal season was occurring. later monitoring and investigation reports on the site identified revegetation of Dysons' landform as an increasing problem due to insufficient depth of plant growth medium and the raising of acid mine water by capillary action from the oxidisation of the underlying copper ore and associated contaminated soils (Pidsley, 2002). Increased slopes developed through surface subsidence, combined with this loss of vegetative cover is likely to be contributing to the significant surface scour that was noticed during a visual site survey, post monsoonal season 2008 (Appendix B). Further exposure of the copper ore material for oxidisation and transport of resulting acid material during future heavy monsoonal rains may cause further increased pollution to the downstream Finniss catchment.

1.4.2 Ranger Uranium Mine

The Ranger Uranium mine is an operational Uranium ore, open cut mining lease surrounded by Kakadu National Park World Heritage area in the Northern Territory, approximately 230 kilometres east of Darwin (Appendix B). The mine has been in operation since the early 1980's. The mine site consists of two open cut pits, ore body N^{o}'s 1 and 3. Extraction from Pit N^{o} 1 has ceased and is now receiving the tailings from the current open cut pit N^{o} 3 (the numbering of pits is associated with the ore deposit

N^{o}'s). When mineral extraction ceases from pit 3, the tailings housed in the tailings dam will be deposited into pit 3. The broad rehabilitation proposal method involves capping these contaminated tailing wastes essentially sealing them from the environment for up to 10,000 years by preventing leaching, infiltration and subsequent water table rising. Waste rock is then used to shape the bulked landform which is then overlayed with a sequence of drainage, stabilising and vegetation supporting material zones. The final shaped landform is to maintain plant growth and minimise the erosion impacts on the downstream catchement ecosystem. Subsidence of the shaped landform may increase the likelihood of adverse erosion and deposition affects on the surrounding, sensitive ecosystem by way of a combination of surface erosion, vegetation dieback and down catchement deposition.

1.5 Literature Review

There are two main processes by which soil settlement occurs, primary compression and secondary compression (Mitchell, 1993 & Smith, 1990), Primary compression is generally the first process by which soil volume decrease results. It is due to the excess pore water pressure build up from stress loads applied at the surface of the soil. Consolidation continues to occure until the excess pore pressure is balance with the applied surface pressure. Consolidation duration is a function of how fast this excess pressure can dissipate which is primarily a function of the soils permeability. Therefore, saturated, low permeable soils (such as tailings) may undergo extended durations of consolidation and therefore settlement (Mitchell, 1993 & Wels 2000). Secondary compression involves involves the volume change of the soils due to changes in the skeletal structure or creep (Mitchell, 1993).

Prediction of soil settlement due to consolidation was pioneered by Terzaghi with his simple theory of soft soil consolidation (Mitchell, 1993 & Smith, 1990). The assumption that make up the theory are that the soil is saturated, the void ratio and effective stress relationship is linear and soil properties are assumed to not change throughout the consolidation process (Mitchell, 1993). Lekha (2007) proposed a theory based on Terzarghis but incorporating variable permeability and compressibility with results that compaired well with laboratory testing.

The project involved aquiring historical information pertaining to the character, quantified measures and historical accounts of events for the site of Dysons Open Cut.

The bulk of this information was obtained from two key documents (McNamara, 1984 and Alan & Verhoven 1986). Other documents reviewed are referenced throughout the report.

1.6 Methodology

By sourcing and reviewing the historical reports and documents relating to the rehabilitation of Rum Jungle Mine, a better understanding of the factors that have influenced and contributed to the current settlement of Dysons landform was gained. Measured quantities were extracted from this information for developing parameters required for modelling the predicted settlement of the landform from construction completion, to present day. Due to the lack of geotechnical data some key model parameters were derived from those documented for mine sites of similar type and character. A comprehensive topgraphic survey was undertaken of the current surface at the Dysons rehabilitated landform. This information was compaired to the as constructed surface information provided within a contour map of the landform. Current gridding and mapping software technology was used to produce surface models to quantify the total settlement over the full surface area. The settlement prediction model was then calibrated by value manipulation of the coefficient of volume decrease until the predicted settlement value equalled that of the observed maximum settlement.

Chapter 2 - Understanding the settlement problem

2.1 Introduction

This section was aimed at gaining a better understanding of the factors influencing the settlement of the Dysons rehabilitation landform to assist modelling the landform settlement due to the compression of underlying tailings. In the foregoing sections the geology of the site, historical characteristic accounts, the design of the landform, events encountered during the landforms construction, and geotechnical characteristics of the tailings material below the landform were investigated for consideration with regard to modeling the current landform settlement.

2.2 Geology and Historical pre-rehabilitation account of Dysons Open Cut

Dyson's open cut was used as a tailings repository on cessation of ore extraction in 1958. These un-neutralised, processed, uranium ore, tailings of unknown specific characteristics were discharged into the Open Cut between the years of 1961 and 1965 (Allen & Verhoeven, 1986). The tailings were deposited into the pit via slurry pumping and on ceasation of pumping the Cut was at its maximum holding capacity (Report of The Working Group, 1978). The discharge point was located at the South Western end of the cut and resulted in a beached sand zone forming around the discharge point. The saturated finer material and waste water occupyied the remainder of the area (Report of The Working Group, 1978). Therfore, it was assumed that these saturated finer materials, sludge and slimes settled and accumulated further north into the deeper sections of the cut coinciding with the location of the extracted, main ore body (Refer Figure 2.5). In more recent years (closer to the time of rehabilitation) the tailings level within the Cut was several meters below the cuts confines (Mining & Process Engineering Servoces, 1982). Therefore, these impounded tailings material had undergone an unquantified settlement due to consolidation under self weight loading. Imediately prior to rehabilitation work the open cut was estimated to contain approximately 20*m* in depth of saturated tailings (Department of mines and energy, 1984). Further Dysons Open Cut statistics of interst were as follows:

- Maximum cut depth: 45.7 *m*
- original volume: 0.92 x 10^6 m^3
- Weight of rock extracted (including ore and overburden): 2.5 x 10^9 *kg*
- Unfilled volume: 0.7 x 10^6 m^3

Note: Volume estimates are accurate to +/-. 20 %

(Rum Jungle Rehabilitation Project, 1981)

Refering to the geology map of the Dysons site in Figure 2.5 a system of faults are identified. For the this project, the fault system was assumed not to be a contributing factor to the current landform settlement at the Dysons site and was ignored.

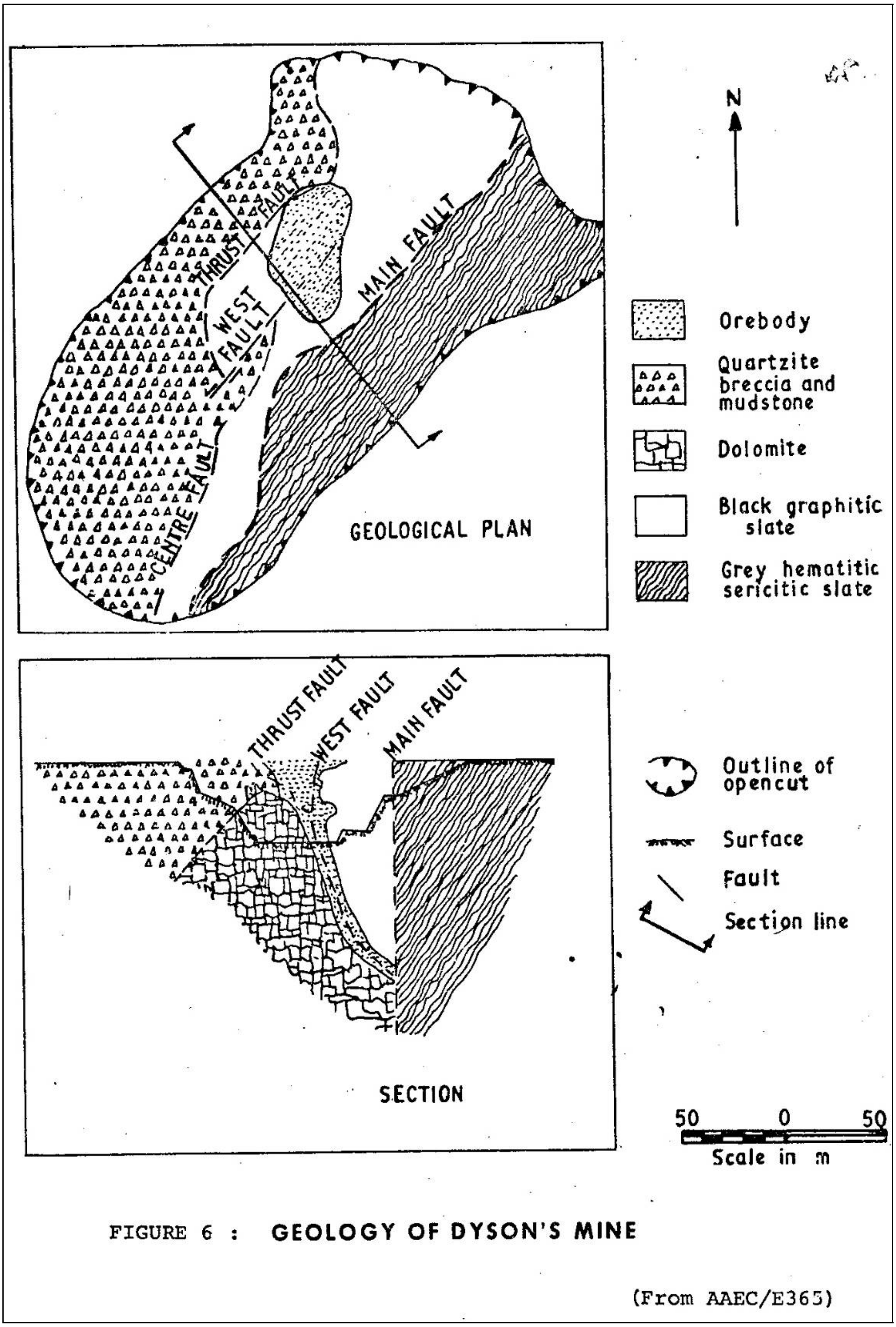


Figure 2.5 Dyson's Open Cut Geology Map taken from Report of the working group (1978)

2.3 Design and construction Details of Dyson's Rehabilitation Landform

2.3.1 Landform design details

The design of Dysons landform and the associated design criterion were crucial factors to be considered and understood in assessing the processes responsible for the current settlement of the rehabilitation landform at Dysons Open Cut. The design cross sectional drawings are presented in Figure 2.2 for reference.

Due to the toxic nature of the mine tailings derived from the processing of uranium ore, isolation of this material from the environment was a primary design objective. Therefore, with reference to Figure 2.2 the tailings fill were to be completely confined within the Cuts boundary to a maximum level of 1*m* below the lowest point of its lip. Disposal of the low grade copper ore and contaminated sub-soils from the nearby Copper Heap Leach Pile were to be placed above the impounded tailings to form the bulk of the landform. Due to the Pyritic nature of the low grade ore it required isolation. Therefore preventing water circulating through it and providing a medium for acid production by oxidation.

The percolation of rain and runoff water from the surface of the landform and capillary rise of the excess pore water from the consolidation of the underlying tailings werer the two main avenues for water ingress dealt with in the design. Reducing water ingress from the top was dealt with by the slopping of the surface to prevent pooling, and providing a low permeable, compacted clayey layer (zone 1A, **Error! Reference source not found.**) directly above. The one meter, thick rock blanket, between the the bulk landform and underlying tailings material was to act as an intercepting drain for excess pore water expelled from the consolidation of tailings material below. Further a series of intercepting drains and filter material layers were to contol the movement of water through and around the landform (Cut off drain and 500 *mm* rock blanket,). The landform surface was sloped with a gentle cross fall towards the central rock lined drain to collect and discharge surface runoff with minimal surface erosion (McNamara, 1984).

The tailings material was to be loosely place with some consolidation provided by the earth moving equipement. The material constituting the bulk of the landform was to be compacted to a modified dry density (MDD) of 95 %. However due to the expected low bearing capacity of the loosly placed tailings the first two meters of the bulk fill was to be compacted to the reduced MDD of 90 %.

From the above the following assumptions were made with regards to modelling the settlement of the Dysons landform:

- The majority of currently observed settlement is due to consolidation of the tailings material
- Settlement of the bulk fill material has contributed little to the current observed settlement
- The base and sides of the Cut should be considered an impermiable boundary
- The surface of the tailings is the impermiable boundary for the settlement due to consolidation
- External sources of pore water pressure do not exist

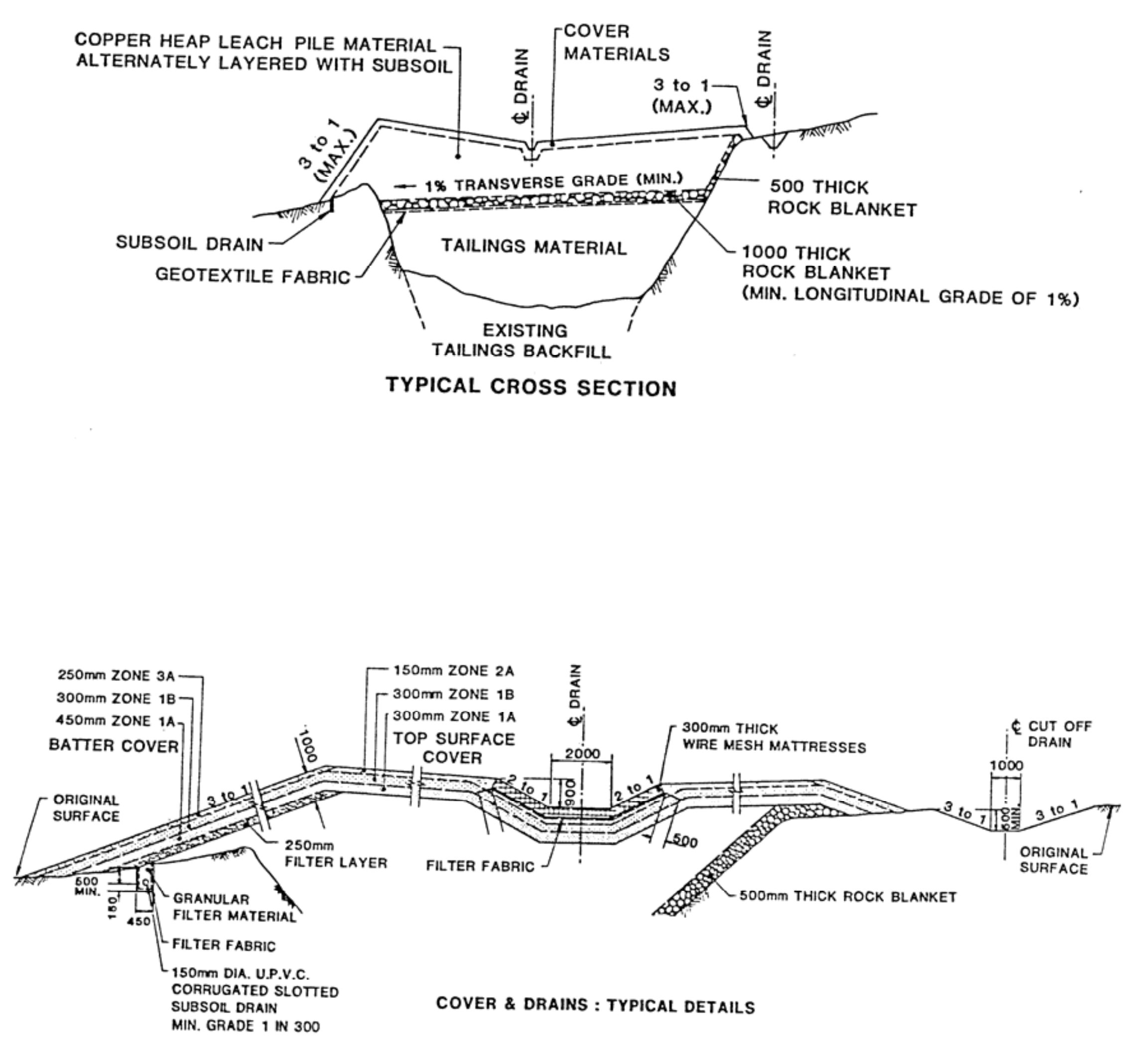


Figure 6.2 Dysons landform design taken from McNamara (1984)

2.3.2 Documented events during the landform construction

In order to better understand the processes by which the Dysons landform had settled between the present day and construction completion, consideration of recorded observations and events prior to and during the construction phase of Dysons rehabilitation were considered to be of importance. Therefore, the following discussion presents important historical accounts that were considered important to understanding the settlement of Dysons landform for modelling purposes.

Prior to commencement of the sites rehabilitation program the North Eastern boundary (the natural low point of the Open Cut) had been dammed to confine the un-neutralised, saturated tailings and significant volumes of contaminated waste water. This retaining structure was breached during the 1983/1984 wet season allowing the detained water to drain (notably un-treated) into the East Branch of the Finniss River and out to the Finniss River main. Prior to the construction process, a rock embankment was constructed at the previously dammed, downstream location(removed to allow discharge impounded water) to retain the tailings displaced by the filling operation of the tailings material from the Old Tailings Dam site. Further up into the cut another embankment was constructed to assist in retaining the liquefied tailings at the Cuts centre (Allen & Verhoeven, 1986).

The filling operation utilised low displacement earthmoving equipment due to the saturated, existing tailings high mobility potential. The imported tailings excavated from the Old Tailings Dam site were placed into Dyson's Open Cut commencing from the Southern end, where the more stable, beached sand deposits (tailings discharge site) were located (refer Figure 2.7 & Figure 2.8). Filling progressively advanced in the direction of the Cuts low point (North East). The imported tailings were dumped onto the previously placed tailings and the fill pushed forward in an attempt to assist the expulsion of water vertically from the saturated, fine tailings. Therefore keeping the highly saturated tailings material at the surface rising with the progressive fill level (Allen & Verhoeven, 1986).

During the tailings placement operation there were many occurrences of surface failures. These failures occurred as pools of liquefied tailings created due to the excess pore pressures and the low shear strength of the material being placed, and that of the underlaying tailings material. Strength failures on occasions saw the entire tailings fill area liquefy to the point of flowing. On these occasions the rate of fill placement was increased to displace this liquefied material towards the centre of the cut. To commence placement of the Rock blanket material and subsequent fill it was necessary to place a double course of geotextile fabric over this area to allow machinery access. The low ground pressure Plant and equipment were replaced by conventional machinery once sufficient material had been placed to produce a stable platform (Allen & Verhoeven, 1986).

With reference to the above accounts the central, deepest section of the Cut housed the most unstable, saturated tailings material placed into the confines of Dysons Open Cut. Further, the 2008 topographic survey showed that the region of the greatest settlement coincided with this location.

Figure 2.7 First tailings deposites to Dysons Open Cut 1984, taken from Allen & Verhoven (1986)

2.4 Geotechnical characteristics of the tailings materials

The talings deposited to Dysons Open Cut were identified as coming from 2 main sources as previously stated. The lower tailings type, were deposited prior the the rehabilitation works and the second deposited imediately above during the rehabilitation work, being derived from excavation works at the Old Tailings Dam site to the North East. The Geotechnical properties investigated for each tailings type are discussed below. The general characteristics of mine tailings according to (Henderson, 1999) can be described as geomechanically unique, in that they can be characterised as relatively homogeneous and geologically young. They generally exhibit low strength, are prone to extremely large consolidation amounts, are susceptible to liquefaction when disturbed and have high excess pore water pressures. Further, in the vicinity of the discharge point of mine waste tailings, sub aerial sands settle, with the finer cohesive materials of low permeability, sludge and slimes settling in the more distal areas to consolidate under self weight (Barnekow *et al*, 2002). The time dependent consolidation behaviour of these finer tailings is important to the timing of the water covers being drained and the stability of the covers placed. The existing tailings impounded within the Dyson's Open Cut had undergone undisturbed (assumed) self weight consolidation between the years 1964 (cessation of tailings discharge) and late 1982 (commencement of the Rum Jungle Rehabilitation Program). Therefore, the tailings had undergone approximately 18 years of self weight consolidation prior to rehabilitation works and loading of the impounded tailings.

2.4.1 Pre rehabilitation impounded tailings at Dysons Open Cut

Geotechnical investigations were undertaken on the impounded, existing tailings material within the Dyson's Open Cut by Dames and Moore. The data and results were documented in the design report, McNamara (1984). The geotechnical testing was limited to the following:

- One hand auger hole to refusal at 0.45 *m* used for;
    - Soil profile and chemical analysis
    - Particle size analysis
    - Plasticity Index
- Four Dynamic Cone Penetrometer tests and one (1) static cone penetrometer test
- Two Seismic refraction spreads

The Geotechnical report sheets are included in Apendix C

Investigations into the existing tailings material in the open cut were spatially limited with regards to in situ testing and the testing of collected samples. Sampling and testing was confined to one broad location over the area of the tailings deposits (Refer Figure 2.8). With reference to Figure 2.8, the sampling location approximately coincides with the site of the tailings discharge point. Therefore, suggesting that the sampled material was not truly representative of all the impounded tailings material present within the cut. According to Barnekow, (2002) the material sampled was most likely that of the larger granular sands that were first to settle out of suspension. According to the geotechnical report in McNamara, (1984) the yellow/brown, existing tailings material were classified as Silty Sands. The particle size distribution (PSD) results taken from McNamara, (1984) are reproduced in Table 2.3. The data shows that the greater part of the sample consisted of particles between 1.18 *mm* and 0.150 *mm* (fine sand).

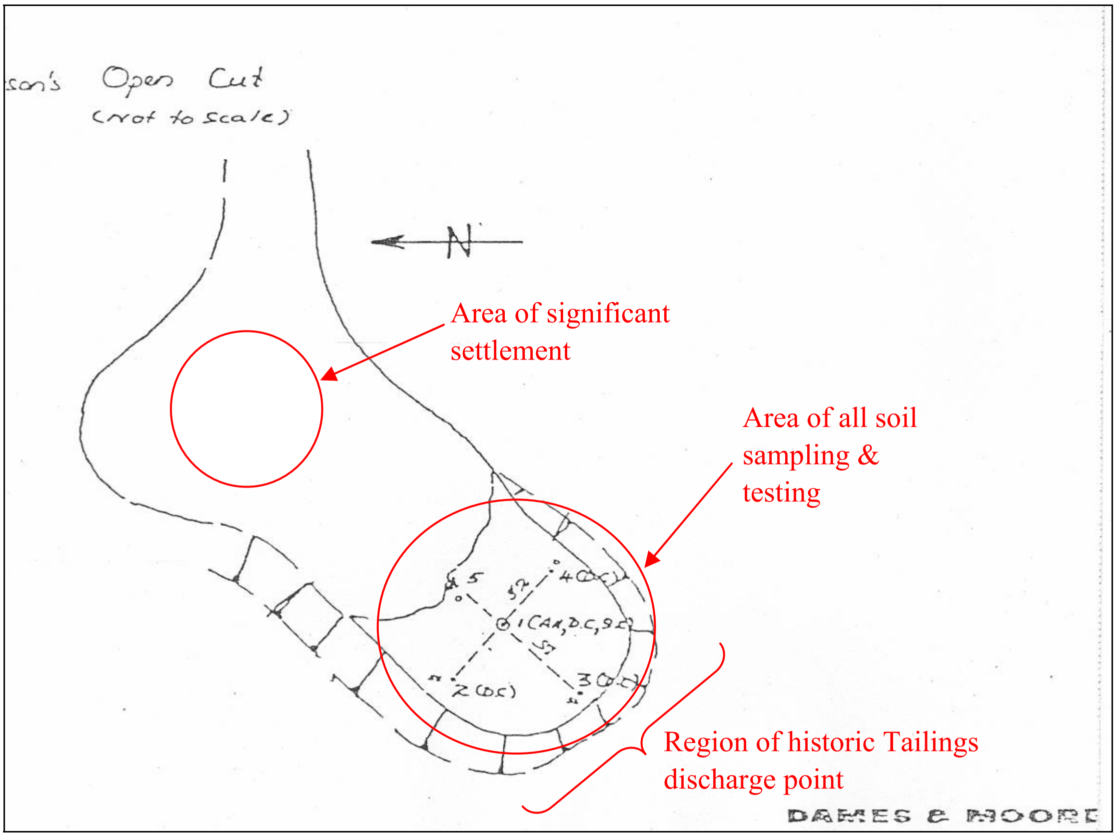


Figure 2.8 Dyson's existing in-pit Tailings, soil sample locations (McNamara 1984).

The reported moisture content of the sample tested was 12.4 %, and the Atterberg limits reported to be as the following:

- LL or W_L = 0.28 or 28 %
- PL or W_L = 0.24 or 24 %
- Plastic Index PI or I_P = 0.28 – 0.24 = 0.04

Therefore, the tailings material at the site of investigation were found to be unsaturated to an in situ depth of 450 *mm*. with a moisture content well below the plastic limit.

The estimated shear strength of the tailings from the static cone penetrometer test were reported to be between 10 *kPa* and 12 *kPa* (Refer Table 2.2)

Sieve Aperture (mm)	Mass Retained (g)	Percent Retained (g)	Cumulative Percent Retained (g)	Percent Passing (%)
4.750				100
2.360	0.1	0.03	0.03	100
1.180	5.1	1.7	1.73	98
0.600	45.1	15.0	16.73	83
0.425	39.4	13.1	29.83	70
0.300	47.1	15.6	45.43	55
0.150	55.7	18.5	63.93	36
0.075	22.9	7.6	71.53	28.5
Pan	1.0	0.3	28.7 Fines washed out	28

Table 2.3 PSD data of existing tailings, Dyson's Open Cut (taken from McNamara, 1984)

The results of an investigations into the characteristics of pit impounded Uranium tailings in Wels (2000) yielded the following results from laboratory testing for various geotechnical properties. The testing was performed on essentially undisturbed samples extracted by core drilling. The tailings were classified into course (sandy) and finer (clayey) types:

1. Sandy classified as silty sands with typically less than 20 % particle diameter < 0.06 *mm*
2. Clayey with 50 – 60 % of clay sized particles of diameter < 0.006 *mm*

Test No.	Location	Depth (*mm*)	Readings (Pounds Force)	Readings conversion to Newtons (*N*)	Estimated shear strength (*kPa*)
6	Dysons Open Cut No.1	0	110	24.729	12
		150	100	22.481	10
		300	105	23.605	11
		450	110	24.729	12
Average			**106.25**	**23.886**	**11.25**

Table 2.2 Static cone penetrometer derived shear strength

NOTE: Approximate conversion from Pound-Force to Newton: $0.22418 lb_f = 1N$

2.4.2 The Old Tailings Dam material

From 1953 to early 1961 Tailings from the Uranium ore treatment plant (at the Rum Junglle Mine site) were discharged, un-neutralised, to the adjacent Tailings dam area. Approximately $640{,}000*10^3$ *kg* of tailings material from the treatment plant were deposited to a gently sloped area of approximately 30 hectares (300,000 m^2). The general tailings type was of finely ground, acid-leached waste from the processing of Uranium and Copper ore (Allen & Verhoeven, 1986). The tailings had been subjected to many years of seasonal flooding resulting in large volumes of the finest fraction along with the slimes, and sludges being washed into the adjacent Finniss river. These tailings were excavated from the dam site as part its rehabilitation and disposed of in Dysons Open Cut as stated previously.

McNamara (1984) reports the following geotechnical testing was undertaken on this tailings material:

- One 100 *mm* diameter auger hole to 2.3 *m*
    - Soil profile and chemical analysis
    - PSD
    - Plasticity index
- Five dynamic cone penetrometer tests

- Five static cone penetrometer test
- One shear vane test

The Geotechnical report sheets are included in Apendix C

Unlike the limited spatial spread of the impounded Dysons tailings, the spatial spread of sampling and testing covered representative areas of the entire tailings dam site (McNamara 1984). Therefore, unlike the Dysons tailings the geotechnical results were taken as, describing all material types present. The geotechnical report characterised the grey tailings material as Sandy Silt (of finer fraction to the tailings in Dysons Cut) and other results as follows:

- Moisture content = 20.8 *%*
- LL or W_L = 0.25 or 25 %
- PL or W_L = 0.21 or 21 %
- Plastic Index PI or I_P = 0.25 – 0.21 = 0.04
- Remoulded shear strength between 1 and 5 *kPa*

(Refer to Appendix B for full result sheets)

2.4.3 Conclusion

The geotechnical investigation conducted on the two tailings material types that made up the base soil layer of the Dysons landform were considered to be inadequate for determining parameters for settlement modelling. Testing methods to quantify the volume change behaviour of the tailings were not conducted. However, resulting from the knowledge gained in this chapter, a better understanding of the factors that were likely to have influenced the current differential settlement of the landform is achieved.

Chapter 3 - Dyson's Open Cut Rehabilitated Landform Surveys

3.1 Introduction

To quantify the current subsidence of the Dysons landform, the as constructed and current surface levels needed comparing. While the current survey information was collected in the XYZ, point data format, the survey information of the as constructed surface level was in the form of a basic contour map providing elevation information only (Refer Figure). The information type and format difference complicated the comparison process. The contour map information needed digitising, geographical alignement to the Dysons landform surface (as did the 2008 survey data, for reasons detailed in the following sections) and interpolated surfaces created for both survey data. The following sections detail the steps taken to compare the elevation information from both surveys and quantify the settlement over the entire surface to the best possible accuracy.

3.2 Dyson's Open Cut rehabilitated landform 2008 surface survey

In early 2008 a visual site inspection of the Dyson's Open Cut rehabilitated landform was conducted. Large areas of the surface were thickly vegetated with tall grasses making it difficult to evaluate the condition of the ground surface (Refer Figure 3.1). However the general slope changes suggested that a substantial surface depression had developed near the middle of the landform. This area of suspected subsidence possibly coincided with the location of the main extracted ore body and the Cuts' deepest section. A comprehensive topographic survey was conducted in mid 2008 on the landform using the Total Station, Topcon GTS-229 to quantify the subsidence. Almost 1700 XYZ point data were collected during the survey (Refer appendix C)

A problem was encounted prior to the commencement of the survey. Due to the isolated nature of the site the location of an easily accessable, referenced datum (bench mark) could not be found. During the initial site inspection two survey monuments were located within the vicinity of the landform. The monuments consisted of a driven star picket surrounded by concrete with a stamped brass annulus embedded (Refer Figure 3.), however, no additional identifying marks or identification numbers were attached.

The GPS coordinates were recorded at these monuments to assist in their identification via registered survey or historical records (however as discussed later, no recorded information for these features were found).

At the time of the topographic survey, fire had removed much of the vegetation previously covering the landform and surrounds, (Refer Figure 3.). The bare landscape more clearly highlighted the suspected surface depression as well as revealing additional survey monuments and groundwater bores, all located adjacent to the base of the main batter slope (Refer Figure 3.). One of these survey monuments had been tagged with what was suspected as geodetic grid references and elevation (Refer Figure 3.). Additionally, identification numbers were attached to the bore casings (Refer Figure 3.). A permanent mark was installed on the top Eastern edge of the landform surface with a clear, unimpeded visual of the entire Dyson's surface, bores and the existing survey monuments below the landform. The Total Station instrument was set up over this mark, the tagged survey monument used as the backsight and all potential, reference datum features picked up (Refer Figure). Due to the uncertainty of the reference coordinates attached to the backsite monument, arbitrary datum and grid values were chosen with the veiw of editing the data when the information attached to the tagged monument could be confirmed accurate.

An irregular survey point spacing was adopted, the number and spacing of points were dictated by visual surface changes (the number of points increasing and spacing's decreasing in areas of prominent change in slope/elevation).

The collected survey data were downloaded via the Civilcad version 5.7 software and saved to an Neutral (.NEU) file format compatible with software programs used for data analysis. The data was imported to a Microsoft Excel spreadsheet and the X-Y data plotted in order to highlight any gross errors or areas of insufficient data points and was found to be satisfactory for further data treatment and mapping (Refer Figure).

3.2.1 2008 Survey Data Treatment

As mentioned above, arbitrary grid coordinates and height datum were used for the 2008 survey. To quantify settlement that had occurred, the two surveys (1986 & 2008) needed to be spacially aligned to each other and surface level information compared. The first step was to confirm the accuracy of the infromation attached to the backsight used, then align the survey information to the Dysons landform, referenced to a gridded map (base map) that would then become the common reference for the comparison. This process is detailed in the following.

Using the gridding and mapping program ArcMap, the coordinates tagged to the back sight monument used for the 2008 survey (Easting: 718740, Northing: 8563353) were ploted on a grid map referenced in the Map Grid of Australia 1994, zone 52 (MGA94z52) coordinate system. The plotteded position however, was visually assessed to be inacurate. The coordinates were found to be referenced to the Australian Geodetic Datum 1984 (AGD84) and required conversion to the MGA94z52 coordinate system. Replotting found the position of the monument to be reasonable, but the accuracy still requiring confirmation. The current coordinates and elevation of the 2 bores picked up in the survey were sourced in the Catalogue of Groundwater Monitoring Bores in the Top End to 2005 (Zaar & Farrow, 2005). The positional accuracy of this information was assessed with reference to the report by Lowery & Staben (2007), in which a number of bores at the Rum Jungle site had been checked and validated for coordinate accuracy. The Two bores however, were not among the list of those checked in the report. Of the bores that were checked for positional accuracy (49 in total) the range of positional difference to the published locations in Zaar and Farrow (2005) range between 1 and 258 meters.

The published coordinates (Zaar Farrow, 2005) of the two bores were converted from the AGD84 coordinate system to the MGA94z52 system and located on the base map. The survey data was brought into the map, geographically rectified and pinned to the map using the backsight MGA94z52 coordinates (Refer Figure 3.11). The 2008 survey data points were rotated, pivoting at the backsight point to align the data with the landforms central drain, being the most identifiable feature common to both the base map and the surveyed points (Refer Figure 3.11). The surveyed bore points did not coincide with the plotted position of the bores as seen in Figure. By using the distance measuring feature of ArcMap the diffence between the ploted bore locations were found to be three and seven meters. According to Lowery & Staben, (2007), this is not a significant difference. Therefore the grid coordinates assigned to the backsight were deemed to be sufficiently accurate and the 2008 survey data correctly aligned to the base map. The 2008 survey points were assigned the corresponding base map coordinates as defined by their location on the map.

The 2008 elevation data were aligned to the tagged monument (backsight) Z-value of 73.46 m. The 2008 elevation data of the two bores was checked against the published elevations of Zaar and Farrow (2005). The difference in elevation was within 100mm and accepted as accurate enough for the purposes of evaluating the settlement magnitude of the Dyson's landform. Finally, the point data was interpolated using the kriging technique of estimation producing a raster data set for use in 3-D surface modelling.

Figure 3.1 Dyson's Open Cut Rehabilitated Landform, June 2008.

Figure 3.2 Existing survey monument

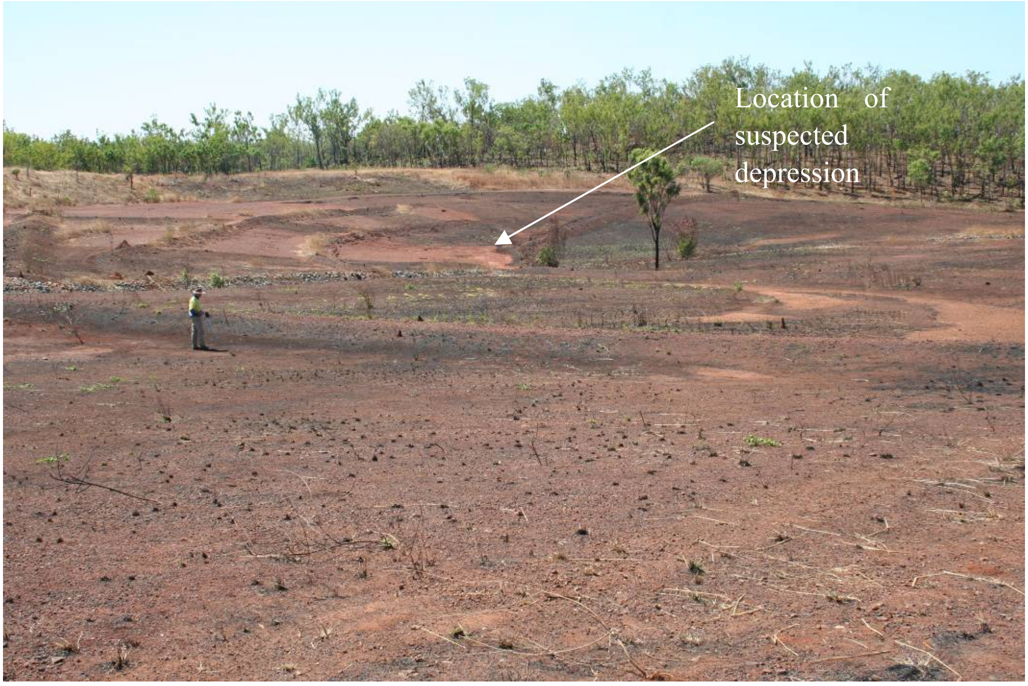


Figure 3.3 Landform at time of topographic survey

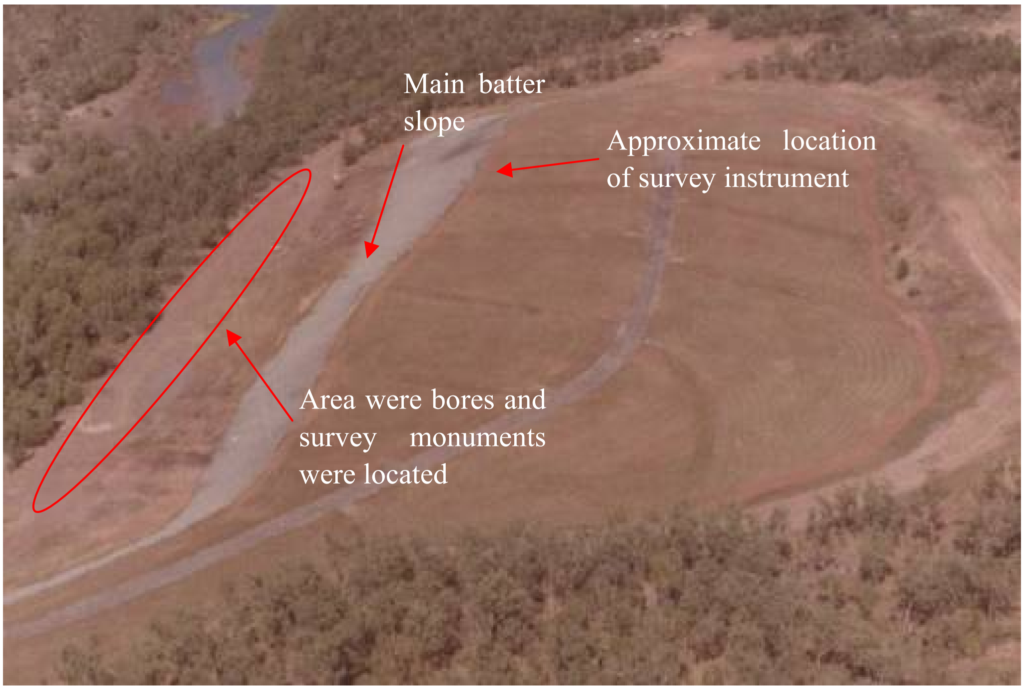


Figure 3.4 Dyson's rehabilitated landform, between late 1984 & 1986

Figure 3.5 Tagged survey monument RL, Easing & Northing

Figure 3.6 Bore identification located adjacent to main batter slope

Figure 3.7 Survey setup location 2008

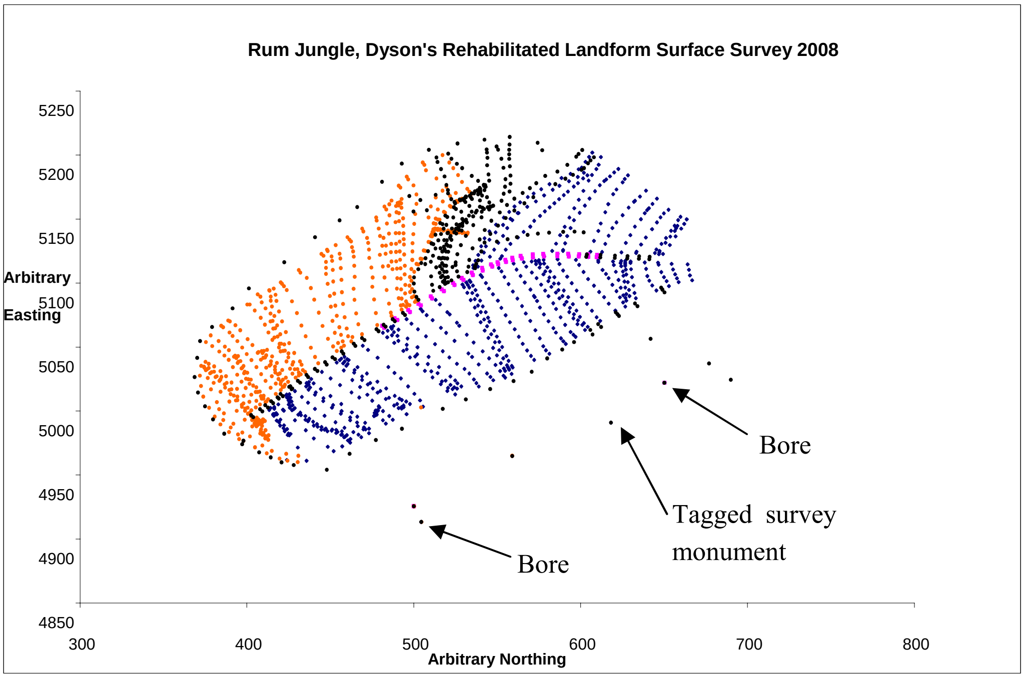


Figure 3.8 Dyson’s 2008 Survey Data Plot (X, Y) produced in Microsoft Excel.

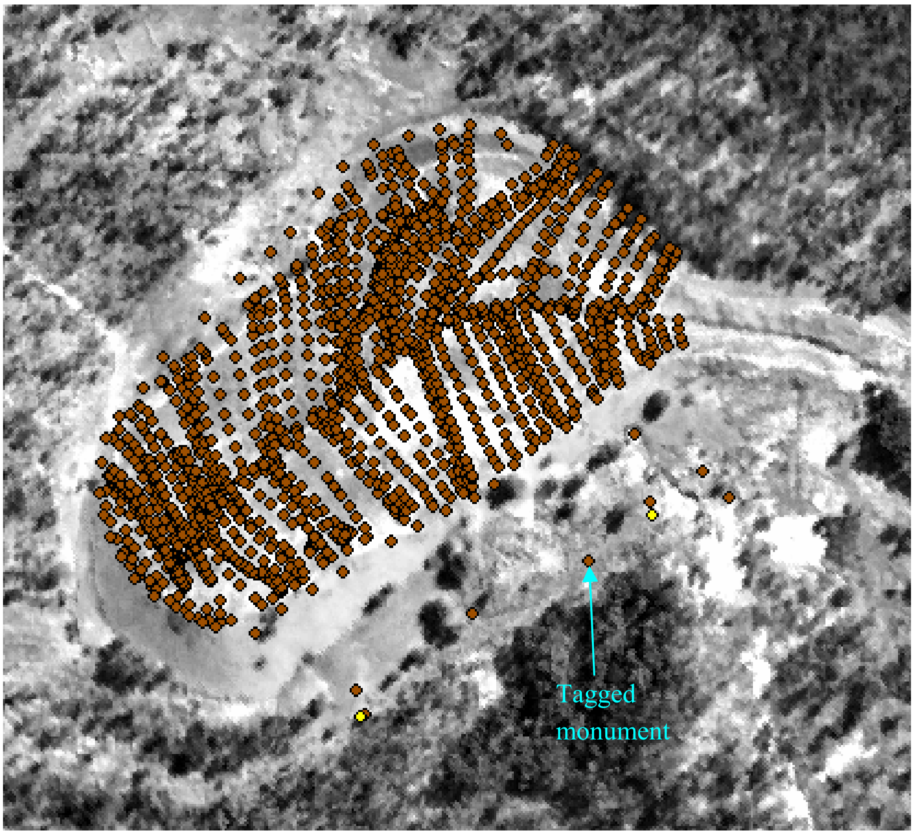


Figure 3.9 Geographical rectification of 2008 survey data to Dyson’s base map coordinates system. 2008 Survey data points (Brown), published coordinate location of bores (Yellow)

3.3 Dyson's Open Cut rehabilitated landform 1986 as constructed survey

As previously stated, the actual survey data for the as-constructed landform could not be sourced, however, a contour map of the surface, taken at the time of the rehabilitation landform completion was located in Allen & Verhoeven (1986), (Refer Figure 3.10). This map had no other information attached to it with regards to the input survey data and the method employed to produce it. However, as there were no other survey information, the contour map was assumed to correctly model the surface elevation of the Dyson's Open Cut rehabilitated landform. In Allen & Verhoeven (1986) also discussed, was the installation and use of permanent survey marks to monitor the magnitude of the fills settlement and that these marks were used in the survey data collection and its subsequent use for the contour maps production was assumed. These same survey marks were assumed to be those located during the 2008 survey. With regard to the above assumptions, it is likely that the 2008 survey data and the survey data used in the production of the contour map referenced the same survey monument height datum. Therefore determination of the settlement magnitude could be made by directly comparing the 2008 and 1986 elevation values. The process of geographically aligning the 1986 data to the reference base map is detailed in the following section.

3.3.1 1986 Survey Data Treatment

The 1986 contour map was required to be converted to a Digital Elevation Model (DEM) for comparison to the 2008 survey data DEM. The contour map was first scanned to create a digital image (.tif format File) and imported to the mapping and editing software program ArcMap. The contour image file was then converted to a raster image data set of 1.0 m square pixel/grid size. The map was positioned over the coordinate base map of Dysons thereby geographically rectified (aligned) it to the base map cordinates. To refine the alignment three points (triangle formation), easily identifiable on both the base and contour image were selected and marked to the contour image (Refer Figure 3.10Figure). In turn, each point identified on the contour image was dragged to its corresponding point on the base map and pinned. By this process, the base map grid coordinates at the points new location were assigned to that same point on the contour image. All grid points on the contoured raster image were now rectified to the base map in 2-D space. The contours on the geographically rectified map were traced, creating a shape file were each contour line was assigned its documented elevation value. A Raster data file was then created from this geographically rectified contoured file using the Special Analyst tool in ArcMap. The process produced an imterpolated surface data set using an iterative finite difference interpolation technique that could then be used to generate a three dimensional surface model of the landform.

3.4 Vertical alignment of the Georectified 2008 and 1986 raster data sets

Through the processes described above the 2008 and 1986 raster data had been aligned to a common base map coordinate system and the grid points assigned corresponding cordinates. However, errors in the vertical alignment between the two data sets were likely due to each alignment processes occurred independent of each. Therefore the raster data sets were exported to the image processing software ENVI for layer stacking. The layer stacking process involves an iterative sampling and realignment of the pixel/grid data from both files bringing them into vertical alignment. A new banded file is built from the georeferenced, raster data sets for a more accurate evaluation of settlement magnitude over the time period between the two surveys. Finally, these newly aligned files were exported to ASCII grid files of XYZ data.

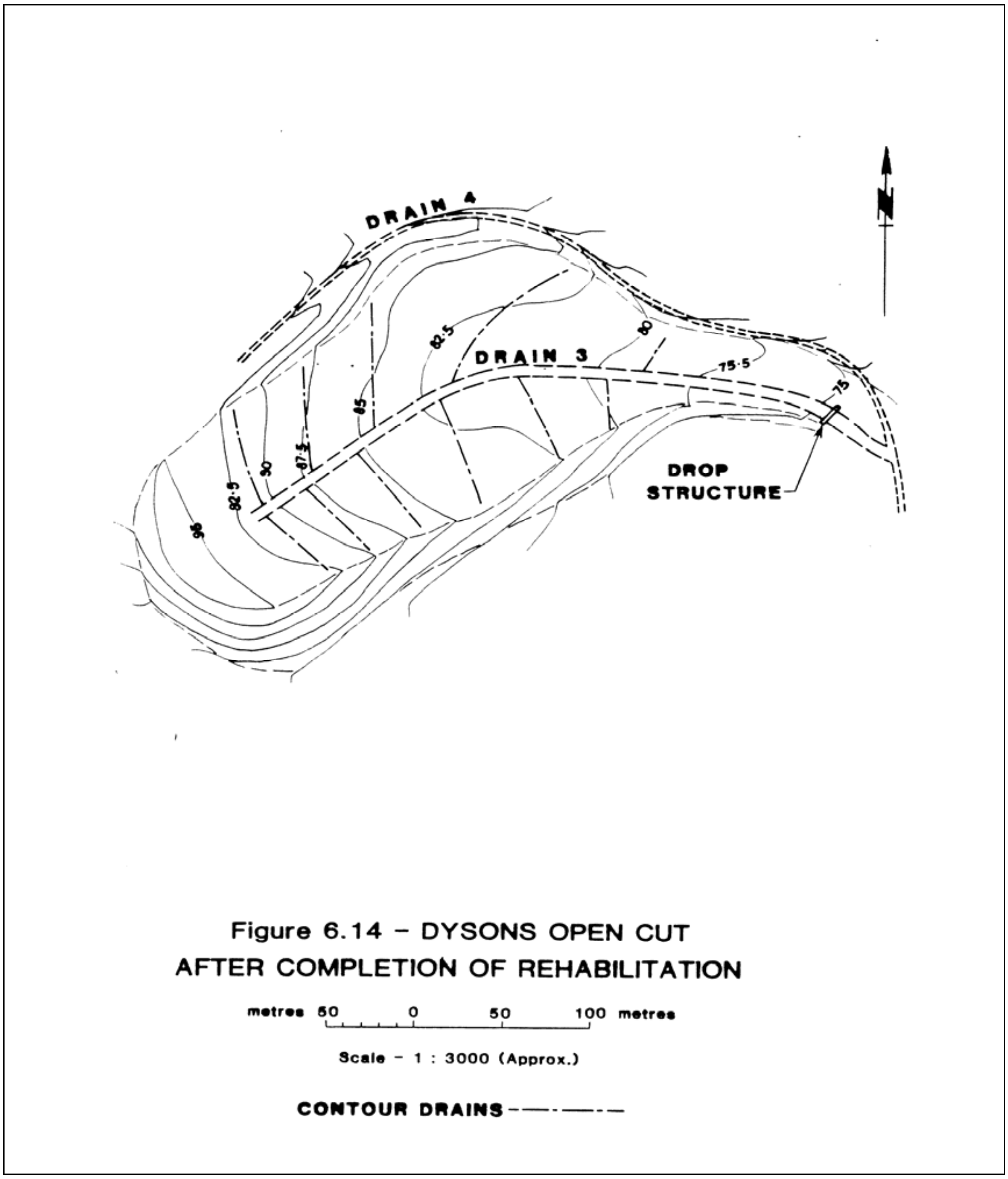


Figure 3.10 Digitised Contour map of Dyson's rehabilitated landform 1986 (taken from Allen & Verhoeven 1986)

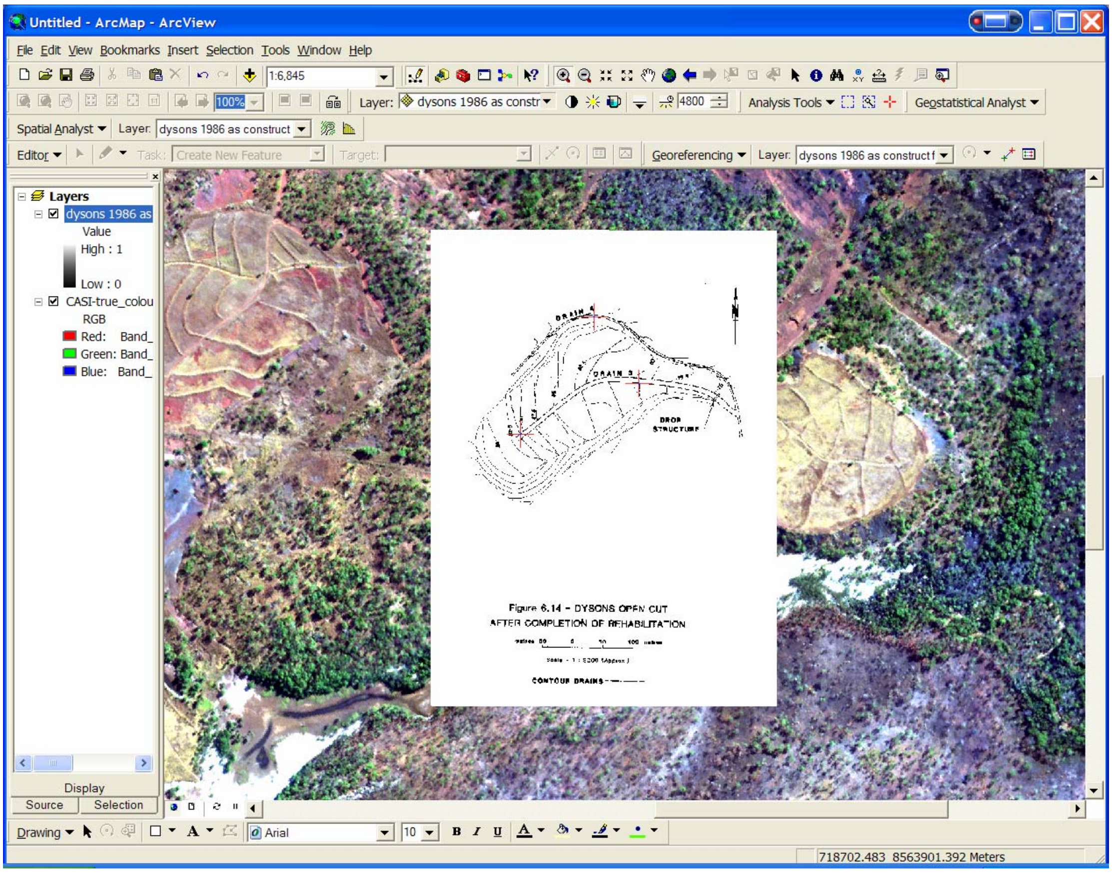


Figure 3.11 Screen display of the process of geo-rectifying the digitised contour image and the geographical base map (extract from ArcMap software program)

3.5 Surface Mapping of the 2008 and 1986 Surveys

Surface models created using the geographically rectified survey data from the above processes and the process involved in their production is presented in the following.

3.5.1 2008 Current surface

The corrected Dyson's 2008 survey data were imported to the grid and mapping software, Golden Software Surfer to create a three dimensional surface and a contour map of the landform in its current condition (Refer Figure & Figure). A grid file was created using the Nearest Neighbor gridding method, which assigns the values of the nearest point to each grid node. Using this method allows the pixel data from the two Raster surface files returned from the ENVI alignment process to be used directly as the grid values. The three dimensional surface was then created using these grid file values. The three dimensional surface model clearly shows the surface depression, the site of excess settlement (Refer Figure).

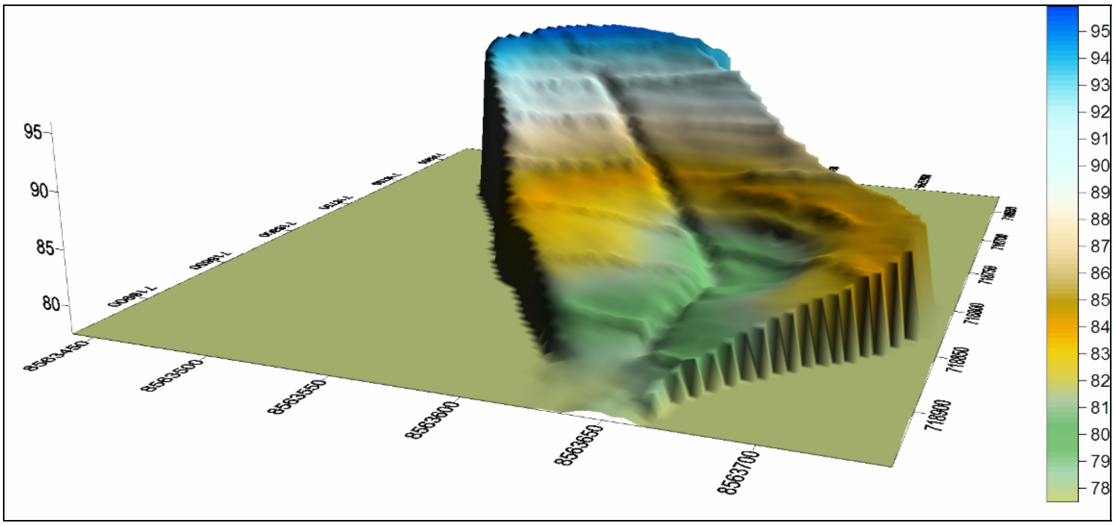


Figure 3.12 Boundary defined Dyson's landform 3-D surface from 2008 survey data created using the mapping software Golden Software Surfer.

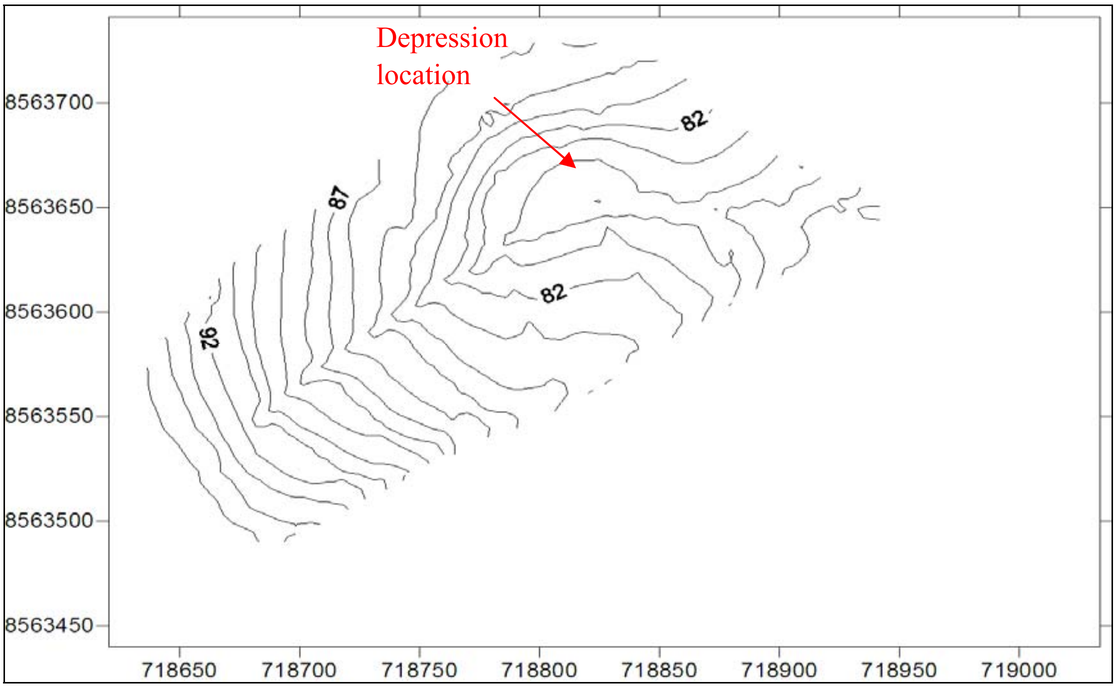


Figure 3.13 Dyson's 2008 Survey Data Contour map. Produced using Golden Software Surfer mapping software. (1m Contour interval)

3.5.2 1986 surface

A three dimensional surface and contour model were also produced using the same process employed for the 2008 models(Refer Figure & Figure). The 1986 three dimensional surface also shows a depression at the same location as the 2008 surface

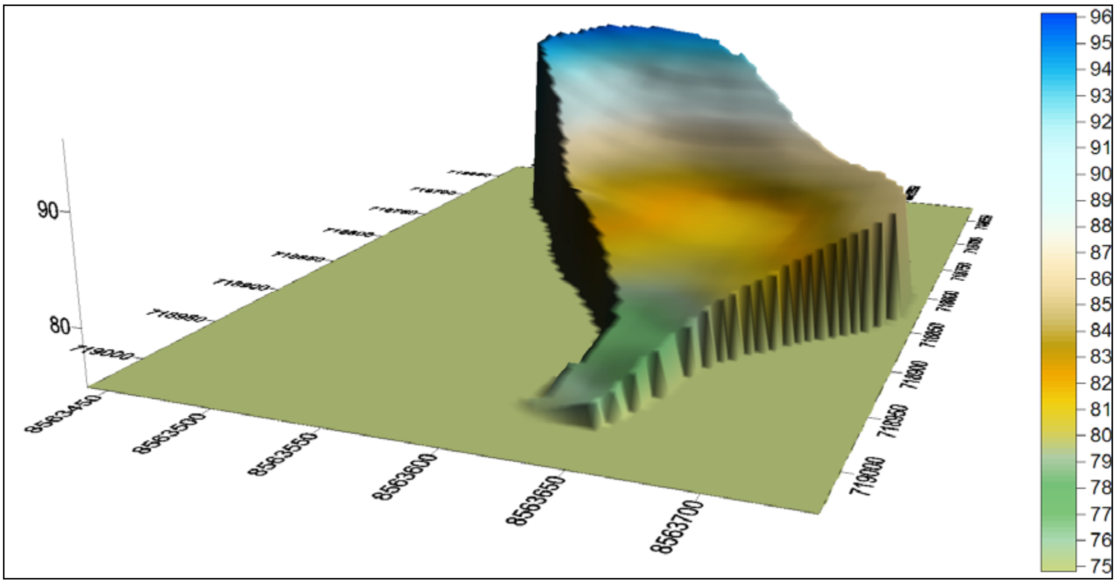


Figure 3.14 Boundary defined Dyson's landform 3-D surface from 1986 survey data created using the mapping software Golden Software Surfer.

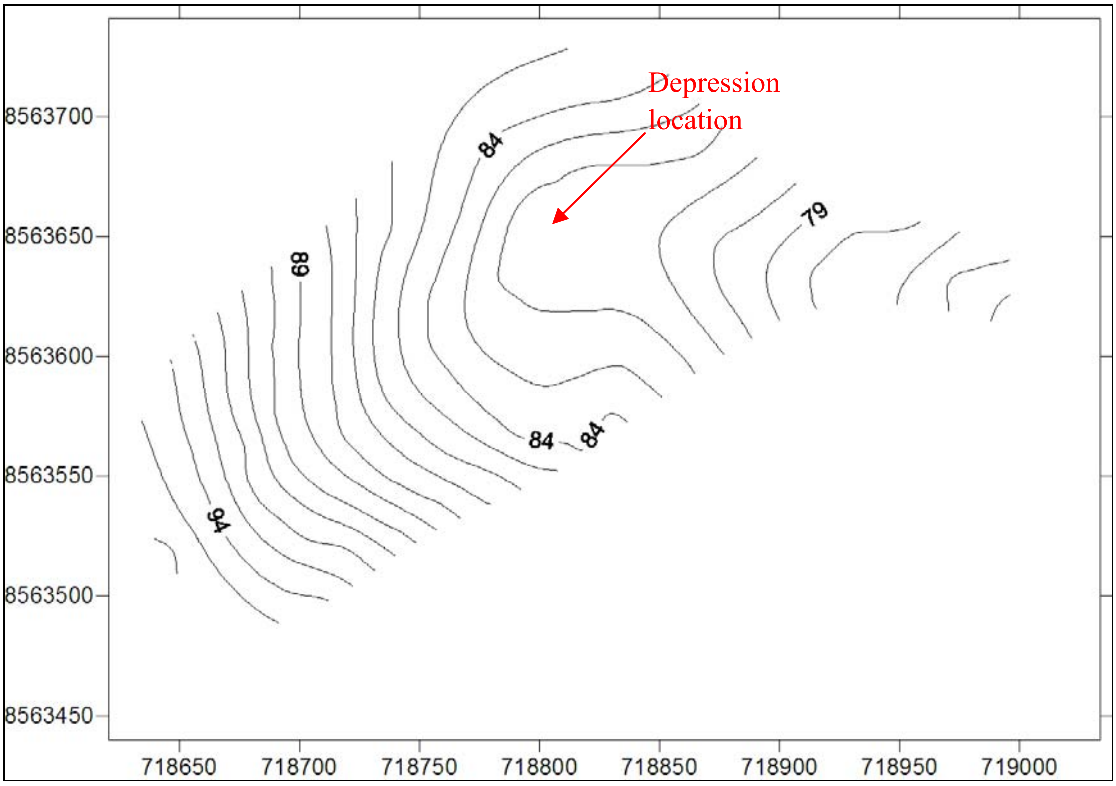


Figure 3.15 Dyson's 1986 Survey Data Contour map. Produced using Golden Software Surfer mapping software. Geographic coordinates have been rectified (1m Contour interval)

3.6 Determination of settlement magnitude

The two aligned surface data files (2008 & 1986) were used to create three dimensional surfaces using ArcMap for the analysis and calculation of vertical settlement. The 1986 surface was identified as the reference plane and the difference between it and the 2008 surface were calculated. The analysis identified the areas of surface elevation change, plotting the height difference between the two surfaces as colour delineated areas within a value range (Figure 3.16). The area of maximum settlement (1.474*m* to 2.532*m*) is identified as the approximate location of the extracted ore body and the deepest section of the excavated Open Cut (the depression location as shown above in Figure to Figure). It is to be noted that Figure shows significant settlement along the central collection drain, however the central collection drain was not picked up in the 1986 survey and hence was not included in the 1986 surface data used to produce the surface models. The same central drain was included in both the 2008 survey and the surface models produced from it, thus the difference values attached to the drain are not reliable. Similarly, the surface water diversion banks show up in the model as areas of surface bulging or soil deposition. For the purposes of settlement evaluation these features have been ignored. Despite these two minor miss-representations the model clearly shows significant settlement over most of the landform. An estimate of the maximum settlement can be made by subtracting the depth of the channel from the range maximum. From the reduced level point data, the depth of the channel is approximated as 800 *mm*, thus a maximum settlement of 1800 *mm* can be estimated.

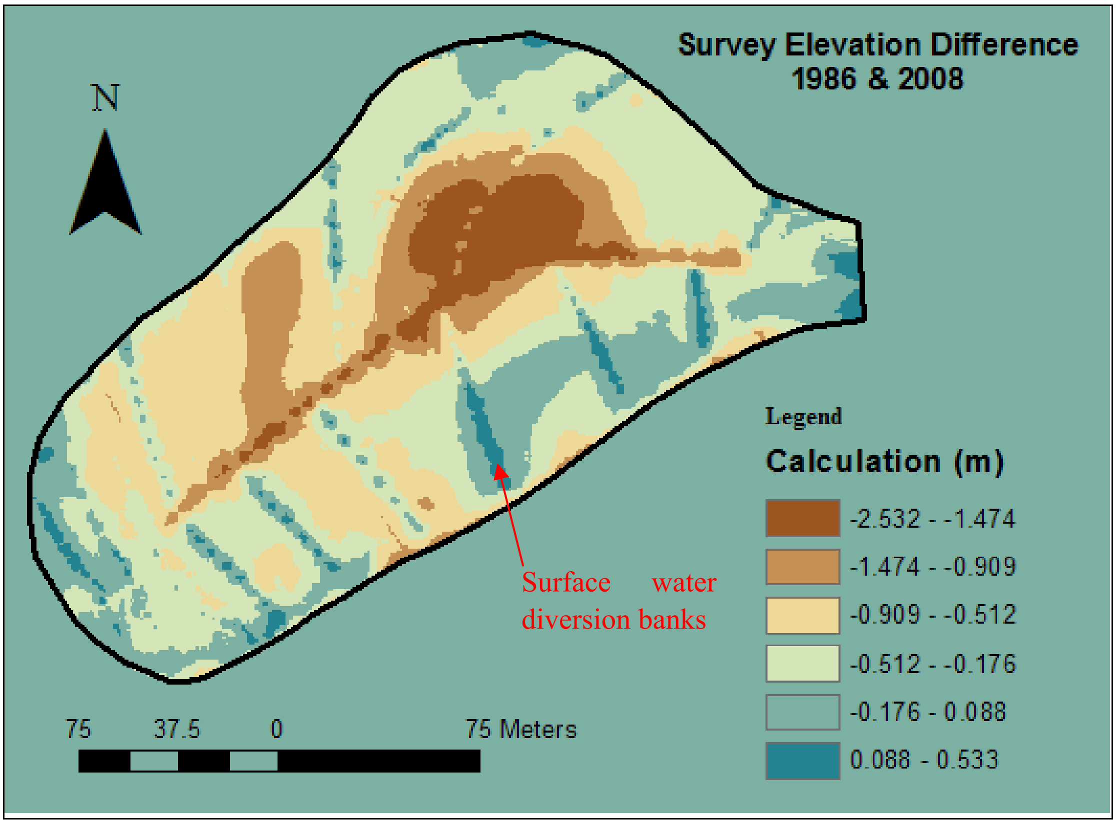


Figure 3.16 Dyson's surface overlay of 1986 & 2008 data showing difference in height

Sections were taken throught the landform (Figure & Figure), using the mapping and graphing software program Surfer. The location of these sections are shown in Figure and Figure 3.19.

Section A-A was made approximately perpendicular, and through, the central collecting channel (Refer Figure). The cross sectional data from the two surfaces, plotted together in Figure clearly shows the elevation difference between the 1986 surface level compaired with the existing 2008 surface. As noted previously the elevation comparison is missrepresented due to the central drain elevation data being included in the 2008 survey but omitted from the original 1986 survey. To evaluate the maximum settlement from the plot in Figure , the central channel on the 2008 line plot needed to be ignored. Scaling the maximum vertical difference on the plot in Figure , against the y-axis gives an approximate 2000 *mm* settlement value.

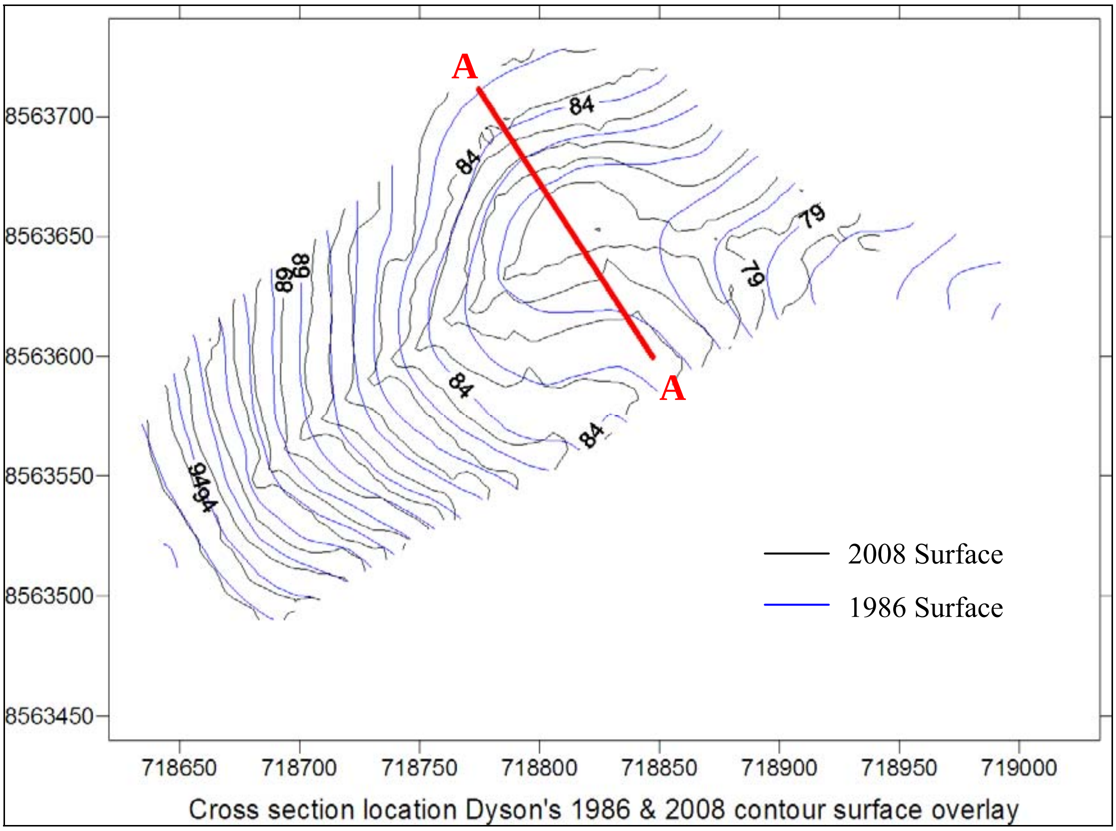


Figure 3.17 1986 & 2008 contour map overlay with line showing cross section. (Produced in Golden Sofware Surfer)

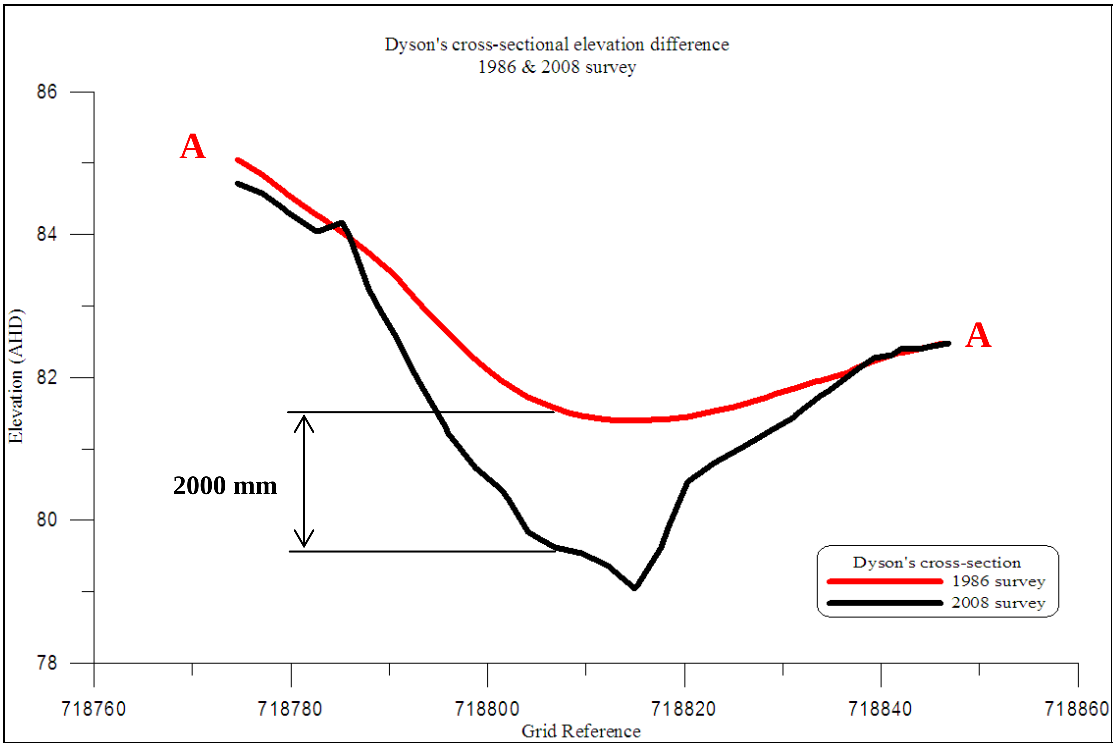


Figure 3.18 Surface cross sectional plot, 1986 & 2008 surface data (Produced in Golden Software Grapher)

Section B-B was made in a direction approximately parallel to the central collection drain but did not include it in the cross sectional data (Refer Figure 3.19). The cross sectional plot generated and shown in Figure also indicates a settlement value of approximately 2000 *mm.*

The above three methods of analysing the surface elevation difference to determining the settlement magnitude of the Dyson's rehabilitated landform over the 22 year period between the years 1986 and 2008 yielded similar values and is taken to be 2000 *mm*.

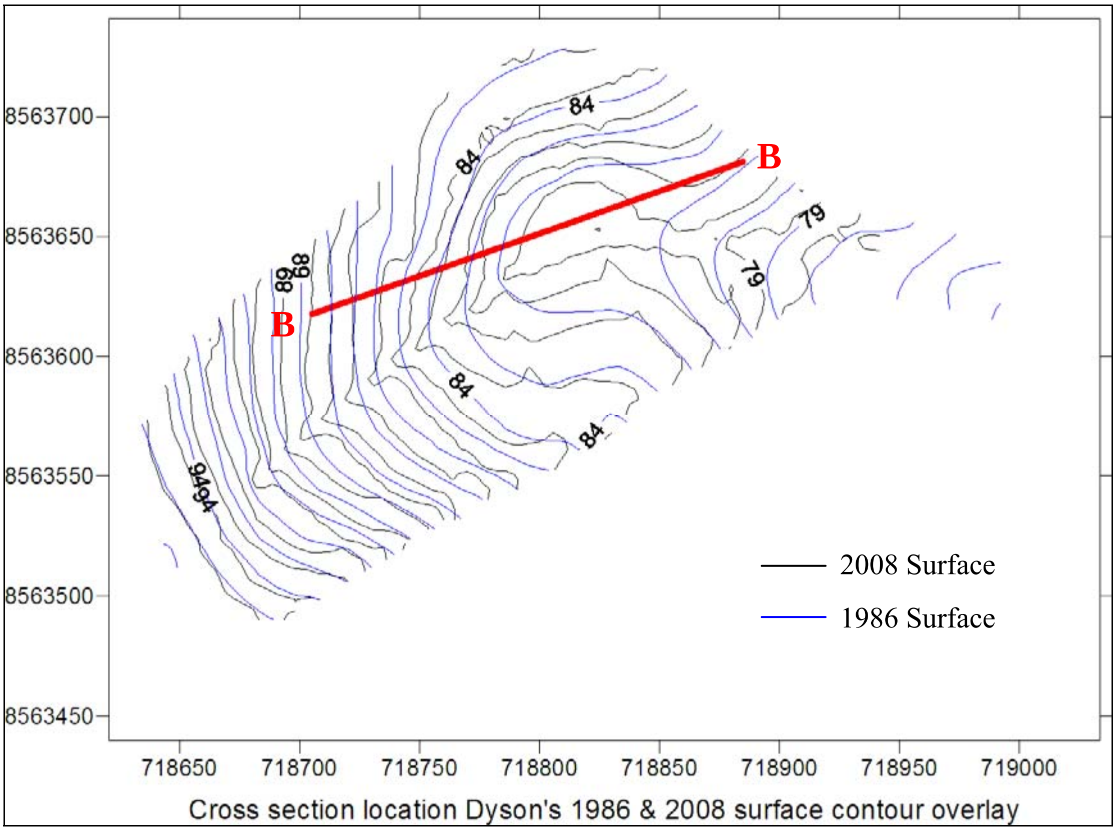


Figure 3.19 1986 & 2008 contour map overlay with line showing cross section. (Produced in Golden Sofware Surfer)

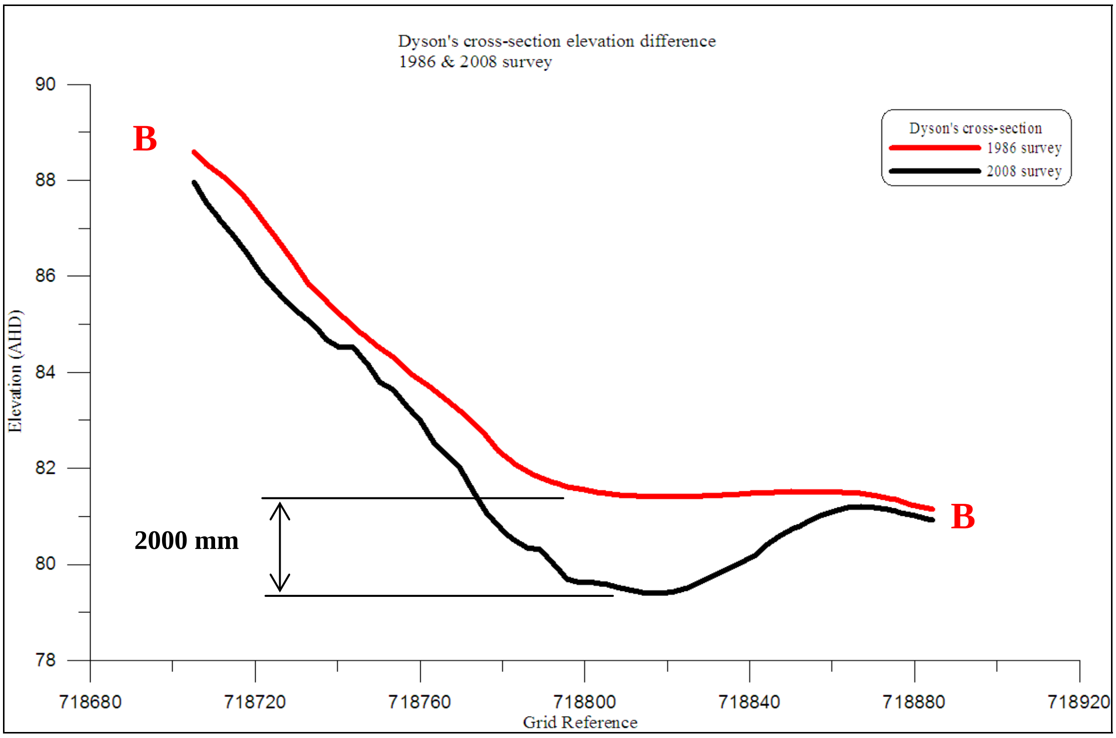


Figure 3.20 Dyson's surface cross sectional plot, 1986 & 2008 surface data (Produced in Golden Software Grapher)

Chapter 4 - Model estimate of landform settlement due to compression of underlain mine waste tailings

4.1 Introduction

In the previous sections differential surface settlement of Dyson's landform has been shown to have occurred. The quantified maximum settlement was also shown to coincide with the Cuts deepest section and the likely location of the saturated finer grained, sludge and slime tailings material placed into Dysons Open Cut. Further, substantial gully erosion was identified in this maximum settlement zone with the remainder of the surface showing only minor signs of erosional effects. Therefore the area of observed maximum settlement is of primary interest. Given that little knowledge of the tailings geotechnical properties exist calibrating a settlement model to the observed settlement is difficult, if not impossible. However, since the construction records documented the tailings condition as being saturated and highly unstable at the time of the fill being placed above the tailings, settlement due to the process of consolidation will be discussed. Further to this, only one dimensional consolidation is considered as a preliminary to possible further work to aquire better geotechnical knowledge of the tailings. In the following section the simple theory of one dimensional consolidation by Tezaghi (1945) is presented together with a simple numerical solution to this theory for modeling consolidation settlement. The required input factors for the model (with respect to the tailings material) are discussed and estimated. The model is then used to simulate the the landforms settlement at the maximum observed settlement zone by manipulating the governing factor. Finally the results and deficiencies of the model are discussed.

4.2 Thezaghis Theory of one dimensional consolidation

The simplified linear and elastic consolidation theory for fine grained soils by Tezaghi (1945) is well documented and has been the basis for estimating the settlement magnitude of soft soil layers due to consolidation and the rate at which it occurs. Allthough the theory is heavily simplified using assumptions that somewhat detract from the realistic processes that occur during consolidation settlement, the application of the theory can, in some cases return reasonable estimates of actual settlement (Smith 1990) The simple theory is presented here for a preliminary evaluation of settlement modelling.

The main assumptions in the theory are:

1. The soil is essentially homogenous and saturated
2. Both the soil pore water and soil particles are incompressible
3. The coefficient of consolidation is held constant
4. Darcy's law of saturated flow is applied and valid
5. The compression induced consolidation is one dimensional (vertical down) only
6. Expulsion of water from the soil voids is in one direction only (Vertical)
7. Volume change of soil is only due to a change in the void ratio, which in turn is due to a corresponding increase change in the effective stress. The relationship between void ratio (e) and effective stress ($\sigma^{'}$) is linear
8. There is no instantaneous volume change on application of the overburden pressure increase (Total stress increase)

To visualise the consolidation processes assumed, the problem of one dimensional consolidation is shown in Figure 4.1.

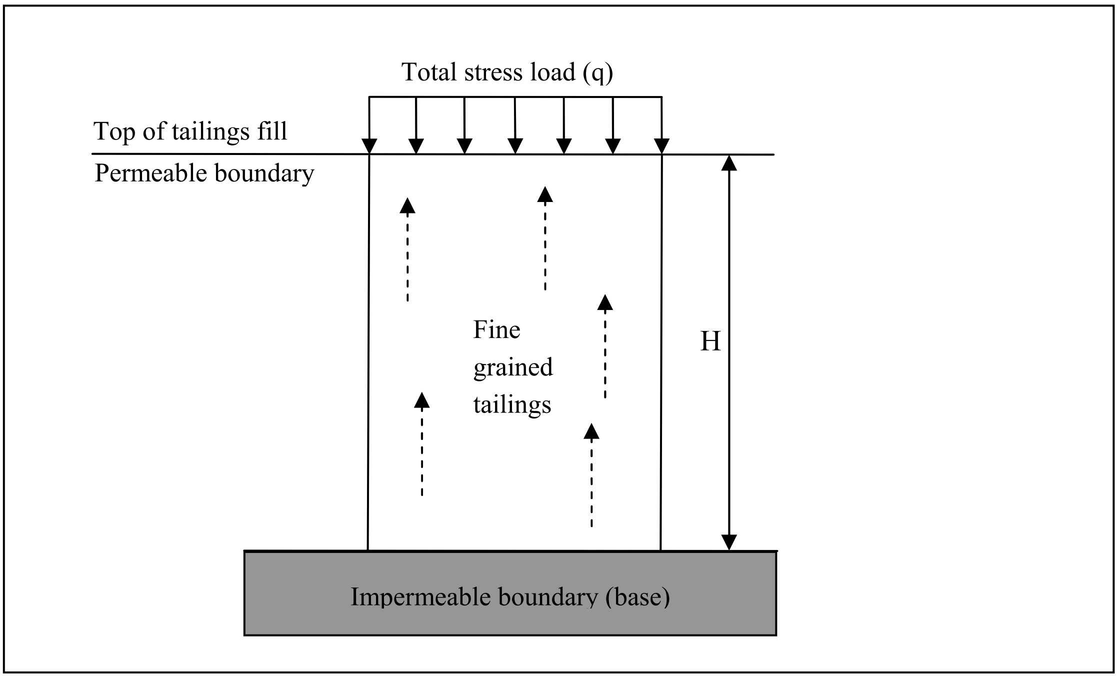


Figure 4.1 Sketch of the consolidation process

The rate of volume decrease (settlement) of the soil is equal to the rate at which the fluid in the soil pores flows out due to the constant stress applied by the tailings layer overburden. Darcy's law is valid therefore the pore fluid velocity (v) is evaluated from:

$$v = k\frac{\partial h}{\partial z}$$

Where: $k =$ Soils Coefficient of Permeability, vertical (z) direction

$h =$ Hydrostatic pressure head causing flow

$z =$ Vertical soil thickness

The head causing flow (h) is the excess pore water pressures in the soil medium thus:

$$h = \frac{u}{\gamma_w}$$

Where: $u =$ Excess pore water pressure

$\gamma_w =$ Unit weight of water

Therefore the change rate of volume becomes:

$$\frac{\partial}{\partial z}\frac{k}{\gamma_w}\frac{\partial u}{\partial z} = \frac{k}{\gamma_w}\frac{\partial^2 u}{\partial z^2}$$

As the volume change is assumed to occur due to the change in void ratio (e) over time, the change rate of volume may be expressed in terms of the void ratio as follows:

Soil Porosity $n = \frac{V_v}{V} = \frac{e}{1+e}$

Change rate of volume $= \frac{1}{1+e}\frac{\partial e}{\partial t}$

Equating the two equations gives the equation of consolidation:

$$\frac{k}{\gamma_w}\frac{\partial^2 u}{\partial z^2} = \frac{1}{1+e}\frac{\partial e}{\partial t}$$

The overburden pressure is equal to an increment of applied pressure (dp) and together with the assumption that no lateral strains exist then dp is equal to, but opposite in sign to the resultant increment of excess pore water pressure (du)

The slope of the void ratio – effective pressure (e – p) curve derived from a consolidation test being the coefficient of consolidation (C_v)

$$C_v = -\frac{de}{dp} = \frac{de}{du} \quad \text{then} \quad de = C_v du$$

The coefficient of consolidation may also be represented as:

$$C_v = \frac{k}{\gamma_w}(1+e) = \frac{k}{\gamma_w m_v}$$

Where: m_v = Coefficient of volume decrease. That is the unit volume decrease per unit increase in effective pressure.

Therefore substituting:

$$C_v \frac{\partial^2 u}{\partial z^2} = \frac{\partial u}{\partial t} \quad \text{OR} \quad \frac{k}{\gamma_w}\frac{\partial^2 u}{\partial z^2} = m_v \frac{\partial u}{\partial t}$$

The above equation is a one dimensional and linear partial differential equation

The analytical solution to the above equation gives the value of excess pore water pressure (u) at depth (z) and at time (t).

$$u = 2q\sum_{n=0}^{\infty}\frac{1}{\alpha_n}\sin(\alpha_n Z)e^{-\alpha_n^2 T}$$

Where: $\alpha_n = \frac{1}{2}(2n+1)\pi$

$Z = \frac{z}{H}$ (dimensionless distance factor)

$T = \frac{C_v t}{H^2}$ (dimensionless time factor)

$H =$ The maximum distance water is required to travel within the soil depth.

The vertical surface settlement of the full depth soil layer can be given by summing all the vertical strains of the infinitely small soil layers constituting the full soil depth and is represented by:

$$S = \int_0^H m_v (q - u) dz$$

Where: q = the applied load at the surface of the soil and,

m_v is assumed constant.

Then substituting:

$$S = m_v q \int_0^H \left[1 - 2 \sum_{n=0}^{\infty} \frac{1}{\alpha_n} \sin(\alpha_n Z) e^{-\alpha_n^2 T} \right] dz$$

The integral gives:

$$S = m_v q H \left[1 - 2 \sum_{n=0}^{\infty} \frac{e^{-\alpha_n^2 T}}{\alpha_n} \right]$$

The above equation gives the surface settlement due to consolidation at any time over the full layer depth.

The required evaluation of the integral analytically may be substituted by numerical techniques as described in the following section.

4.3 Numerical solution to the one dimensional consolidation equation

A simple numerical solution to the one dimensional consolidation equation can be achieved using the finite difference method of approximations. By the use of this method the excess pore water pressures at specified points in time and space (soil depth) are evaluated. (Refer Figure)

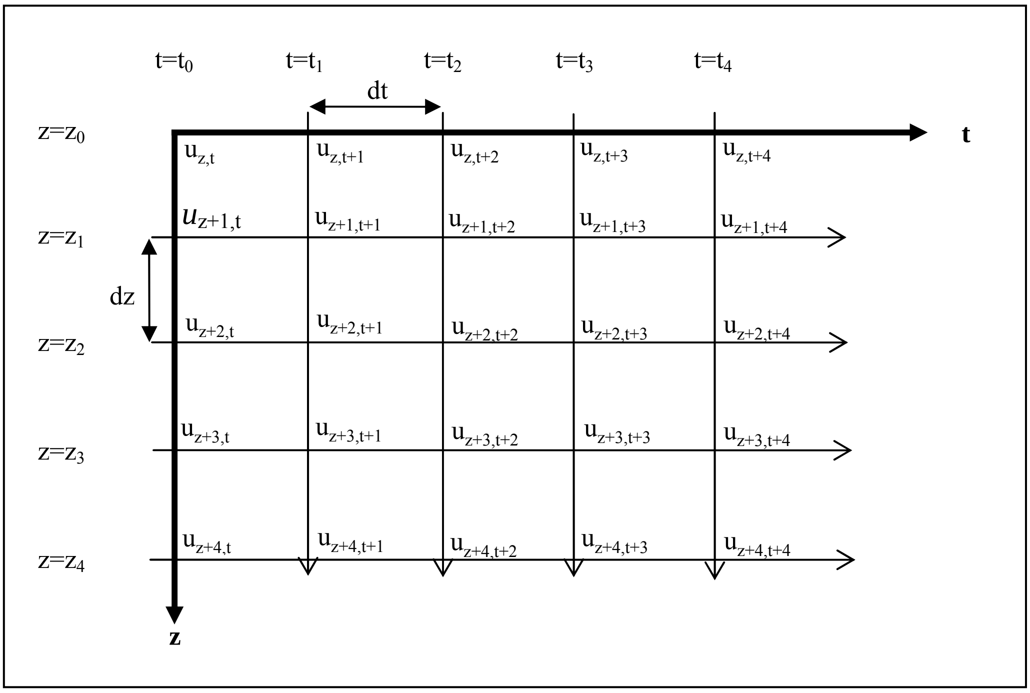


Figure 4.2 Scematic of the finite difference method of estimation

To illustrate the finite difference method and its application to the one dimensional consolidation equation we can assume that the excess pore water pressure over the full range of the soil depth approximates a parabolic shape when the variation of *u* with *z* is plotted (Refer Figure).

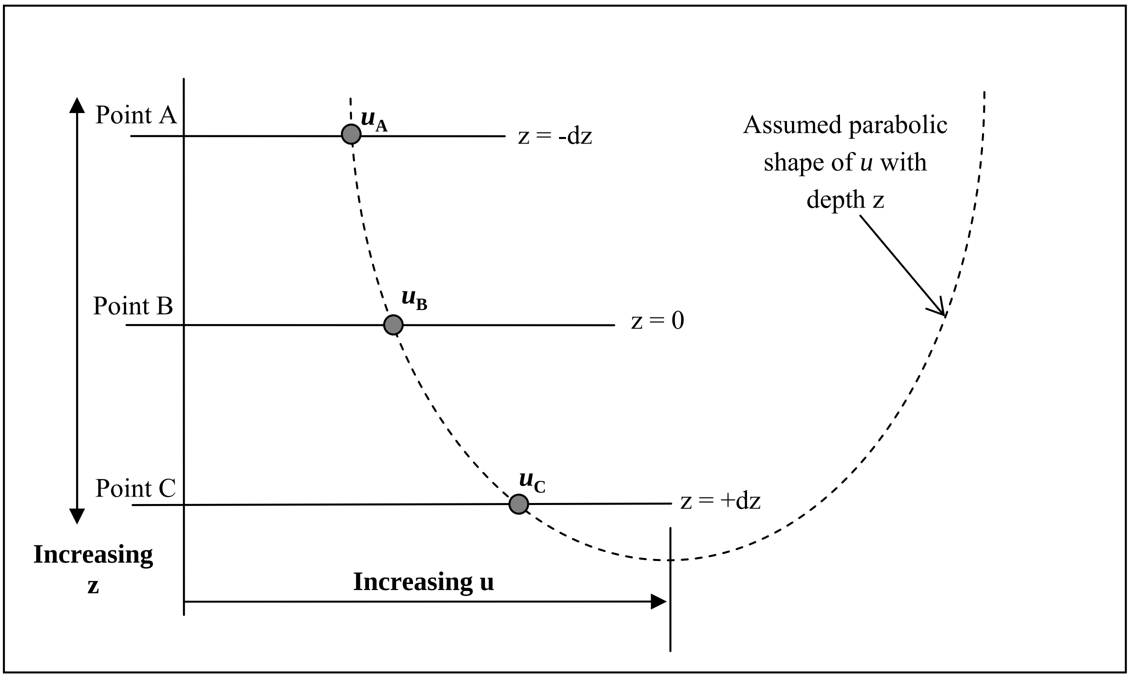


Figure 4.3 Plot diagram of excess pore water pressure against vertical soil depth (Parabolic curve)

Therefore the parabolic equation becomes:

$u = a_1 + a_2z + a_3z^2$

Where: a_1, a_2 and a_3 are fitted constants

Evaluating the excess pore water pressures (u), from the reference position of Point B in Figure :

u at point A = $a_1 – a_2dz + a_3dz^2$;

u at point B = a_1

u at point C = $a_1 + a_2dz + a_3dz^2$

Then relating the constants (a) to the points of interest in Figure :

$a_1 = u_B$

$$a_2 = \frac{u_C - u_A}{2dz}$$

$$a_3 = \frac{u_A + u_C - 2u_B}{2dz^2}$$

Then the slope of *u* at point B is: $\left[\frac{\partial u}{\partial z}\right]_B = \frac{u_C - u_A}{2dz}$

The curvature at point B is: $\left[\frac{\partial^2 u}{\partial z^2}\right]_B = \frac{u_A + u_C - 2u_B}{dz^2}$

Using the above equation for the curvature at point B and relating it to the one dimensional, partial derivative, consolidation equation:

$$C_v \frac{\partial^2 u}{\partial z^2} = \frac{\partial u}{\partial t},$$

and the excess pore water pressure at point B can be expressed as:

$$\left[\frac{\partial^2 u}{\partial z^2}\right]_B = C_v \frac{u_A + u_C - 2u_B}{dz^2}$$

Then by integrating the previous equation over the period of *t* to *t* +*dt*, the change in pore water pressure at point B is evaluated by the following equation:

$$du_B = dq_B + \frac{C_v}{dz^2} \int_t^{t+dt} \left(u_A + u_c - 2u_B\right) dt$$

The integral in the previous equation is approximated by assuming the integral of the time function over the time step is approximately equal to the function of *t*, multiplied by the time step (trapezoid method) which is graphically represented in Figure below.

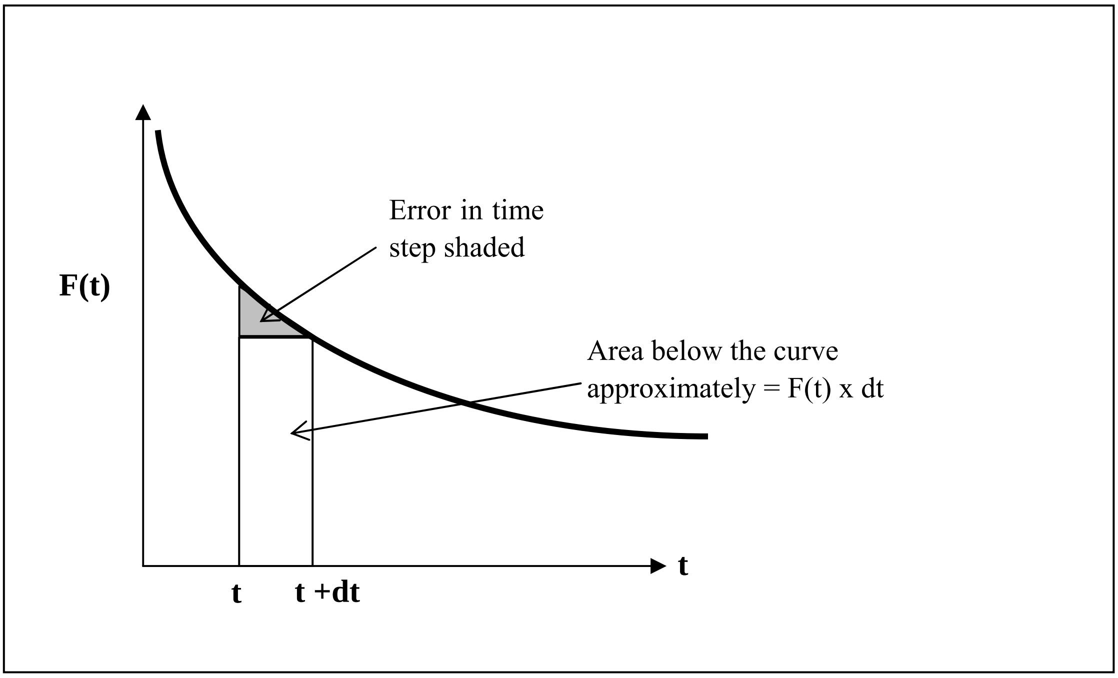


Figure 4.4 Trapezoidal method of estimation of the integral of F(t)

In its simplified form the equation then can be expressed as:

$$u_B(t+dt) = dq_B + \beta[u_B(t) + u_C(t) - 2u_B(t)]$$

Where: $\beta = \dfrac{C_v \Delta t}{\Delta z^2}$

For the case where the lower boundary being considered impermeable the above equation is further simplified to:

$$u_B(t+dt) = dq_B + \beta[u_A(t) + u_C(t)]$$

There is a stability issue with the use of the above equation. The condition if not adhered to will become unstable with the results being invalid.

The stability condition to be followed is:

$$\beta = \frac{C_v \Delta t}{\Delta z^2} \leq 0.5$$

The results for the excess pore pressure dissipation rate is dependent on the flow path distance to a permeable boundary for expulsion of the pore water and subsequent increase effective stress required for induce settlement.

For the boundary condition of:

- Lower boundary (Open Cut base) is assumed impermeable
- Upper boundary (Interface of tailings deposit and rock drainage mattress) assumed permeable

At the assumed impermeable boundary $\frac{\partial u}{\partial z} = 0$, as there can be no water flow across this boundary (Refer Figure).

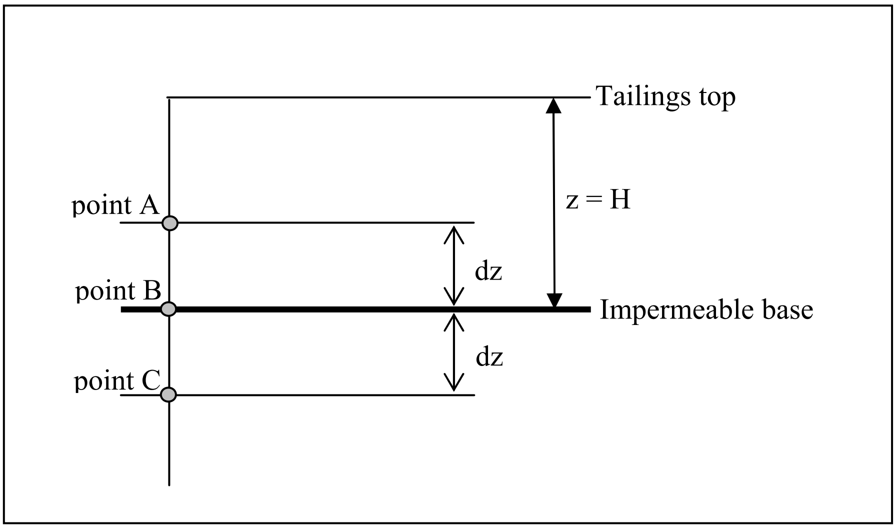


Figure 4.5 Impermiable boundary condition allowance

With reference to Figure , using the finite difference approach and letting $\beta = 0.5$:

At point B, $\frac{\partial u}{\partial z} = 0 = \frac{u_C - u_A}{2dz}$

Then: $u_A = u_C$ must be the resulting case

Therefore it is necessary to place a fictitious point (point C in Figure 4.5), below the impermeable base point for the progression of the finite difference approximation of the excess pore water pressure through time and layer depth.

The equation for estimation of the settlement magnitude (S), with constant m_v and q then becomes:

$$S = \int_0^H m_v (q - u)\, dz = m_v q H - m_v \int_0^H u\, dz$$

Since the finite difference method evaluates the excess pore pressures at specified points in time and space on an established grid system, the integral of *u* can not be evaluated exactly however the trapezoidal approximation method as described previously can be used as follows:

$$\int_0^H u\, dz \approx 0.5(u_0 + u_1)dz + ... + 0.5(u_{n-1} + u_n)dz$$

4.4 Settlement model material properties discussion

As described previously the geotechnical data collected prior to the rehabilitation works for the processed tailings material placed into Dyson's Open Cut was sparse. The geotechnical investigation did not include any compression or consolidation testing for the assessment of soil volume change behaviour. Further, the surface area spread of the investigation on the in situ tailings material within the Cut was confined to the likely location of the courser, more stable (less compressible) material. Therefore, the finer grained, more compressible tailings material was neglected. What can realistically be gained from the geotechnical data recorded for the tailings material is that its shear strength is very low, suggesting an even lower shear etrength characteristic for the fine grained, slurry tailings of interest. Coupled with this lack of soil property knowledge, depths of the materials that existed and placed within the Cut at the time of construction were not recorded and therefore unknown. Therefore, an estimation of the overburden pressures placed on the tailings layer was required.

Soil properties that can be considered essential to utilising any settlement model are generally derived from various compression and consolidation testing methods. Such volume change behaviour parameters tested for are:

- Permeability (k)
- Void ratio (e)
- Compression index (C_c)
- Coefficient of consolidation (C_v)
- Coefficient of volume compressibility/decrease (m_v)

None of the above soil volume change parameters were investigate for with regard to the tailings material placed below the landform. Therefore, representative, typical or assumed values are required for input to the model for settlement evaluation. A discussion on the possible use of typical volume change parameters follows.

Typical values of m_v for the general soil types, presented in Smith (1990) are reproduced in Table 4.1.

Soil Type	m_v range (m^2 / kN)	
	from	to
Peat	0.01	0.002
Plastic clay (normally consolidated alluvial clays)	0.002	0.00025
Stiff clay	0.00025	0.000125
Hard clay	0.000125	0.0000625

Table 4.1 Typical soil type coefficient of compressibility values (Smith C N, 2000). pg. 333

With reference to Figure 4.1 above, the coefficient of volume compressibility for the fine grained tailings material in Dyson's Open Cut are likely to fall into the large range of values attributed to the Plastic clay or Peat soil types. The values in the above table are usefull for identifying gross errors of the coefficient only.

Since the permeability of a soil depends on the soils porosity, which in turn is related to the soils particle size distribution (PSD), an estimate of the soils permeability can be arrived at using the soils PSD data.

Hazen (1892) proposed the following emperical formula to estimate the permeability of a soil based on its PSD data:

$$k = 10D_{10}^2 \; mm/s$$

Where: D_{10} = effective size in *mm* (largest size of the smallest 10%).

Using the above equation it is possible to determine an approximate value of permeability for the reported sandy silt and silty sand tailings material using the PSD data in McNamara C, (1984) (Refer Appendix C). However the particle size analysis was restricted to the the smallest sieve aperture of 0.075 mm used. The sample percentage passing (for both soils) the 0.075 mm sieve were greater than the 10% required by the Hazen formula. However, to illustrate the inaccuracy of using this formula the formula results are presented in Table 4.2.

Tailings source	Soil Classification	% retained on 0.075mm sieve	k (Hazen 1892)
Old tailings dam	Sandy Silt	63.3	$5.625*10^{-5}$
Dyson's Open Cut	Silty Sand	28.5	$5.625*10^{-5}$

Table 4.2 Dyson's tailings estimated permeability from Hazen approximation equation

Comparing the values in Table 4.2 to typical values of permeability for general soil types presented in Table 4 (Smith, 1990), The permeability value returned by the equation at the boundary of the fine sand, course silt permeability range. Given, that the percentage of the material passing the 0.075 mm sieve was also well in excess of the 10% required suggests the permeability for both soils is well below that calculated. Therefore the emperical equation is of no real use in this case.

Soil Type	Permeability Range (k) (*m/s*)
Gravel	$>10^{-1}$
Sands	$10^{-1} – 10^{-5}$
Fine Sands, Course silts	$10^{-5} – 10^{-7}$
Silts	$10^{-7} – 10^{-9}$
Clays	$< 10^{-9}$

Table 4.3 Typical values of soil type permeability (Smith G N, 1990) pg 47

From Table 4 above, the saturated fine grained tailings of interest would likely fall in to the silts and clays soil types values. These values while usefull for identifying gross error, are of little use for determining a representative permeability value for the tailings.

Another possible method to attribute reasonable soil property values for the fine tailings in Dyson's open Cut is to evaluate the reported properties of Uranium tailings at other mine sites to which rehabilitation and or rehabilitation studies have commenced. One such mine site is the former Uranium mine in Eastern Thringia, Germany. The Culmitzsch A tailings impoundment, itself a former open cut, received milled tailings between the years 1967 and 1991. (Wels, 2000)

A portion of the averaged laboratory test results to determine the geotechnical properties of the impounded tailings documented in Wels C, (2000) are presented in Table . The laboratory tests were performed on undisturbed samples retrieved through an extensive drilling program. The tailings material were classified into two main types, course tailings and clay rich tailings as follows:

1. Clayey Typically 50-60% clay sized particles (diameter < 0.006mm)
2. Silty sands Typically < 20% silt sized particles (diameter < 0.06mm)

Tailings Type	Description	Water content	Void Ratio	Attergerg limits		Plasticity Index	Shear strength
		w	e	w_P	w_L	I_P	(kN/m²)
Clayey variety	Average	0.851	2.437	0.258	0.657	0.399	12
	Max.	0.366	1.034	0.178	0.366	0.182	0
	Min.	1.621	4.788	0.293	0.846	0.553	42
Sandy variety	Average	0.248	0.774	0.181	0.354	0.167	20
	Max.	0.176	0.549	0.169	0.316	0.138	8
	Min.	0.405	1.186	0.195	0.391	0.195	35

Tailings Types	Description	Compression index C_c	Coefficient of Consolidation (C_v) m²/s		Hydraulic Conductivity (k) m/s
			Stress =47kPa	Stress = 174kPa	
Clayey variety	Range	0.6 - 0.8	2 - $7*10^{-7}$	1 - $9*10^{-7}$	$2*10^{-9}$ - $6*10^{-6}$
	Void ratio	1.2 - 3.2	1.4 - 2.9	1.3 – 2.1	0.9 – 3.0
Sandy variety	Range	0.02 - 0.08	$3*10^{-7}$ -$1*10^{-6}$	$3*10^{-7}$ – $1*10^{-6}$	$9*10^{-7}$ – $3*10^{-5}$
	Void ratio	0.7 - 0.9	0.5 - 0.9	0.5 – 0.9	0.6 – 1.2

Table 4.4 Part Summary of geotechnical properties of tailings in Culmitzsch A (Wells, 2000)

The values in Table show a large difference between the sandy and clayey tailings. The range of property values for each variety are also large but may be of some use in arriving at an estimate C_v of the tailings in Dyson's for use in modelling consolidation settlement.

The hydraulic conductivity values (k), in Table , for the clayey tailings variety were derived from the standard permeameter test and were considered unreliable so further tests were conducted using a specially designed slurry consolidometer (Wells, 2004). The results of this testing are shown in Table .

Void Ratio (e)	Permiability or Hydraulic Conductivity (k) (m/s)
4.0	$4 – 7*10^{-7}$
3.0	$3 – 5*10^{-8}$
2.0	$2 – 4*10^{-9}$
1.5	$3 – 6*10^{-10}$

Table 4.5 Estimated k-e relationship of clayey tailings (Wells C, 2000)

Comparing the two sets of values for k, the results in Table show a similar permeable soil for the void ratio range than those reported in Table .

Another former Uranium mine of interest is the Cluff Lake Uranium mine in Canada which ceased operation in 2002. Settlement studies have been conducted with regard to the fine grained tailings placed within in a raised embankment facility lined with an impervious clay base. Dykes separate the courser sandy type tailings and the finer grained, sludge type tailings. Full scale test plots of approximately 50m by 50m were constructed and settlement due to controlled cover placement was monitored via survey control points and bore holes housing piezometer nests for pore water pressure assessment within the plots. The data collected was used to determine estimates of the coefficient of consolidation and compression index using the theory of one dimensional consolidation. The values reported are presented in Table 4.6. (Hinshaw L, 2004)

Consolidation Parameter	Average	Minimum	Maximum
Coefficient of Consolidation (C_v) (m^2/day)	0.024	0.020	0.028
Compression Index	2.07	1.48	2.73

Table 4.6 Average Cv & Cc values for Cluff Lake tailings test plots (Hinshaw, 2004)

A Comparison of the C_v results from the above two tables is presented in Table :

Table	Void Ratio Range	Fine Tailings C_V Values		
		m^2/s	m^2/day	$m^2/year$
4	1.3 - 2.1	$1*10^{-7}$	0.009	3.154
4		$2*10^{-7}$	0.017	6.307
4		$3*10^{-7}$	0.026	9.461
4		$4*10^{-7}$	0.035	12.614
4		$5*10^{-7}$	0.043	15.768
4		$6*10^{-7}$	0.052	18.922
4		$7*10^{-7}$	0.060	22.075
4		$8*10^{-7}$	0.069	25.229
4		$9*10^{-7}$	0.078	28.382
Average	**1.7**	$5*10^{-7}$	0.043	0.078
6		$2.8*10^{-7}$	0.024	8.760

Table 4.7 comparison of fine grained tailigs C_v values from Table & Table

The above discussion of general soil Uranium derived tailings geotechnical properties, essentially means that representative values of k, e, C_c, C_v or m_v for Uranium ore derived tailings can not be arrive at. This is mainly due to factors such as the varying ore properties and the processing method that the tailings were derived from. Other factors such as temperature, pore water chemistry, physiochemical interactions, chemical precipitate induced particle cementation will contribute to variability (Mitchel, 2000).

4.5 Estimated material layer depths within the Cut and final landform overburden stress

Due to the sloping nature of Dysons landform the fill material placed over the full tailings area, within the Cut's confines varies in depth spacially. Therfore the value of the total load stress applied at the surface of the tailings also varies spacially. Excluding the cover materials of fill zones 1A, 1B, 2A and the rock blanket, historical records of the fill material depths, in any section of the constructed landform were not obtainable. Therefore, a reasonable estimate of placed fill depths (at the location of maximum observed settlement) was required for the calculation of the total stress, as applied to the surface of the tailings layer.

From the historical records obtained the tailings materials were placed to a maximum height of one meter below the Cut's rim, at its lowest point (Allen & Verhoeven, 1986). The final maximum excavated depth was documented as 45.7m (Davey, 1975 & Verhoeven, 1988). However no datum was linked to the above measures for quantifying of the tailings thickness. Therefore, the maximum drainage path for the one dimensional consolidation equation is not readily obtainable. Resulting from the above, a basic estimate of the material thicknesses was required for input to the settlement model. The method is described in the following:

4.5.1 Estimate of total stress to tailngs material at the location of maximum settlement

Working from the surface of the landform down through the stratum the following material thickness and associated stress loadings were estimated.

The contribution of the uppermost cover to the total load stress as applied to the tailings layer were calculated using average soil density data from in situ testing conducted at the time of construction (Dames & Moore, 1985). (Refer Table 4.8)

Material Description	Averged Placed Thickness (m)	Averaged in situ Density (kg/m^3)	Resulting Averaged Load Stress (kPa)
Zone 2A	0.170	2250	3.752
Zone 1B	0.350	1980	6.798
Zone 1A	0.380	1840	6.823
Totals	**0.900**		**17.373**

Table 4.8 Determination of cover material load stress

The bulk of the fill material placed between the cover and tailings layers came from two main sources:

1. The Copper Heap Leach Pile (CHLP)and associated contaminated subsoil
2. The Old Tailings Dam (OTD) contaminated subsoils

As described previously the CHLP and OTD materials were placed in an alternate sequence of 1000mm and 300mm thickness respectively (McNamara, 1984). The average, in situ material densities reported in Dames & Moore (1985) were used to determine the load stresses for the specified material thickness (Refer Table 4.9)

Material Description	Specified Placed Thickness (m)	Averaged in situ Density (kg/m^3)	Resulting Averaged Load Stress (kPa)
CHLP	1.000	1980	19.424
OTD	0.300	1870	5.503
Totals	**1.300**		**24.927**

Table 4.9 Determination of fil material load stress

An estimate of the total thickness of the layered CHLP and OTD material placed was calculated using the 2008 survey data, 1986 contour map and documented historical observations. The reduced level of the maximum settlement area from the 2008 survey data was averaged at RL 80.5m. The observed settlement of 2000 *mm* (between 1986 and 2008) and the recorded 900 *mm* settlement documented wihin the first 1.5 years from the landforms completion (Allen & Verhoeven, 1986) result in a 2.9m total settlement. Therefore, the original reduced level at the current depressed site was calculated at RL 83.4 *m*.

The top surface of the tailings within the pits confines was reported to be 1 *m* the rim of the original Cut, at its lowest point (Allen & Verhoeven, 1986). Inpectiing the 1986 contour survey and historical photographs the reduced level of the Cuts rim was estimated at RL 75 *m*. Therefore the reduced level of the placed tailings material was RL 74 *m*. Neglecting the rock blanket material the thicknes of the fill material was:

$$83.4m - 0.9m - 74m = 8.5m$$

The total load stress from the CHLP and OTD material then became:

$$\frac{8.5m}{1.3m} \times 24.927kPa = 162.984\ kPa$$

The estimated total applied load stress upon the tailings material was:

$$17.373kPa + 162.984kPa = 180.375\ kPa$$

4.5.2 Estimate of the tailings thickness

The assumption was made that the Datum used for the reported maximum Cut depth of 47.5 *m* (Allen & Verhoeven, 1986) coincided with the lower lip of the Cut which gave the reduced level of the base at:

$$75m - 47.5m = RL\ 27.5m$$

Therefore the maximum thickness of the tailings was estimated as 46.5 *m*

4.6 Consolidation settlement model, results and discussion

Settlement due to one dimensional consolidation was estimate using the numerically method with constant (C_v) which implies constant values (k) and (m_v)

The model is restricted to the area of the largest observed settlement, near to the centre of the Cut and at the assumed deepest section of the original excavation. As estimated previously this is the likely site of the finer grained tailings, slime and sludge components of the tailings material of which a high value of compressibility is assumed.

The finite difference method described previously was applied to the one dimensional consolidation equation using a Microsoft Office Excel spreadsheet to calculate the excess pore pressure and settlement. A plot of the settlement variation over the consolidation time period was produced using model rsults. The model input values were:

Applied instantaneous load stress = 180.375 kPa

Tailings depth = 46m

Consolidation duration = 22 years

The coefficient of consolidation (C_v) was arbitrarily chosen from the data in Table 4.7 $C_v = 8.5m^2/year$

dt = 0.055 years

dz = 1m

Betta = 0.4675 < 0.5

These values were used in the model equation and the value of m_v was changed until the current, estimated total observed settlement value of 2.9 m was returned for the period of 22 years. A representative portion of the data is included in Appendix D and the plot of settlement against time is presented in Figure .

The final value of m_v was equal to 0.00104 m^2/kN, which is comparable to the value range of normally consolidated alluvial clays in Table 4.1. The permeability coefficient (k) can be calculated with manipulation of the equation from Terzarghis theory of one dimensional consolidation:

$$C_v = \frac{k}{\gamma_w m_v}$$

Taking the unit weight of water as 9.81 kN/m^3, the k coefficient is calculated as 0.0867 m/year or 2.75×10^{-9} m/s and is a plausable value on comparison to those in Table .

The observed maximum settlement of the landform surface after approximately a 1.5 year time lapse from construction completion was reported to be 900mm (Allen & Verhoeven, 1986). This observed value compared well with the approximate 800mm settlement value returned by the model for the same elapsed time (Refer Appendix D). This 100mm settlement difference suggests a reduced pore water dissipation rate in the model. The plot in Figure 4.6 describes the decreasing rate of settlement over time as expected. The slope of the curve also suggests that settlement due to consolidation has a long way to go before excess pore pressures are full dissipated and equilibrium is achieved (volume change due to consolidation ceaseing).

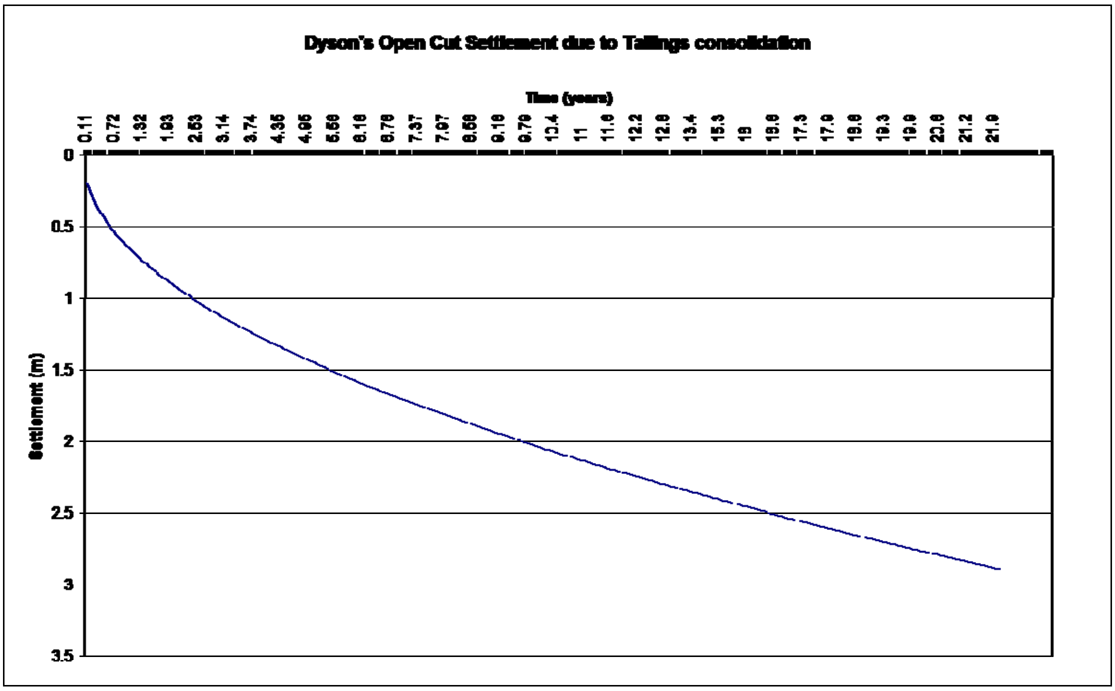


Figure 4.6 Plot of one dimensional consolidation settlement against time.

4.6 Discussion of the model deficiencies

The model and results presented showed that if the all the assumptions and input parmeters are in fact correct the predicted settlement agrees well with the observed settlement. However this condition is highly unlikely to exist. In many cases the predictions of volume change settlement and the rate at which it occurs based on the above simple theory yields inaccurate results (Mitchell, 1993). The potential for a reasonable settlement agreement are reduced due to the compounding affect of the following many reasons.

- The inherent assumptions that form the basis of Terzarghis one dimensional consolidation equation are not representative of the realistic process;
    - The void ratio-effective stress relationship is not linear
    - Void ratio decreases with volume change
    - Permeability decreases with decreasing void ratio
    - Coefficient of volume decrease is not constant with respect to time nor depth in the layer.
    - The tailings material not likely homogenous through the full layer depth

- The saturated soil condition may not be the case for the full 22 year time period
- Soil creep (secondary compression) is not considered
- Self weight of the material within the layer is at no time considered to contribute to effective pressure through the layer depth.

- Errors associated with the Finite difference equation and Trapezoidal approximation method.
- Many potentially inaccurate assumptions were made with respect to fill material thicknesses for determining the constant load stress place on the tailings
- High potential inaccuracy of the tailings thickness estimate and distance to permeable drainage surface.
- Potential inaccurate assumption of an impervious base and one way drainage during consolidation as the potential pervious nature of the Cut base, due to the documented geological fault system was ignored.
- Limited Geotechnical investigation data of the tailings material. Characteristics for estimating deformation behaviour of the finer saturated material were not investigated resulting in assumed input values
- Two and three dimensional stress and drainage effects may be substantial.

Chapter 5 – Conclusion

The specific objective of the project was not met. The comparison of model predicted consolidation settlement to the measured actual long term subsidence of the rehabilitated, Dysons Open Cut at Rum Jungle Mining Lease could not be achieved the lack of geotechnical data. However several associated outcomes have been achieved. The settlement of the Dysons rehabilitated landform between the years 1986 and 2008 has been quantified with good accuracy given that actual historical XYZ survey data could not be found and an existing contour map had to be used. The major characteristics that will influence the potential instability of a landform constructed above a layer of impounded tailings are now better understood. Also Terzaghis one dimensional consolidation model was successfully calibrated using a combination of field survey to measure settlement and published geotechnical properties. The knowledge gained from this study could be used for improvement of other mines future investigations and design of stable capping structures. Further, The investigation process has identified the areas to which further work is necessary to complete the project (described in the following section).

Chapter 6 - Further work Required

The major limiting factors influencing a realistic comparison of model predicted settlement to the observed settlement at Dysons is the limited knowledge of the tailings geotechnical characteristics.

The geotechnical characteristics can be investigated by developing and implementing a drilling program that recovers relatively undisturbed tailing samples for laboratory testing. This drilling program has the potential to yield many beneficial outcomes such as:

- The soil stratum could be mapped quantifying layer depths both in the landform and the tailings.
- The volume change behaviour of the tailings would be better understood through laboratory testing of the samples recovered.
- Toxicity analysis's can be performed on the samples to better understand and assess the environmental risks existing at the site.
- The process by which further settlement occurs can be determined by installing piezometers in the bore holes on completion of sampling and pressures monitored. The excess pore water pressures then may be monitored over an extended period of time. If the recorded pressures remain relatively constant, futher settlement may be attributed to secondary compression alone and the consolidation process completed. The pore pressure information could then be used in developing a more realistic settlement model.
- Water pressure data could be compared to data from the adjacent bores to determine the the true flow path boundary coditions.
- Water toxicity could be monitored within the landform and tailings layers via installed probes and/or a water sampling program.
- Armed with even some of the above outcomes investigations into using or developing a more accurate settlement model could then commence.

Appendices

A. **Project Specification**

B. **Site Photos and maps**

C. **Tailings material geotechnical data**

D. **Model data results & 2008 Survey Data**

Appendix A - Project Specification

University of Southern Queensland

Faculty of Engineering and Surveying

ENG4111/4112 Research Project

Project Specification

For: Richard John Houghton

Topic: Assess impact of tailings subsidence on rehabilitated landform erosional stability

Supervisor: Jim Shiau

Ken Evans, ERISS

Enrolenent: ENG 4111 – S1, D, 2008

ENG 4112 – S2, D, 2008

Project Aim: To estimate the likely extent of post-rehabilitation waste rock dump settlement as a result of tailings consolidation/subsidence and simulate the effects of settlement on long term erosion using landform evolution modelling.

Specific objectives: Compare the predicted consolidation settlement to the measured actual long term subsidence of the rehabilitated, Dysons' open cut pit at Rum Jungle Mining Lease. If the predicted and actual subsidence rates do not agree an investigation into modifying the prediction model parameters and apply for an agreement with actual measured subsidence will be performed.

Sponsorship: Department of the Environment, Water Heritage and the Arts

Environmental Institute of the Supervising Scientist (ERISS)

Programme:

1. Through the detailed documentation of the rehabilitation of Rum Jungle Mineincluding material characteristics, survey information, engineering design and construction methods a simple theoretical model will be presented to estimate the subsidence of the landform due to consolidation. The adequacy of this model can be tested against the measured actual subsidence that has occurred at this same site. If the theoretical model calculations agree with actual measured subsidence, the model can be said to be of good reliability.
2. A current site level survey will be performed and compared to the rehabilitated, as constructed survey for the total subsidence value. At the time of writing, the location of post site rehabilitation survey data has not been found although the

monitoring reports listed above make mention of them being performed. However an as-constructed design diagram is contained in the final rehabilitation report (Allen C & Verhoeven T, June 1986). When these surveys are located it may be possible to determine an actual subsidence rate curve.

3. An attempt will be made to build a relatively simple model to predict the actual settlement at Dysons' Pit, investigating parameter manipulation such as modifying exponent values.

4. In addition an investigation into commercially available computer models will be undertaken testing for predicted and actual subsidence agreement at Dysons' Pit.

As Time Permits:

1. Incorporate the results from the above consolidation model to estimate the evolutionary consolidated settlement of the rehabilitated, open cut pit N^{o}1, landform at the Ranger Mine which is due to begin rehabilitation in the near future.
2. Extend the application in Part 2 to the rehabilitation of pit N^{o} 3 which is currently being mined.
3. Estimate the erosion effects of this evolutionary subsidence stability of the proposed rehabilitated landform on the surrounding catchments.

Agreed:

________________(Student)________________ , _________________(Supervisors)

Examiner/Co-examiner:____

Appendix B - Site Photos and maps

B. 1 Location map of the Ranger Uranium Mine (Fourie & Tibbet, 2006)

B. 2 Rum Jungle mine site plan

B. 3 Dysons landform design

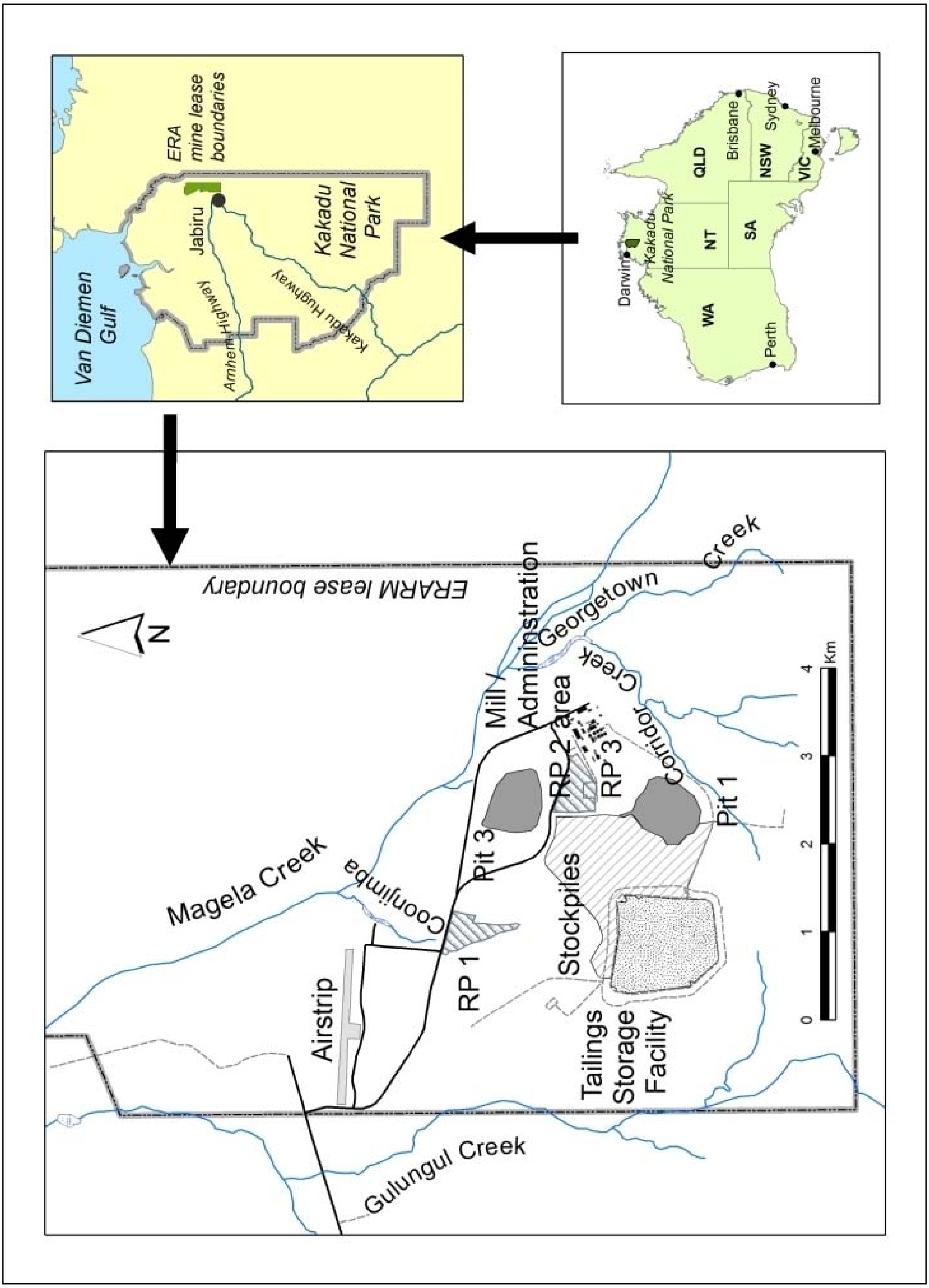
B. 4 Dysons Open Cut 1962 taken from Archives of Australia

B. 5 Dysons Open Cut 1958 taken from Archives of Australia

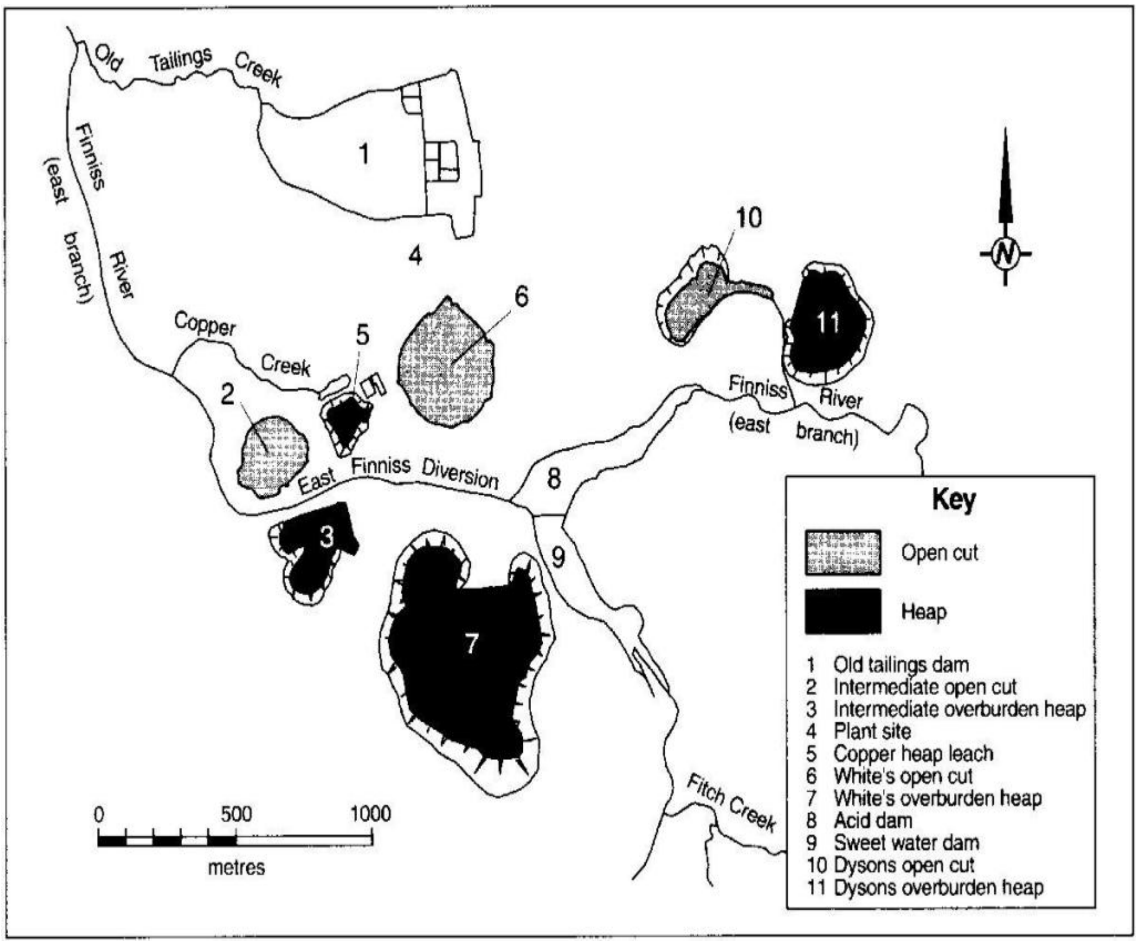
B. 6 Dysons Open Cut 1958 taken from Archives of Australia

B. 7 Dysons landform, evidence of monsoonal scour at site of maximum settlement, April 2008

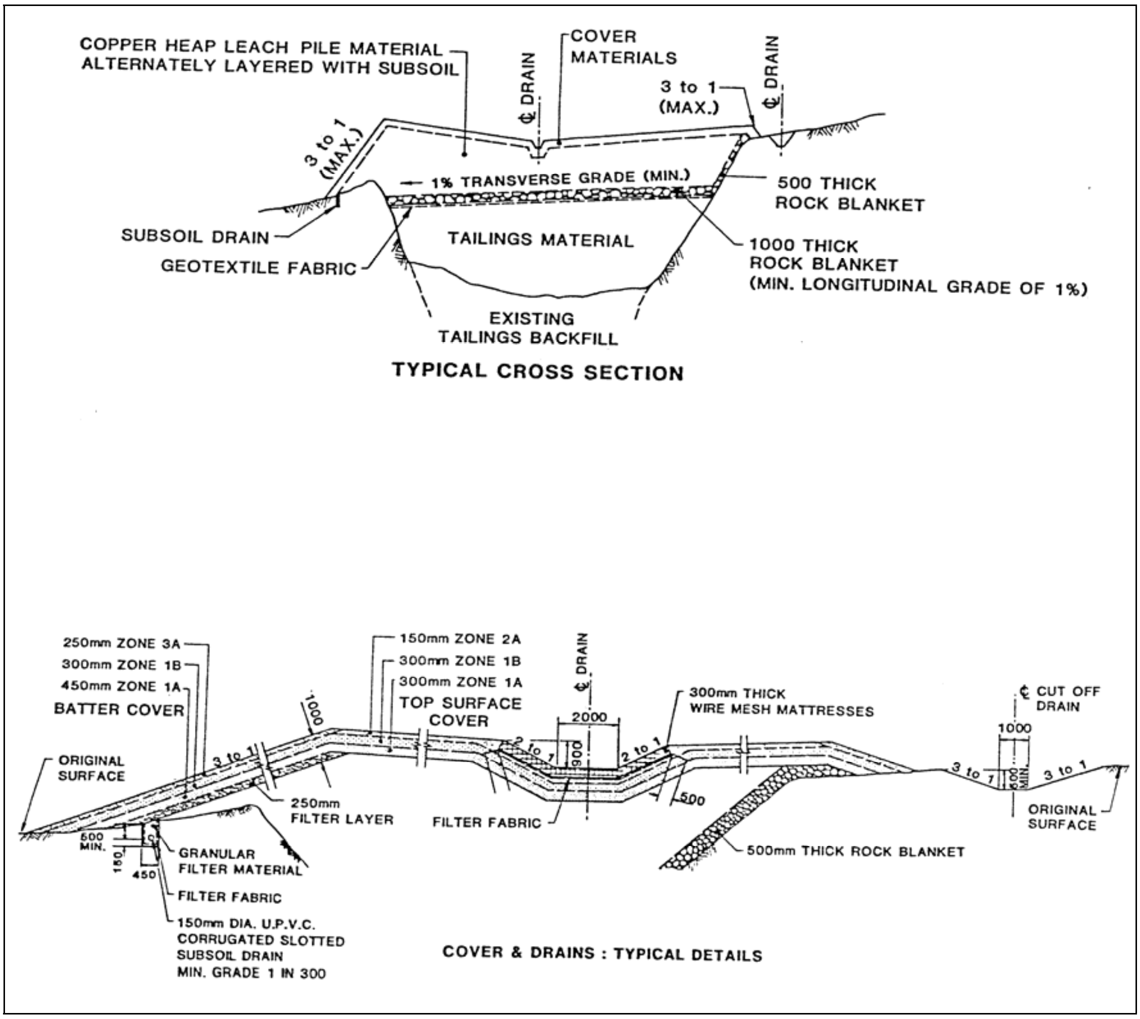
B. 8 Dysons landform, evidence of monsoonal scour at site of maximum settlement, April 2008



B. 1 Location map of the Ranger Uranium Mine (Fourie & Tibbet, 2006)



B. 2 Rum Jungle mine site plan



B. 3 **Dysons landform design**

B. 4 **Dysons Open Cut 1962 taken from Archives of Australia**

B. 5 Dysons Open Cut 1958 taken from Archives of Australia

B. 6 Dysons Open Cut 1958 taken from Archives of Australia

B. 7 Dysons landform, evidence of monsoonal scour at site of maximum settlement, April 2008

B. 8 Dysons landform, evidence of monsoonal scour at site of maximum settlement, April 2008

Appendix C - Tailings material geotechnical data

Dysons Open Cut Geotechnical data taken from McNamara, (1984)

C. 1 Dysons Cut soil tesing location plan

C. 2 Dysons existing, in cut tailings Atterberg Limits

C. 3 Dysons existing in cut tailings PSD data

C. 4 Old Tailings Dam PSD data

C. 5 Old Tailings Dam Atterburg Limits

C. 6 Old Tailings Dam Dynamic Penetrometer test results

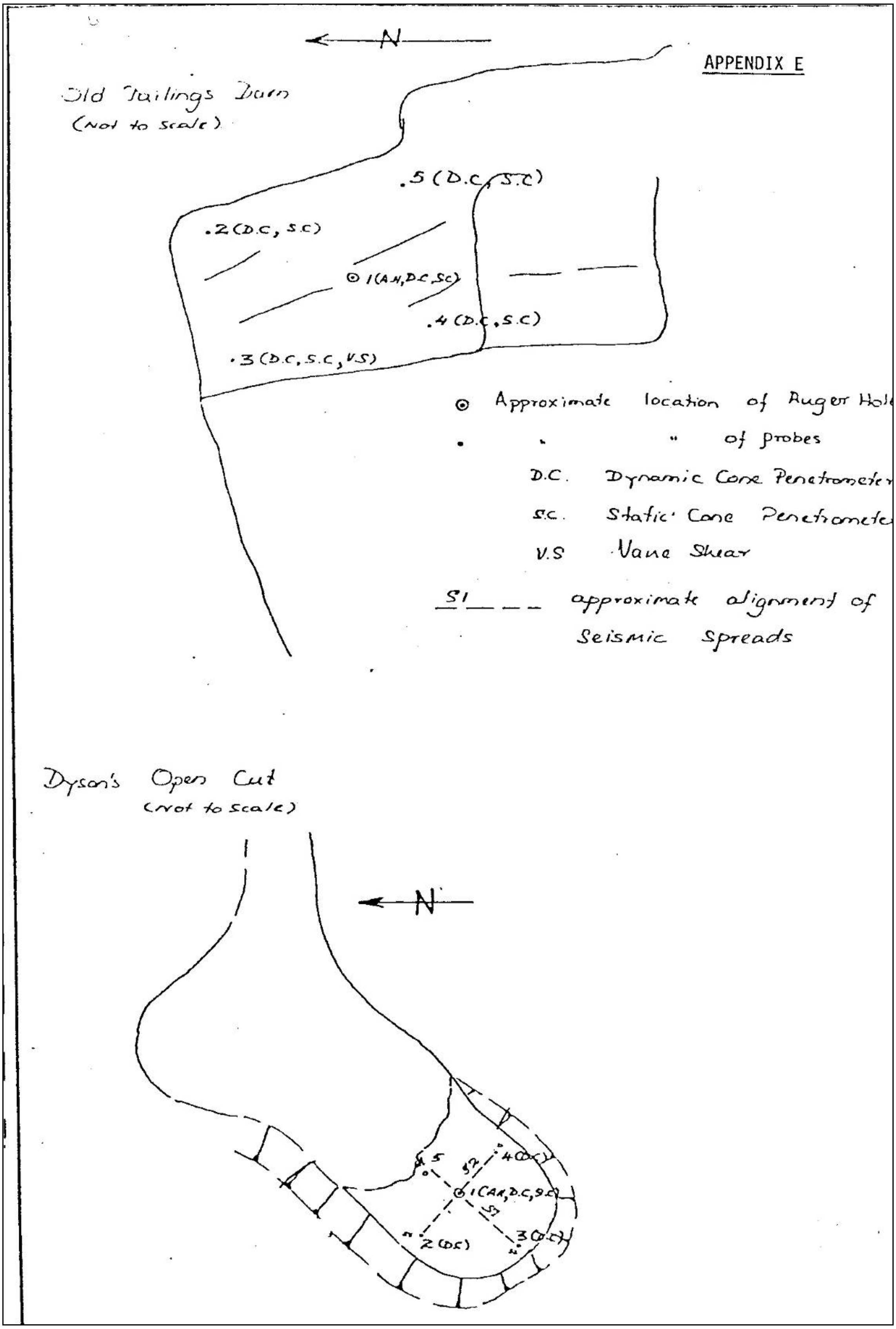
C. 7 Old Tailings Dam Dynamic Penetrometer test results

C. 8 Dysons Open Cut Dynamic Penetrometer test results

C. 9 Dysons Open Cut Dynamic Penetrometer test results

C. 10 Static cone penetrometer test results

C. 11 Old Tailings Dam in situ shear vane test results



C. 1 Dysons Cut soil tesing location plan

[illegible] & MOORE - CLASSIFICATION TESTS
AS 1289 B[illegible] 1, C1.1, C1 2, C2.1 and C4 1

APPENDIX E

Sub[illegible] by: U G	Client: A.EC	Lab Sample No: 6122
Date Sampled: 8/2/84	Project: Rum Jungle Stage 3	Client Sample No:
Date Tested: [illegible]	Sample Origin:	Job Number: 13137-004
Tested by: LB	AH.1 SH #1 DYSONS OPEN CUT 0.0-8.45	Work Item:

Sample Description: SANDY SILT

Method of Preparation:

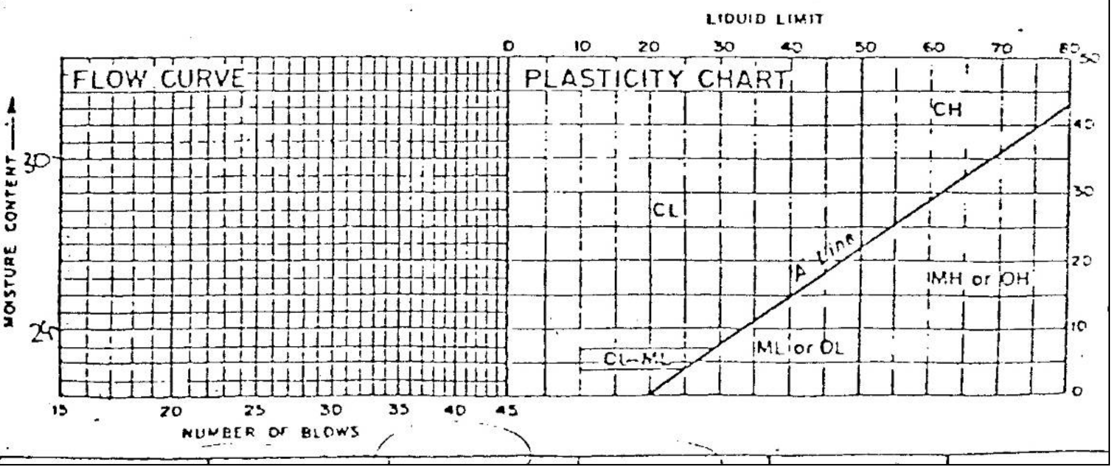
LINEAR SHRINKAGE		
Mould Number	[illegible]	#
Shrinkage distance	3.0	mm
Length of mould	250	mm
Percent shrinkage	1.2	%
Crumbling	Nil	
Curling	Nil	

FIELD MOISTURE CONTENT	
Dish Number	
Mass wet soil and dish	
Mass dry soil and dish	
Mass of moisture	
Mass of dish	
Mass of dry soil	
Moisture Content	

PLASTIC LIMIT			
Dish Number	[illegible] #	[illegible] #	#
Mass wet soil and dish	35.45 g	[illegible].76 g	g
Mass dry soil and dish	32.88 g	31.40 g	g
Mass of moisture	2.57 g	2.36 g	g
Mass of dish	[illegible] g	[illegible] g	g
Mass of dry soil	10.99 g	9.96 g	g
Moisture Content	23.38 ✓ %	23.69 ✓ %	%

Number of blows	Factor	Number of blows	Factor
15	0.95	26	1.00
16	0.96	27	1.01
17	0.96	28	1.01
18	0.97	29	1.02
19	0.97	30	1.02
20	0.98	31	1.02
21	0.98	32	1.03
22	0.99	33	1.03
23	0.99	34	1.03
24	1.00	35	1.03
25	1.00		

LIQUID LIMIT				
Dish Number	[illegible] #	111 #	119 #	[illegible] #
Number of blows	15	7		
Mass wet soil and dish	48.43 g	43.66 g	g	g
Mass dry soil and dish	43.56 g	39.79 g	g	g
Mass of moisture	4.87 g	3.87 g	g	g
Mass of dish	[illegible] g	[illegible] g	[illegible] g	26.3[illegible] g
Mass of dry soil	16.77 g	13.21 g	g	g
Moisture Content	29.04 ✓ %	29.30 ✓ %	%	%



C. 2 Dysons existing, in cut tailings Atterberg Limits

EAT. DRIED.

DAMES & MOORE
PARTICLE SIZE DISTRIBUTION
AS 1289 C6.1&2

APPENDIX E

Sampled by: UG.	Client: ~~[illegible]~~ Atomic Energy Comm		Lab Sample No: 6122
Date Sampled: 8/2/84.	Project: Rum Jungle Stage 3.		Client Sample No:
Date Tested: 13/2/84	Sample Origin: DYSONS OPEN CUT AH·1 S18 E11 0.0-0.45		Job Number: 13137-004
Tested by: AC			Work Item:
Sample Description:		Sample quantity did/did not comply with code	

Minimum Sample (g)	Max Mass On Sieve (g)	Sample / Subsample (g)	Sieve Aperture (mm)	Mass Retained (g)	Percent Retained (%)	Cumulative Percent Retained	Percent Passing (%)
125000	3750		200.0				
45000	3000		75.0				
20000	2750		53.0				
15000	2200		37.5				
10000	1800		26.5				
5000	1200		19.0				
2500	400		13.2				
1000	250		9.5				
500	200		4.75				100.
200	150		2.36	0.1	0.03,	0.03,	100,
200	100		1.18	5.1	1.7,	1.73,	98.
150	75		0.600	45.1	15.0,	16.73,	83.
50	60		0.425	39.4	13.1,	29.83,.	70.
50	50		0.300	47.1	15.6,	45.43	55,
50	40		0.150	55.7	18.5,	63.93,	36,
50	25		0.075	22.9	7.6,	71.53,	28.5.
			PAN	1.0	0.3,	∴ 28.7, ∴ fines washed out	·28

	Mass Soil+Dish	Mass of Dish	Mass of Soil		MOISTURE CONTENT	
		# 72				
Total Mass Retained 19.0mm				(g) M_1	FRACTION PASSING	..19.. mm
Mass passing 19.0mm				(g) M_2	Dish Number	82
Mass of subsample	566.3	265.1	301.2	(g) M_3	Mass wet soil and dish	359.4 g
Calculated dry mass subsample			301.2	(g) M_4	Mass dry soil and dish	328.6 g
Mass of washed/dried soil	480.8		215.7,	(g) M_5	Mass of moisture	30.8 g
Mass of fines washed out			85.5,	(g)	Mass of dish	79.4 g
Percent fines washed out			28.4,	(%)	Mass dry soil	249.2 g
Total mass of sample			301.2	(g) M_s	Moisture content	12.4 / %

$$M_s = \frac{M_4 \times M_2}{M_3} + M_1$$

Use this formula when there is coarse sieving carried out on a sample, followed by a subdivision, with a moisture content determination of a separate representative subsample of that subdivision.

When there is no coarse sieving and no subdivision before washing, then $M_4 = M_3$

$$\% \text{ Retained} = m_R \times \frac{100}{M_s}$$

This formula is used to calculate % Retained of masses retained in sieving before any splitting of the sample.

$$M_4 = \frac{M_3 \times 100}{(100 + M/C)}$$

$$\% \text{ Retained} = m_R \times \frac{M_2}{M_3} \times \frac{100}{M_s}$$

This formula is used to calculate % Retained of masses retained following subdivision of the sample after coarse sieving.

$M_4 = M_3$ when the sample is dried in the oven

REPORT NUMBER	CHECKED BY: RJ 13 FEB '84	SAMPLE NUMBER: 6122

C. 3 Dysons existing in cut tailings PSD data

EN · DRIED.

PARTICLE SIZE DISTRIBUTION

AS 1289.C6 1977

APPENDIX E

Submitted by: G.G.	Client: AEC.	Lab Sample No: 6124
Date Sampled: 8/2/84	Project: Rum Jungle Stage 3.	Client Sample No:
Date Tested: 13/2/84	Sample Origin: OLD Tailings Dam AH1 SA#2 0.5-1.0m	Job Number: 13137-006.
Tested by: AC.		Work Item:

Sample Description:

Sample quantity did/did not comply with code

Minimum Sample (g)	Max Mass On Sieve (g)	Sample / Subsample (g)	Sieve Aperture (mm)	Mass Retained m_R (g)	Percent Retained (%)	Cumulative Percent Retained	Percent Passing (%)
125000	3750		200.0				
45000	3000		75.0				
20000	2750		53.0				
15000	2200		37.5				
10000	1800		26.5				
5000	1200		19.0				
2500	400		13.2				
1000	250		9.5				
500	200		4.75				
200	150		2.36	—			100
200	100		1.18	0.2	0.07	0.07	100
150	75		0.600	0.3	0.1	0.17	100
50	60		0.425	0.3	0.1	0.27	100
50	50		0.300	1.0	0.4	0.67	99
50	40		0.150	33.9	12.3	12.97	87
50	25		0.075	65.4	23.7	36.67	63.3
			PAN	5.6	2.0	% fines washed out 63.7	63

	Mass Soil+Dish	Mass of Dish #63	Mass of Soil	MOISTURE CONTENT		
Total Mass Retained 19.0mm			(g)M_1	FRACTION PASSING	......	mm
Mass passing 19.0mm			(g)M_2	Dish Number	47	
Mass of subsample	630.9.	275.3	355.6 (g)M_3	Mass wet soil and dish	441.7.	g
Calculated dry mass subsample			276.2 (g)M_4	Mass dry soil and dish	381.3	g
Mass of washed/dried soil	381.1		105.8 (g)M_5	Mass of moisture	60.4	g
Mass of fines washed out			170.4 (g)	Mass of dish	91.1	g
Percent fines washed out			61.7 (%)	Mass dry soil	290.2	g
Total mass of sample			276.2 (g)M_5	Moisture content	20.8	%

$M_5 = \frac{M_4 \times M_2}{M_3} + M_1$ — Use this formula when there is coarse sieving carried out on a sample, followed by a subdivision, with a moisture content determination of a separate representative subsample of that subdivision.

When there is no coarse sieving and no subdivision before washing, then $M_4 = M_5$

$\% \text{ Retained} = m_R \times \frac{100}{M_5}$ — This formula is used to calculate % Retained of masses retained in sieving before any splitting of the sample.

$M_4 = \frac{M_3 \times 100}{(100 + M/C)}$

$\% \text{ Retained} = m_R \times \frac{M_2}{M_3} \times \frac{100}{M_5}$ — This formula is used to calculate % Retained of masses retained following subdivision of the sample after coarse sieving

$M_4 = M_3$ when the sample is dried in the oven

REPORT NUMBER	CHECKED BY RJ. 13 FEB 84	SAMPLE NUMBER 6124.

C. 4 Old Tailings Dam PSD data

DAMES & MOORE - CLASSIFICATION TESTS
AS 1289 B1.1, C1.1, C1.2, C2.1 and C4.1

APPENDIX E

Submitted by: G.G.	Client: A.E.C	Lab Sample No: 6124
Date Sampled: 8/2/84	Project: Rum Jungle Stage 3	Client Sample No:
Date Tested: 10/2/84	Sample Origin: OLD Tailings Dam.	Job Number: 13137-004
Tested by: RM	A.H 1 S/H # 2 0.5-1.0m	Work Item:

Sample Description:

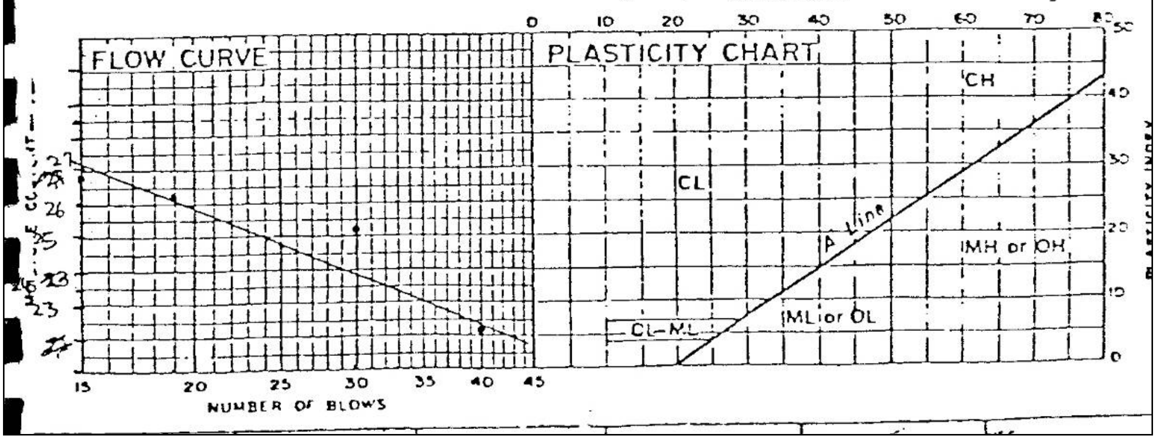
Method of Preparation:

LINEAR SHRINKAGE			FIELD MOISTURE CONTENT	
Mould Number	5	#	Dish Number	#
Shrinkage distance		mm	Mass wet soil and dish	g
Length of mould	254	mm	Mass dry soil and dish	g
Percent shrinkage	1.6	%	Mass of moisture	g
Crumbling	Nil		Mass of dish	g
Curling	Nil		Mass of dry soil	g
			Moisture Content	%

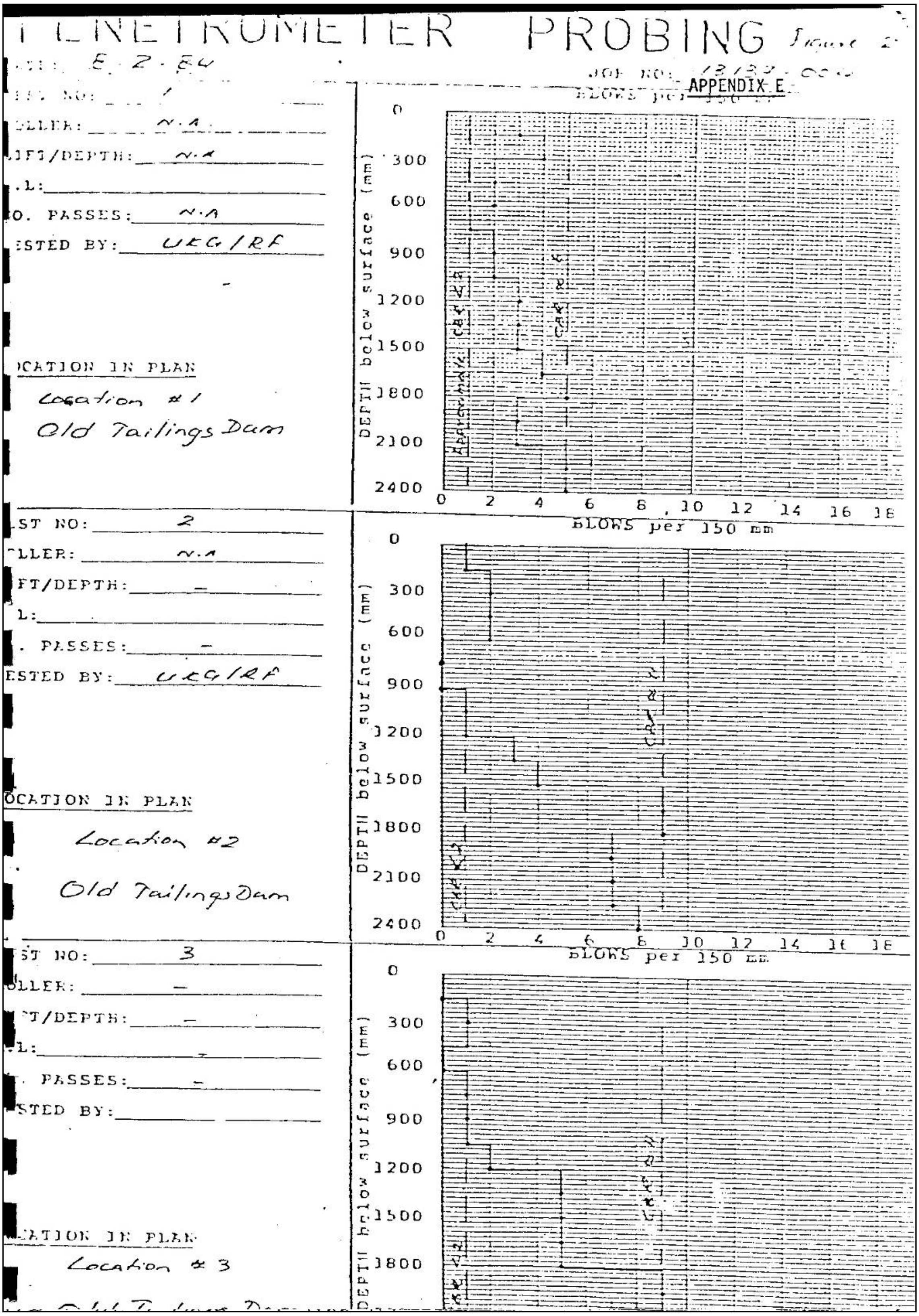
PLASTIC LIMIT			
Dish Number	146	151	
Mass wet soil and dish (g)	32.98	31.41	
Mass dry soil and dish (g)	31.19	29.84	
Mass of moisture (g)	1.79	1.57	
Mass of dish (g)	22.63	22.55	
Mass of dry soil (g)	8.56	7.29	
Moisture Content (%)	20.91 ✓	21.54 ✓	

Number of blows	Factor	Number of blows	Factor
15	0.95	26	1.00
16	0.96	27	1.01
17	0.96	28	1.01
18	0.97	29	1.02
19	0.97	30	1.02
20	0.98	31	1.02
21	0.98	32	1.03
22	0.99	33	1.03
23	0.99	34	1.03
24	1.00	35	1.03
25	1.00		

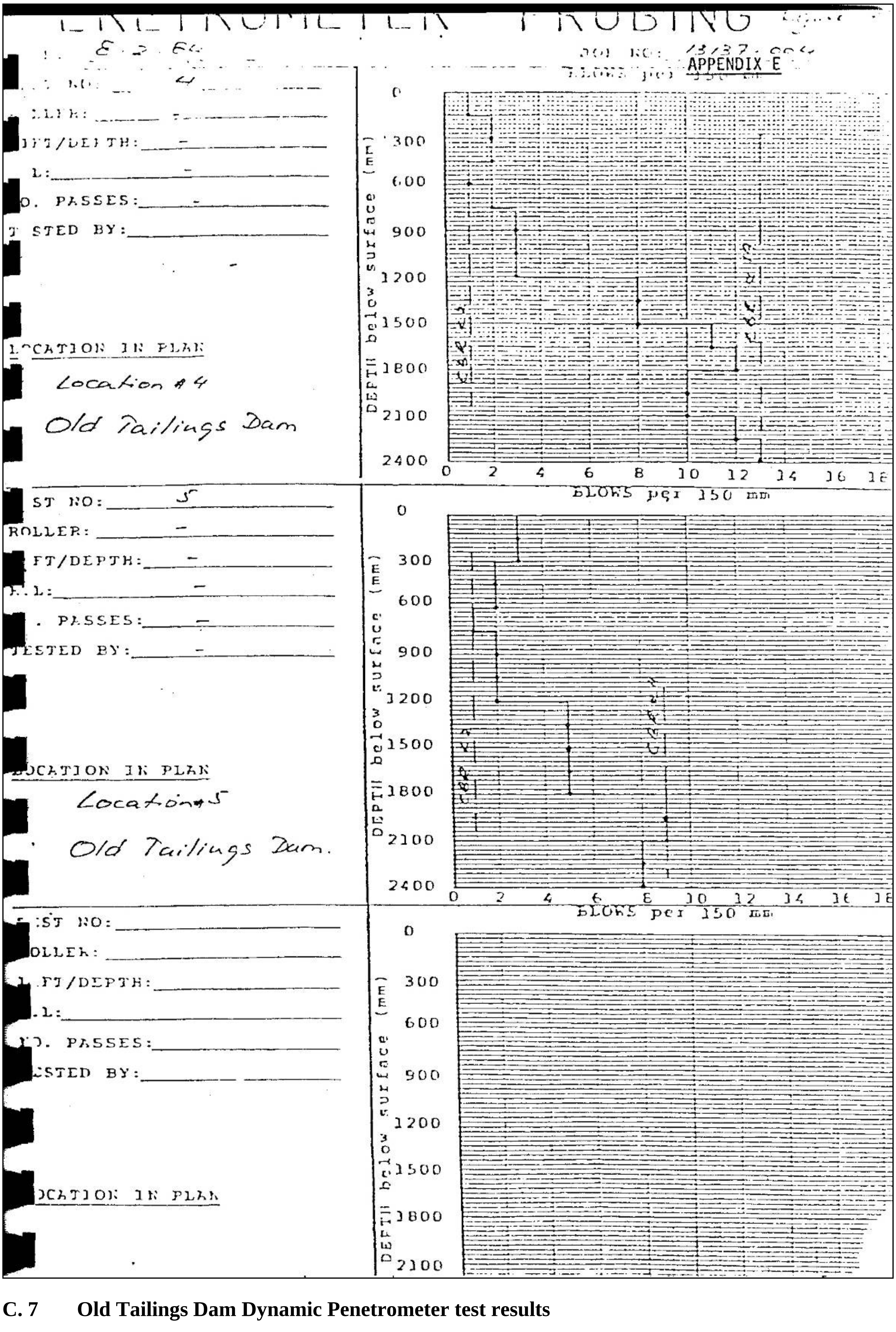
LIQUID LIMIT				
Dish Number	117	104	105	107
Number of blows	40	30	19	15
Mass wet soil and dish (g)	54.41	52.26	52.08	50.60
Mass dry soil and dish (g)	49.52	47.15	46.77	45.39
Mass of moisture (g)	4.89	5.11	5.31	5.21
Mass of dish (g)	27.67	26.80	26.65	26.06
Mass of dry soil (g)	21.85	20.35	20.12	19.35
Moisture Content (%)	22.38 ✓	25.11 ✓	26.39 ✓	26.93 ✓



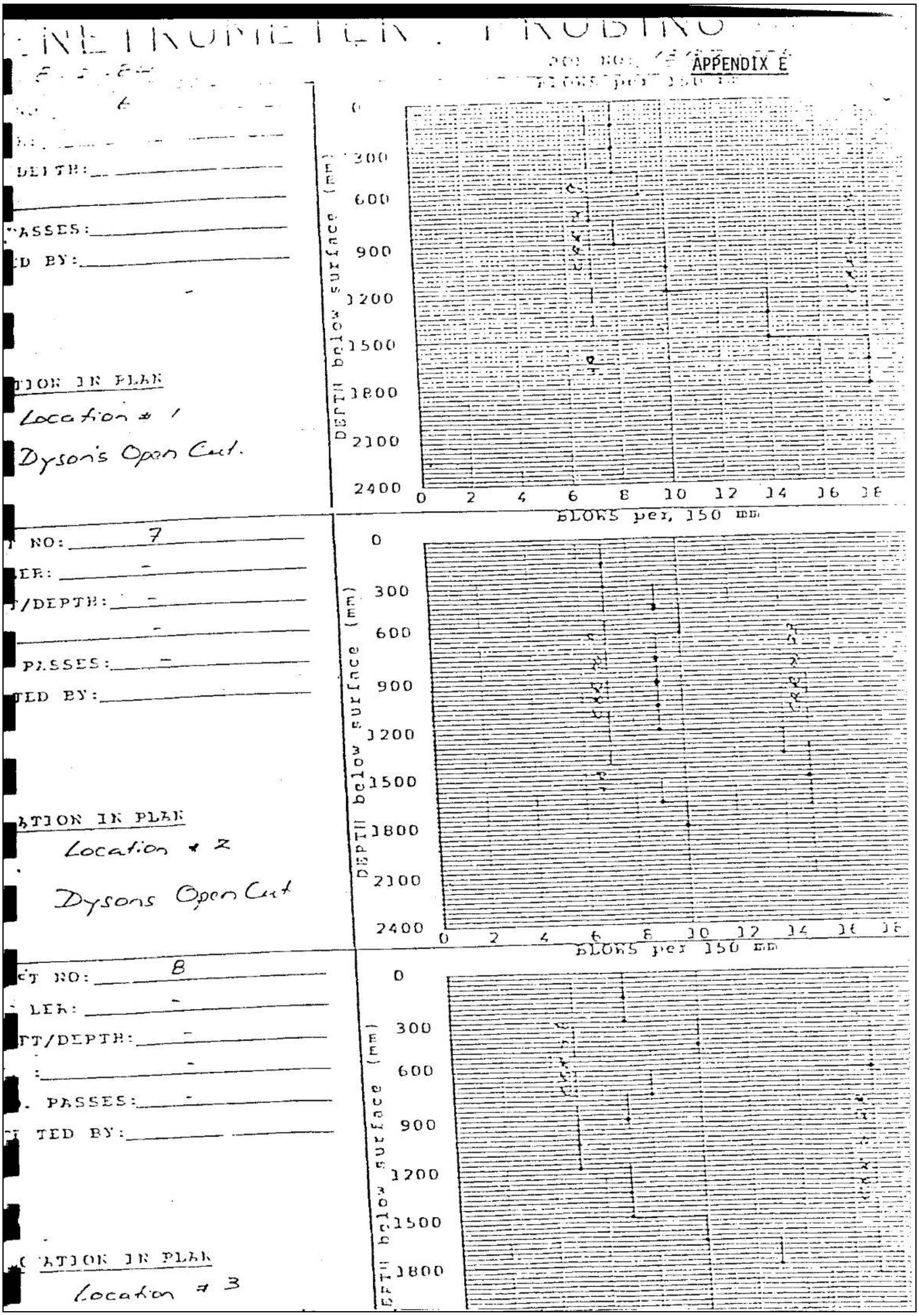
C. 5 **Old Tailings Dam Atterburg Limits**



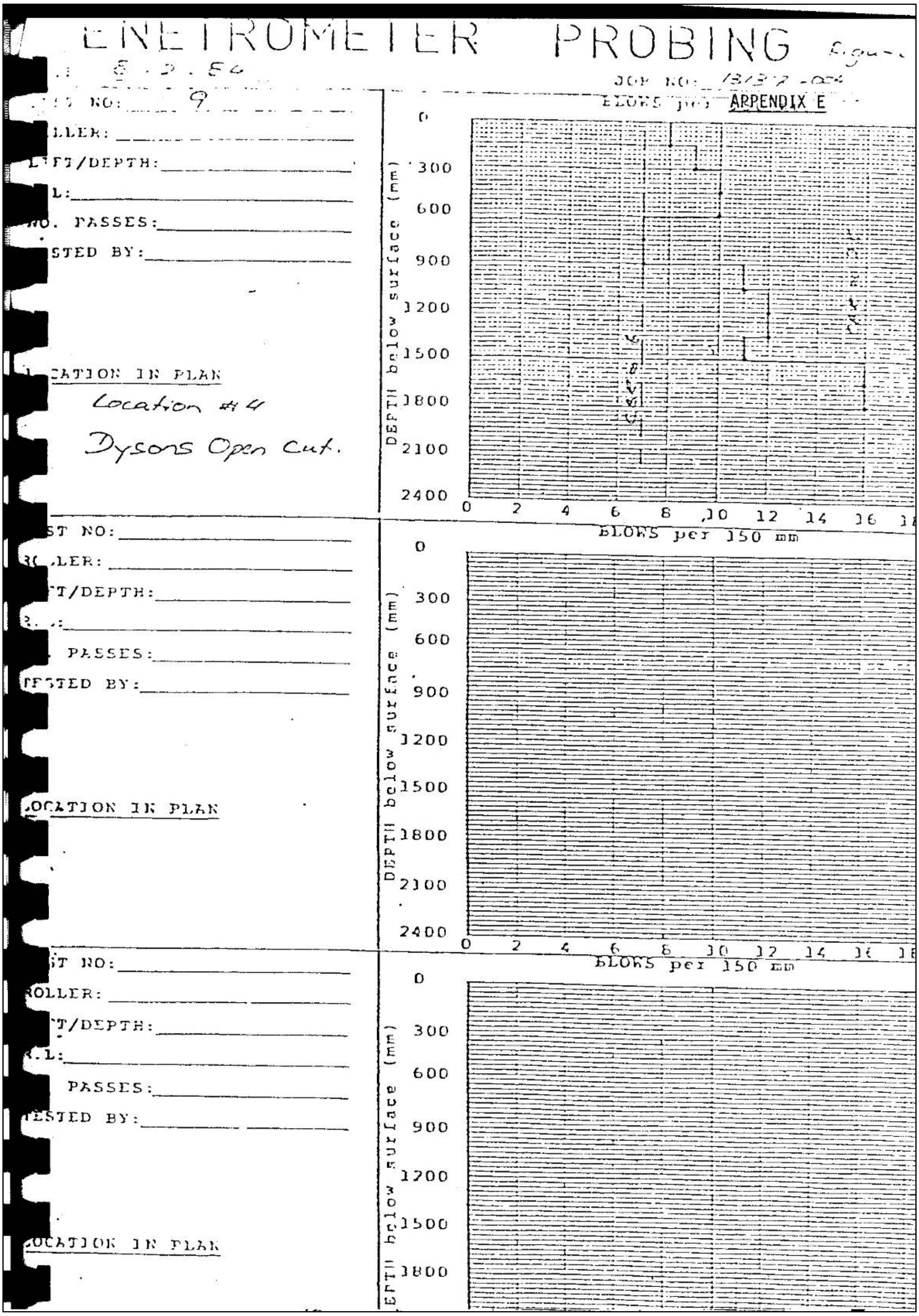
C. 6 Old Tailings Dam Dynamic Penetrometer test results



C. 7 Old Tailings Dam Dynamic Penetrometer test results



C. 8 Dysons Open Cut Dynamic Penetrometer test results



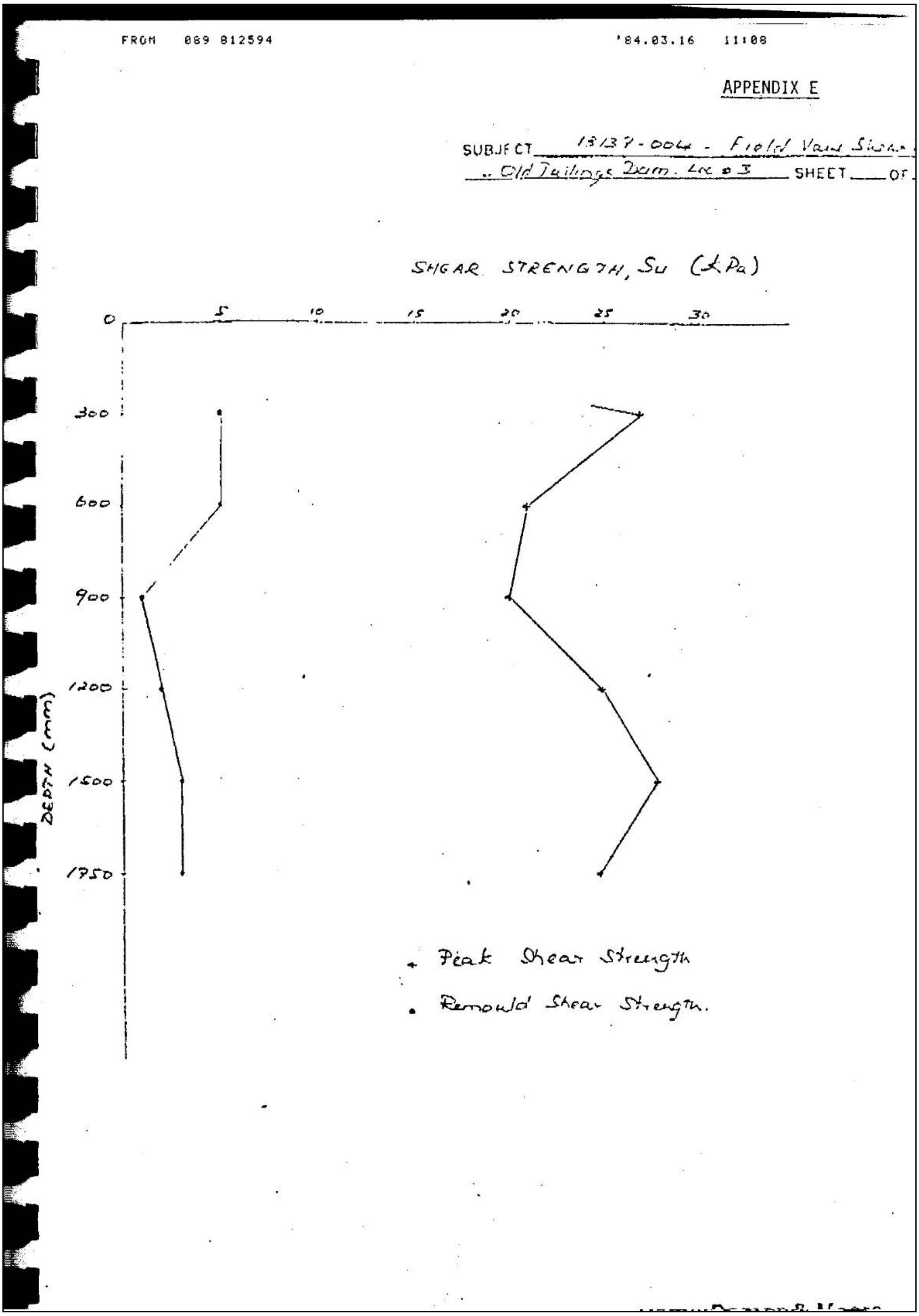
C. 9 Dysons Open Cut Dynamic Penetrometer test results

DAMES & MOORE
APPENDIX E

STATIC CONE PENETRATION RESULTS

TEST NO.	LOCATION	DEPTH (MM)	READINGS (POUNDS FORCE)	ESTIMATED SHEAR STRENGTH (KPA)
1.	Old Tailings Dam - No. 1	0	45	54
		150	70	84
		300	69	83
		450	37	44
		600	37	44
2.	No. 2	0	37	44
		150	34	41
		300	35	42
		450	39	47
		600	35	42
3.	No. 3	0	19	23
		150	23	28
		300	6	7
		450	6	7
		600	6	7
4.	No. 4	0	37	44
		150	25	30
		300	49	59
		450	24	29
		600	33	40
5.	No. 5	0	39	47
		150	57	68
		300	25	30
		450	27	32
		600	21	25
6.	Dyson's Open Cut No. 1	0	110	12
		150	100	10
		300	105	11
		450	110	12

C. 10 Static cone penetrometer test results



C. 11 Old Tailings Dam in situ shear vane test results

Appendix D – Model data results & 2008 Survey Data

D. 1 Dysons 2008 survey data

D. 2 Dysons 2008 cross section data (parallel to central channel)

D. 3 Dysons 2008 cross section data (orthogonal to central channel)

D. 4 Dysons 2008 survey data

Point	X	Y	Z	Point	X	Y	Z
1	500	4925.63	79.947	58	442.412	4987.91	93.036
2	500	4925.63	79.948	59	436.98	4992.97	92.941
3	499.97	4925.76	79.699	60	432.438	4997	92.951
4	504.488	4913.29	80.03	61	427.933	5001.51	92.937
5	504.505	4913.48	79.254	62	426.157	5003.9	92.895
6	558.962	4964.9	76.068	63	425.501	5006.56	92.807
7	618.188	4990.94	73.448	64	425.209	5008.82	92.769
8	397.864	4976.79	95.892	65	424.811	5010.71	92.807
9	423.905	4961.73	95.329	66	423.852	5012.93	92.51
10	435.75	4961.28	94.784	67	423.396	5012.41	92.393
11	430.506	4971.55	94.699	68	423.993	5010.72	92.612
12	425.462	4981.19	94.014	69	424.862	5008.41	92.667
13	424.774	4982.44	94.298	70	425.003	5005.2	92.689
14	421.942	4986.8	94.321	71	425.663	5002.58	92.68
15	419.303	4991.32	94.31	72	427.089	5000.83	92.704
16	416.567	4996.91	94.187	73	430.797	4997.24	92.736
17	416.472	4997	93.71	74	435.125	4993.31	92.753
18	416.373	4997.6	93.83	75	436.674	4992.18	92.794
19	416.242	4997.77	94.214	76	440.039	4988.74	92.821
20	414.099	5002.53	94.436	77	444.649	4985.5	92.887
21	413.366	5000.96	94.183	78	448.234	4984.34	92.911
22	415.675	4997.64	94.103	79	453.469	4982.94	93.034
23	415.856	4997.4	93.917	80	456.441	4981.44	93.177
24	415.822	4996.74	93.863	81	458.213	4979.6	93.373
25	416.135	4996.49	93.914	82	460.593	4977.17	93.614
26	416.181	4996.43	94.095	83	462.076	4978.3	93.403
27	417.877	4992.74	94.125	84	459.825	4981.22	93.09
28	419.851	4988.74	94.158	85	456.927	4984.17	92.774
29	422.6	4984.31	94.162	86	453.44	4985.33	92.698
30	424.394	4981.4	94.065	87	451.075	4985.63	92.684
31	426.093	4982.27	93.946	88	447.298	4986.36	92.601
32	423.981	4986.01	93.871	89	444.722	4987.56	92.574
33	422.169	4988.88	93.88	90	441.93	4989.89	92.499
34	420.066	4993.33	93.806	91	439.66	4991.74	92.497
35	417.926	4997.46	93.746	92	437.348	4994.03	92.471
36	417.765	4997.7	93.553	93	435.009	4996.11	92.461
37	417.648	4998.06	93.549	94	432.038	4998.73	92.45
38	417.494	4998.36	93.703	95	428.645	5002.35	92.44
39	416.305	5001.92	93.64	96	427.388	5004.59	92.337
40	416.357	5003.13	93.558	97	426.697	5007.58	92.215
41	418.766	5005.23	93.123	98	426.138	5010.58	92.194
42	421.603	5001.1	93.124	99	425.447	5013.3	92.016
43	421.927	5000.58	93.031	100	428.711	5015.67	91.614
44	422.092	5000.3	93.124	101	432.89	5011.14	91.54
45	428.745	4992.83	93.101	102	436.643	5006.52	91.583
46	435.231	4985.03	93.24	103	440.815	5001.7	91.674
47	440.094	4978.6	93.513	104	446.51	4996.36	91.785
48	448.472	4972.13	94.066	105	453.08	4991.31	91.922
49	451.975	4968.67	94.279	106	458.379	4987.04	92.323
50	457.104	4972.45	94.017	107	463.823	4983.61	92.731
51	461.824	4975.41	93.694	108	466.764	4981.61	92.983
52	461.31	4977.33	93.597	109	468.537	4979.59	93.04
53	458.874	4980.05	93.557	110	473.155	4982.73	92.473
54	457.028	4981.76	93.393	111	471.078	4985.71	92.503
55	454.337	4983.71	93.284	112	470.085	4987.26	92.708
56	450.727	4984.68	93.142	113	465.99	4991.16	92.429
57	446.429	4985.6	93.056	114	461.868	4995.06	92.153

Point	X	Y	Z	Point	X	Y	Z
115	456.745	5000.03	91.917	172	455.636	5039.8	88.166
116	451.701	5004.77	91.755	173	457.576	5037.33	88.384
117	445.962	5010.09	91.598	174	459.537	5035.47	88.523
118	441.292	5014.7	91.55	175	464.259	5030.04	88.604
119	437.847	5018.44	91.396	176	469.026	5024.38	88.656
120	436.891	5020.78	91.015	177	472.5	5020.82	88.776
121	437.118	5022.7	90.656	178	475.513	5017.7	88.858
122	435.75	5021.9	90.751	179	478.342	5014.47	88.917
123	435.545	5019.37	91.095	180	483.287	5009.56	89.145
124	436.934	5016.75	91.186	181	488.224	5004.38	89.549
125	440.812	5012.87	91.261	182	490.93	5002.31	89.724
126	445.722	5007.87	91.298	183	492.686	5002.09	89.648
127	450.987	5002.81	91.383	184	495.702	4997.59	89.83
128	456.327	4997.93	91.548	185	493.976	5003.01	89.452
129	461.819	4992.83	91.819	186	497.694	5005.61	88.92
130	466.447	4988.33	92.273	187	495.429	5007.63	88.675
131	469.865	4985.7	92.59	188	492.827	5008.74	88.643
132	473.136	4986.33	92.273	189	491.389	5009.63	88.601
133	470.831	4990.84	91.727	190	488.561	5012.03	88.436
134	466.052	4995.71	91.168	191	483.492	5017.76	88.04
135	462.899	4999.01	90.932	192	478.155	5023.07	87.927
136	456.463	5005.63	90.716	193	471.854	5029.37	87.897
137	450.081	5011.83	90.536	194	466.299	5034.33	87.964
138	444.338	5017.38	90.39	195	460.947	5039.86	87.952
139	439.985	5021.67	90.49	196	460.125	5040.59	88.058
140	438.508	5025.07	90.376	197	458.39	5042.36	87.779
141	444.915	5030.71	89.409	198	456.527	5040.96	88.035
142	450.119	5025.6	89.414	199	458.567	5038.69	88.548
143	455.798	5020.29	89.479	200	460.305	5036.8	88.766
144	462.655	5014.65	89.602	201	464.433	5032.07	88.89
145	467.312	5010.66	89.583	202	468.983	5027.17	88.999
146	477.075	5000.42	90.195	203	473.867	5022.03	89.199
147	476.441	4998.66	90.394	204	479.878	5015.77	89.398
148	476.132	4996.26	90.675	205	485.166	5010.38	89.556
149	477.028	4996.65	90.615	206	490.045	5005.53	89.846
150	477.825	4997.23	90.543	207	492.682	5003.14	89.772
151	477.646	4998.23	90.409	208	493.854	5004.39	89.451
152	478.603	5000.35	90.121	209	505.597	5003.48	88.54
153	479.458	5002.88	89.809	210	503.738	5008.36	88.257
154	479.11	5003.3	89.712	211	500.309	5013.47	87.716
155	478.219	5000.78	89.938	212	496.595	5019.26	87.171
156	477.214	4999.48	90.079	213	492.184	5025.49	86.796
157	477.084	4998.06	90.188	214	488.42	5029.76	86.648
158	476.731	4997.09	90.274	215	484.782	5034.47	86.597
159	476.266	4996.35	90.386	216	478.306	5041.71	86.542
160	481.405	4992.83	91.067	217	472.523	5047.83	86.712
161	483.251	4990.34	91.214	218	469.471	5051.03	86.629
162	487.434	4993.3	90.717	219	481.388	5061.3	85.375
163	485.22	4996.18	90.53	220	484.097	5057.76	85.465
164	481.493	5000	90.077	221	488.294	5053.26	85.405
165	478.998	5003.86	89.697	222	493.765	5047.16	85.258
166	475.11	5008.08	89.425	223	497.702	5042.06	85.308
167	472.143	5012.81	89.132	224	502.222	5036.56	85.471
168	467.775	5018.95	88.879	225	506.663	5031.48	85.594
169	463.178	5024.28	88.72	226	511.168	5026.46	85.781
170	457.979	5031.75	88.603	227	516.184	5021.06	86.131
171	453.781	5037.92	88.346	228	520.101	5015.83	86.569

Point	X	Y	Z	Point	X	Y	Z
229	524.801	5013.16	86.304	286	504.101	5079.79	82.941
230	523.224	5017.14	86.43	287	513.141	5086.95	82.346
231	520.514	5018.21	86.397	288	515.674	5083.36	82.36
232	516.831	5023.31	86.042	289	520.038	5077.31	82.416
233	510.456	5031.11	85.662	290	521.502	5075.63	82.408
234	500.835	5042.64	85.371	291	525.798	5069.12	82.763
235	495.782	5048.42	85.283	292	527.295	5066.7	82.858
236	490.694	5054.82	85.272	293	531.782	5059.65	83.044
237	486.877	5059.22	85.274	294	535.843	5053.6	83.249
238	484.392	5062.84	85.254	295	541.234	5046.63	83.438
239	486.287	5065.63	85.027	296	545.121	5041.25	83.71
240	486.749	5064.37	85.291	297	548.905	5036.06	84.034
241	488.044	5061.64	85.547	298	551.746	5031.4	84.34
242	490.172	5058.81	85.68	299	553.761	5027.75	84.186
243	495.721	5051.81	85.676	300	554.797	5026.13	84.032
244	502.026	5044.4	85.779	301	554.654	5031.55	84.203
245	508.384	5036.82	85.891	302	554.031	5033.29	84.21
246	514.24	5029.71	86.086	303	552.184	5037.49	84.016
247	519.08	5023.86	86.352	304	549.845	5043.53	83.652
248	522.002	5020.47	86.547	305	547.499	5049.34	83.427
249	524.266	5018.56	86.538	306	544.668	5057.12	83.141
250	525.919	5017.59	86.176	307	542.523	5062.91	82.947
251	528.418	5019.36	85.858	308	540.088	5069.51	82.693
252	526.174	5021.67	85.645	309	538.063	5075.07	82.316
253	524.801	5024.04	85.372	310	536.545	5081.03	81.967
254	521.879	5027.13	85.123	311	534.103	5086.76	81.596
255	515.157	5034.43	84.928	312	532.1	5092.5	81.409
256	508.849	5042.38	84.716	313	530.086	5096.86	81.161
257	502.266	5049.98	84.631	314	529.167	5098.93	81.041
258	496.305	5056.78	84.676	315	531.465	5100.5	80.998
259	490.774	5063.72	84.73	316	532.348	5098.46	81.446
260	487.736	5066.52	84.808	317	533.283	5096.55	81.692
261	495.664	5071.85	83.983	318	534.987	5092.26	81.799
262	498.553	5068.33	83.984	319	536.571	5087.54	81.975
263	502.522	5063.91	83.906	320	538.398	5082.47	82.267
264	507.215	5058.45	84.057	321	540.152	5077.39	82.684
265	512.678	5052.3	84.034	322	542.195	5071.61	83.091
266	517.379	5046.77	84.072	323	543.927	5066.32	83.381
267	521.302	5042	84.28	324	546.369	5060.07	83.588
268	525.879	5036.99	84.26	325	548.662	5053.87	83.821
269	530.343	5032.96	84.323	326	551.113	5047.67	84.004
270	533.308	5029.32	84.597	327	553.572	5041.33	84.21
271	536.021	5024.66	85.042	328	555.844	5035.96	84.483
272	537.578	5021.86	85.183	329	556.441	5034.29	84.489
273	538.93	5019.19	85.136	330	556.863	5033.14	84.355
274	547.626	5024.15	84.501	331	557.199	5032.34	84.071
275	545.882	5026.71	84.642	332	558.65	5029.05	83.917
276	543.904	5029.36	84.551	333	559.203	5034.13	83.988
277	538.817	5036.52	83.902	334	558.718	5035.41	84.078
278	534.896	5042.35	83.628	335	556.777	5039.34	83.93
279	532.714	5045.14	83.645	336	555.48	5043.11	83.725
280	524.445	5054.83	83.415	337	552.929	5050.03	83.468
281	519.372	5061.14	83.382	338	551.261	5054.07	83.293
282	516.199	5065.05	83.247	339	549.775	5058.32	83.092
283	511.267	5070.99	83.096	340	548.179	5062.9	82.894
284	507.718	5075.06	83.094	341	545.342	5069.95	82.67
285	505.297	5078.05	83.045	342	544.477	5072.99	82.464

Point	X	Y	Z	Point	X	Y	Z
343	543.117	5077.21	82.178	400	587.97	5073.38	82.47
344	541.402	5081.85	81.795	401	585.253	5079.88	82.329
345	539.71	5086.33	81.526	402	583.575	5084.16	82.298
346	538.003	5090.49	81.317	403	580.736	5089.68	81.963
347	536.897	5094.5	81.14	404	578.658	5094.2	81.704
348	535.411	5098.1	81.026	405	576.302	5098.84	81.34
349	534.005	5100.99	80.922	406	573.556	5103.98	81.051
350	533.401	5102.12	80.732	407	570.783	5108.35	80.834
351	540.097	5106.33	80.444	408	567.41	5112.9	80.566
352	540.962	5104.8	80.569	409	565.939	5116.37	80.304
353	543.217	5100.02	80.819	410	570.686	5116.95	80.387
354	545.002	5095.7	81.035	411	572.933	5117.32	80.55
355	547.414	5091.37	81.247	412	573.235	5114.81	80.582
356	550.339	5086.34	81.62	413	575.341	5112.07	80.853
357	552.507	5080.62	82.086	414	577.748	5106.9	80.987
358	554.959	5074.9	82.482	415	580.66	5101.48	81.222
359	557.657	5069.51	82.758	416	582.431	5097.17	81.439
360	560.395	5064.01	82.937	417	585.14	5092.73	81.756
361	562.974	5058.19	83.15	418	587.334	5088.24	82.083
362	565.329	5052.61	83.311	419	590.296	5083.24	82.191
363	567.911	5047.31	83.472	420	593.119	5077.44	82.304
364	570.226	5043.1	83.583	421	595.619	5072.41	82.433
365	572.146	5040.04	83.54	422	598.064	5067.97	82.486
366	581.196	5044.88	83.216	423	602.624	5063.43	82.356
367	579.213	5047.5	83.348	424	601.021	5067.41	82.439
368	577.57	5050.79	83.295	425	598.359	5070.97	82.715
369	575.465	5056.87	83.194	426	595.992	5075.69	82.749
370	572.811	5063.31	82.97	427	593.588	5080.65	82.668
371	569.862	5070.46	82.825	428	591.488	5085.3	82.591
372	567.109	5076.23	82.631	429	589.129	5089.83	82.428
373	564.886	5082.16	82.256	430	586.709	5094.58	82.256
374	562.088	5087.89	81.793	431	583.994	5099.62	81.928
375	559.339	5093.49	81.408	432	581.274	5104.33	81.644
376	556.803	5099.29	81.036	433	578.799	5109.22	81.422
377	554.285	5104.83	80.679	434	575.908	5114.94	81.154
378	552.567	5109.15	80.361	435	574.891	5116.77	80.851
379	550.968	5111.91	80.15	436	574.987	5118.01	80.415
380	559.827	5115.22	80.142	437	577.792	5118.27	80.328
381	561.551	5110.53	80.552	438	578.068	5115.26	80.686
382	563.931	5105.65	80.86	439	580.056	5112.24	80.779
383	566.542	5100.46	81.15	440	581.771	5109.22	80.799
384	569.91	5094.98	81.492	441	584.276	5104.56	80.987
385	571.985	5090.05	81.816	442	586.785	5099.67	81.302
386	572.432	5089.07	81.97	443	589.939	5094.28	81.548
387	573.913	5086.07	82.176	444	592.568	5089.07	81.804
388	575.617	5080.99	82.399	445	595.376	5083.58	81.964
389	577.974	5075.64	82.569	446	597.524	5078.54	82.074
390	580.726	5070.16	82.684	447	599.602	5073.55	82.244
391	583.656	5064.74	82.884	448	601.875	5068.82	82.31
392	585.197	5061.48	82.996	449	604.231	5065.78	82.272
393	588.152	5056.86	83.02	450	611.75	5070.43	81.786
394	589.599	5054.63	82.988	451	609.595	5073.34	81.926
395	591.118	5052.53	82.827	452	606.806	5078.46	81.777
396	596.959	5058.02	82.629	453	603.796	5083.74	81.629
397	595.648	5059.73	82.706	454	600.733	5088.94	81.47
398	593.992	5061.87	82.746	455	597.556	5094.15	81.35
399	590.682	5067.4	82.653	456	594.61	5099.95	81.082

Point	X	Y	Z	Point	X	Y	Z
457	591.89	5105.08	80.844	514	639.983	5105.54	78.939
458	589.544	5109.86	80.692	515	641.197	5101.95	78.946
459	587.323	5114.93	80.581	516	642.852	5098.29	78.876
460	586.156	5118.58	80.468	517	645.377	5094.23	78.75
461	597.212	5118.26	80.313	518	652.889	5097.7	78.187
462	599.058	5114.26	80.473	519	651.588	5101.57	78.401
463	601.72	5108.77	80.575	520	649.921	5104.68	78.494
464	604.416	5103.14	80.701	521	648.337	5108.63	78.523
465	607.926	5098.03	80.735	522	646.69	5114.41	78.409
466	611.052	5093.17	80.784	523	646.286	5115.96	78.478
467	614.076	5089.04	80.806	524	654.471	5115.12	78.098
468	616.844	5083.99	81.012	525	655.429	5110.73	78.156
469	620.746	5078.59	81.051	526	656.566	5106.9	78.22
470	626.79	5081.68	80.43	527	657.679	5103.8	78.151
471	625.403	5084.95	80.489	528	658.681	5100.87	78.04
472	623.562	5088.92	80.258	529	666.822	5102.17	77.682
473	621.488	5093.72	80.141	530	665.53	5106.03	77.786
474	619.003	5098.72	80.129	531	664.851	5110.5	77.773
475	616.752	5103.92	80.103	532	664.116	5114.62	77.664
476	615.169	5107.18	80.077	533	649.366	5122.78	78.775
477	613.115	5110.35	80.095	534	653.461	5129.71	78.823
478	610.633	5116.51	80.138	535	656.865	5136.52	79.151
479	610.466	5117.77	80.017	536	660.283	5142.64	79.31
480	619.353	5116.89	79.699	537	662.017	5146.34	79.145
481	619.848	5114.16	79.764	538	663.613	5149.85	78.69
482	621.061	5108.89	79.778	539	658.048	5144.73	79.558
483	622.698	5102.43	79.831	540	657.19	5142.82	80.392
484	624.046	5096.36	79.946	541	656.452	5140.83	80.252
485	625.543	5090.43	80.159	542	653.646	5136.38	79.845
486	626.983	5088.42	80.253	543	650.891	5131.57	79.592
487	627.316	5086.28	80.394	544	647.375	5125.16	79.51
488	629.279	5089.85	80.589	545	647.108	5123.99	79.349
489	628.917	5094.75	80.488	546	646.97	5122.58	78.741
490	628.296	5100.73	80.244	547	644.484	5123.52	78.929
491	627.315	5106.8	80.165	548	645.392	5126.25	79.062
492	627.063	5110.61	80.093	549	648.401	5130.66	79.217
493	626.651	5113.55	80.164	550	651.206	5135.25	79.402
494	626.626	5114.97	79.976	551	654.156	5140.89	79.57
495	626.68	5115.94	79.645	552	656.326	5144.92	79.613
496	626.691	5117.37	79.147	553	658.463	5149.32	79.278
497	624.35	5117.22	79.423	554	659.791	5151.86	78.741
498	623.949	5115.62	79.593	555	652.695	5157.32	79.194
499	624.324	5113.22	79.654	556	649.831	5154.45	79.887
500	625.301	5109.05	79.678	557	647.835	5151.31	79.988
501	625.68	5105.7	79.725	558	645.688	5147.39	80.12
502	626.187	5101.27	79.817	559	642.826	5142.14	79.959
503	626.73	5096.52	79.924	560	639.075	5135.63	79.785
504	627.314	5091.46	80.109	561	636.187	5130.17	79.451
505	633.075	5088.13	79.79	562	633.513	5124.62	79.336
506	632.285	5092.3	79.72	563	633.169	5123.48	79.358
507	631.644	5098.24	79.536	564	624.389	5123.98	79.666
508	630.827	5104.64	79.425	565	627.012	5131.37	79.844
509	630.199	5110.92	79.364	566	629.79	5137.48	80.226
510	629.906	5115.88	79.201	567	632.519	5144.19	80.474
511	629.933	5116.98	79.093	568	636.155	5149.9	80.569
512	638.477	5116.16	78.762	569	638.426	5154.58	80.709
513	639.203	5111.17	78.827	570	639.762	5157.1	80.656

Point	X	Y	Z	Point	X	Y	Z
571	640.83	5158.54	80.371	628	600.566	5190.2	83.793
572	643.134	5161.88	80.428	629	598.745	5188.92	83.867
573	645.669	5165.91	79.524	630	593.979	5185.33	83.743
574	639.136	5172.2	79.778	631	588.535	5182.1	83.692
575	635.485	5167.7	81.001	632	581.29	5177.38	83.521
576	632.623	5164.27	81.039	633	576.348	5173.38	83.279
577	632.028	5163.59	81.276	634	571.878	5170.13	82.999
578	628.745	5159.05	81.257	635	568.331	5167.21	82.655
579	625.144	5153.12	81.122	636	563.787	5163.08	82.044
580	621.51	5147.35	80.981	637	560.35	5159.89	81.554
581	618.927	5143.07	80.735	638	557.239	5155.66	81.273
582	616.801	5137.04	80.492	639	553.882	5151.22	80.878
583	614.767	5130.66	80.207	640	549.239	5145.65	80.576
584	612.843	5124.34	80.061	641	545.324	5140.3	80.342
585	605.852	5124.67	80.17	642	542.405	5135.04	80.323
586	607.999	5132.99	80.404	643	540.395	5128.87	80.213
587	610.576	5140.69	80.762	644	538.683	5122.09	80.214
588	611.991	5146.52	81.142	645	536.979	5117.36	80.198
589	614.696	5155.38	81.659	646	535.567	5113.96	80.158
590	616.57	5161.79	81.81	647	535.736	5111.84	80.156
591	619.439	5169.48	82.043	648	538.493	5112.89	79.881
592	621.491	5173.25	82.01	649	540.542	5117.59	79.864
593	625.109	5178.76	81.713	650	542.014	5123.84	79.705
594	626.391	5181.44	81.152	651	543.202	5128.85	79.77
595	628.369	5184.19	80.256	652	545.348	5133.99	79.803
596	622.564	5189.27	80.746	653	549.036	5139.66	79.927
597	620.084	5186.48	81.756	654	553.451	5145.47	80.241
598	617.601	5183.46	82.307	655	557.95	5150.21	80.54
599	615.326	5181.03	82.359	656	562.729	5154.85	80.966
600	614.149	5179.77	82.595	657	567.987	5159.54	81.543
601	611.456	5176.47	82.668	658	573.18	5163.91	82.16
602	608.578	5171.79	82.384	659	578.112	5168.46	82.632
603	605.304	5166.07	82.247	660	583.298	5172.89	83.026
604	602.536	5160.61	82.016	661	587.328	5176.01	83.29
605	599.408	5154.91	81.575	662	593.075	5179.53	83.32
606	595.991	5149.08	81.007	663	598.251	5182.91	83.288
607	593.985	5143.07	80.606	664	601.913	5186.25	83.565
608	591.891	5136.75	80.191	665	604.013	5184.24	83.264
609	590.676	5131.07	80.038	666	601.471	5181.8	83.11
610	589.466	5125.92	80.054	667	598.432	5178.2	83.07
611	589.382	5125.1	79.982	668	595.824	5175.47	82.982
612	582.927	5125.19	79.9	669	592.368	5171.53	82.798
613	585.223	5130.83	79.859	670	589.902	5168.76	82.607
614	587.7	5137.49	80.036	671	587.08	5165.73	82.315
615	590.431	5144.07	80.487	672	584.253	5162.49	81.966
616	593.191	5151.24	81.061	673	581.48	5159.13	81.563
617	596.166	5158.43	81.74	674	578.531	5155.99	81.106
618	598.912	5165.06	82.316	675	575.693	5152.48	80.568
619	601.567	5172.01	82.58	676	572.161	5148.66	80.149
620	604.779	5180.2	82.839	677	569.794	5144.21	79.856
621	606.8	5184.5	83.148	678	569.786	5144.19	79.857
622	609.353	5189.04	83.135	679	565.75	5139.98	79.678
623	610.784	5192.43	83.016	680	562.315	5135.59	79.583
624	612.062	5198.39	81.955	681	557.912	5130.69	79.551
625	607.007	5201.96	82.434	682	555.114	5126.13	79.551
626	605.024	5198.56	83.442	683	552.764	5121.05	79.554
627	602.949	5194.74	83.838	684	551.903	5119.06	79.508

Point	X	Y	Z	Point	X	Y	Z
685	545.604	5120.59	79.607	742	500	4925.68	79.871
686	548.117	5126.13	79.625	743	504.67	4913.38	80.036
687	550.652	5131.5	79.578	744	500.19	4925.57	79.661
688	553.471	5136.98	79.679	745	559.014	4964.99	76.07
689	555.995	5143.08	79.876	746	558.916	4965.07	75.945
690	559.052	5149.25	80.381	747	500.076	4925.63	79.954
691	562.219	5154.71	80.988	748	500.054	4925.75	79.706
692	500	4925.63	79.955	749	504.289	5002.91	88.725
693	499.961	4925.74	79.711	750	397.89	4976.72	95.883
694	500.007	4925.63	79.95	751	404.828	4971.67	95.724
695	499.997	4925.75	79.709	752	411.913	4967.06	95.571
696	650.223	5022.21	73.85	753	419.575	4962.86	95.37
697	609.875	5122.02	79.201	754	424.323	4961.2	95.273
698	609.725	5120.16	79.162	755	430.481	4960.09	94.994
699	604.624	5120.51	79.295	756	430.85	4965.07	95.017
700	604.502	5122.51	79.295	757	423.657	4966.54	95.258
701	599.235	5122.65	79.404	758	414.905	4968.88	95.532
702	598.905	5120.75	79.302	759	409.333	4973.08	95.657
703	592.94	5120.84	79.349	760	401.78	4980.26	95.765
704	592.552	5122.94	79.331	761	397.317	4983.21	95.941
705	586.222	5122.83	79.259	762	391.926	4990.14	95.931
706	586.09	5120.93	79.296	763	386.302	4998.23	95.961
707	578.087	5120.8	79.252	764	382.013	5007.04	95.893
708	577.609	5122.82	79.154	765	378.459	5016.95	95.8
709	571.346	5122.38	79.081	766	376.607	5025.77	95.727
710	571.395	5120	79.225	767	372.689	5035.32	95.673
711	564.819	5119.15	79.134	768	371.861	5027.67	95.716
712	564.114	5121.23	79.077	769	372.496	5019.59	95.725
713	559.026	5119.8	79.015	770	373.841	5011.26	95.748
714	559.312	5117.76	79.097	771	377.368	5002.56	95.696
715	555.301	5116.57	79.011	772	380.687	4995.65	95.899
716	554.851	5118.23	78.929	773	384.117	4989.6	95.919
717	550.21	5116.35	79.018	774	389.316	4983.65	95.882
718	550.698	5114.68	79.016	775	395.309	4978.02	95.853
719	547.071	5113	79.06	776	394.745	4981.72	95.971
720	546.349	5114.49	79.063	777	390.294	4987.2	96.013
721	540.949	5111.82	79.26	778	385.825	4993.01	96.039
722	541.298	5109.86	79.279	779	383.382	5001.49	95.946
723	534.772	5108.22	79.48	780	380.079	5021.98	95.616
724	535.435	5106.33	79.485	781	384.222	5015.11	95.639
725	529.785	5102.47	79.951	782	389.531	5007.48	95.56
726	528.724	5103.87	80.003	783	393.952	5000.25	95.548
727	528.725	5103.88	80.003	784	398.642	4993.28	95.518
728	523.543	5100.06	80.501	785	403.23	4988.04	95.403
729	524.449	5098.49	80.495	786	407.959	4982.42	95.35
730	518.091	5093.72	80.956	787	412.768	4977.56	95.279
731	516.799	5095.14	81.053	788	411.022	4978.6	95.384
732	510.189	5089.66	81.549	789	409.424	4981.46	95.371
733	511.002	5088.01	81.576	790	408.275	4984.55	95.306
734	504.227	5082.49	82.115	791	405.782	4988.21	95.228
735	502.814	5083.84	82.19	792	405.346	4989.15	95.148
736	496.623	5078.99	82.778	793	405.584	4989.32	94.846
737	497.67	5077.38	82.761	794	406.35	4989.74	94.674
738	490.165	5071.25	83.528	795	407.768	4990.5	94.767
739	488.457	5072.49	83.546	796	409.05	4991.57	94.601
740	481.132	5066.62	84.321	797	410.128	4992.86	94.514
741	482.27	5065.08	84.31	798	410.791	4992.19	94.542

Point	X	Y	Z	Point	X	Y	Z
799	409.644	4993.49	94.557	856	384.776	5026.62	95.278
800	409.877	4993.12	94.504	857	380.34	5030.79	95.458
801	410.301	4992.39	94.522	858	377.046	5033.62	95.566
802	409.126	4991.31	94.661	859	374.312	5034.78	95.64
803	409.269	4991.15	94.734	860	375.13	5038.43	95.545
804	408.383	4991.95	94.759	861	377.135	5036.88	95.511
805	407.96	4992.38	94.794	862	380.402	5034.86	95.359
806	406.909	4993.55	94.81	863	384.15	5031.17	95.166
807	405.907	4994.84	95.242	864	387.464	5027.2	94.991
808	406.325	4993.35	94.904	865	390.823	5022.32	94.857
809	407.045	4991.97	94.872	866	394.091	5017.32	94.8
810	407.584	4991.12	94.842	867	398.053	5011.84	94.72
811	407.96	4990.19	94.865	868	401.487	5007.29	94.699
812	409.07	4988.45	94.912	869	405.307	5002.83	94.66
813	411.201	4984.97	94.909	870	407.87	5005.13	94.382
814	413.062	4981.01	95.021	871	405.615	5008.02	94.36
815	412.096	4978.76	95.488	872	402.624	5012.85	94.313
816	411.122	4980.44	95.553	873	399.288	5018.03	94.31
817	409.909	4982.95	95.504	874	396.806	5023	94.374
818	408.559	4985.83	95.398	875	394.201	5028.4	94.421
819	406.627	4989.28	95.33	876	391.577	5034.27	94.533
820	406.084	4990.06	95.184	877	389.071	5039.99	94.658
821	405.894	4990.51	95.38	878	386.538	5043.45	94.874
822	405.326	4991.6	95.541	879	383.5	5046.58	95.068
823	404.518	4993.21	95.543	880	379.183	5050.77	95.103
824	403.801	4994.28	95.23	881	375.518	5053.94	95.198
825	403.102	4992.97	95.279	882	378.293	5059.2	95.112
826	404.589	4990.41	95.245	883	383.039	5054.73	94.89
827	402.587	4995.87	95.267	884	386.829	5050.34	94.754
828	400.653	4997.87	95.295	885	389.242	5047.52	94.647
829	401.672	4998.57	95.56	886	392.91	5043.27	94.264
830	398.925	5000.18	95.338	887	392.295	5042.45	94.403
831	397.024	5003.26	95.347	888	394.457	5037.6	94.361
832	393.419	5008.28	95.391	889	396.751	5033.41	94.245
833	390.207	5013.29	95.391	890	398.263	5029.53	94.167
834	386.988	5018.4	95.444	891	399.52	5025.27	94.201
835	383.519	5023.62	95.523	892	401.618	5021.26	94.186
836	381.271	5026.51	95.553	893	405.317	5014.97	94.138
837	377.985	5029.53	95.612	894	408.863	5009.74	94.089
838	375.362	5031.95	95.701	895	411.173	5007.04	94.082
839	374.613	5033.84	95.761	896	411.847	5007.76	94.382
840	376.072	5032.68	95.751	897	409.86	5009.87	94.473
841	378.827	5030.37	95.706	898	408.338	5011.68	94.355
842	381.974	5027.17	95.691	899	406.45	5014.93	94.271
843	384.109	5024.74	95.686	900	403.693	5019.86	94.304
844	386.701	5020.84	95.641	901	400.915	5024.89	94.407
845	389.477	5016.55	95.563	902	398.667	5030.78	94.278
846	392.088	5012.08	95.533	903	397.226	5033.85	94.329
847	394.393	5008.54	95.57	904	394.97	5038.63	94.442
848	396.986	5004.93	95.578	905	393.617	5041.5	94.57
849	399.016	5001.9	95.512	906	394.704	5043	94.053
850	402.62	5000.56	94.954	907	396.167	5039.07	93.905
851	400.51	5002.63	95.035	908	397.96	5035.21	93.848
852	397.841	5005.99	95.098	909	400.18	5030.01	93.86
853	394.334	5011.35	95.075	910	402.468	5024.51	93.887
854	390.731	5016.92	95.108	911	405.643	5018.67	93.842
855	387.882	5022.01	95.148	912	407.741	5015.28	93.844

Point	X	Y	Z	Point	X	Y	Z
913	410.092	5011.89	93.783	970	425.97	5033.02	91.3
914	412.699	5009.27	93.599	971	423.687	5038.75	91.345
915	417.358	5013.43	92.879	972	420.211	5046.74	91.42
916	414.21	5018.21	92.947	973	419.237	5049.73	91.496
917	411.198	5023.56	93.066	974	415.285	5055.62	91.604
918	408.584	5028.77	93.075	975	412.956	5061.47	91.737
919	405.759	5034.35	93.117	976	410.792	5067.44	91.935
920	402.677	5039.81	93.234	977	408.225	5072.92	92.131
921	399.923	5044.56	93.409	978	404.774	5078.55	92.467
922	397.185	5049.6	93.702	979	401.699	5083.16	92.741
923	394.314	5054.55	93.915	980	400.233	5083.29	93.175
924	391.433	5058.7	94.193	981	408.175	5089.38	92.374
925	389.569	5061.37	94.299	982	406.415	5091.15	92.835
926	385.738	5065.45	94.527	983	408.868	5084.98	92.147
927	384.698	5066.58	94.851	984	411.209	5080.23	91.943
928	388.793	5070.78	94.483	985	414.088	5076.13	91.87
929	389.802	5070.09	94.076	986	415.441	5070.5	91.779
930	393.177	5067.11	93.702	987	414.08	5070.07	91.743
931	396.007	5063.11	93.553	988	416.927	5064.61	91.66
932	400.477	5056.21	93.26	989	415.806	5064.4	91.631
933	403.358	5051.61	92.939	990	418.401	5058.19	91.508
934	406.974	5046.08	92.612	991	416.484	5057.51	91.508
935	409.781	5041.62	92.548	992	420.589	5052.58	91.439
936	413.631	5035.52	92.399	993	419.622	5052.47	91.421
937	417.097	5030.05	92.38	994	422.834	5047.24	91.392
938	419.015	5025.03	92.374	995	421.682	5046.94	91.392
939	420.205	5021.2	92.351	996	424.855	5041.94	91.321
940	421.36	5018.73	92.313	997	427.278	5036.38	91.303
941	420.268	5016.51	92.454	998	428.647	5032.58	91.266
942	417.313	5021.42	92.514	999	431.082	5027.78	91.017
943	414.947	5027.28	92.586	1000	432.297	5028.67	90.747
944	411.652	5033.86	92.553	1001	431.087	5030.14	91.212
945	408.367	5040.14	92.678	1002	430.267	5032.84	91.45
946	406.451	5045.53	92.682	1003	427.814	5038.35	91.564
947	408.927	5046.76	92.45	1004	424.938	5045.06	91.542
948	409.371	5045.44	92.731	1005	422.414	5051.99	91.7
949	410.892	5041.85	92.778	1006	420.01	5059.95	91.876
950	414.281	5036.51	92.598	1007	418.117	5066.92	92.009
951	416.897	5032.23	92.549	1008	416.48	5074.31	92.155
952	418.694	5028.73	92.478	1009	415.038	5081.67	92.244
953	420.458	5022.99	92.455	1010	414.342	5086.24	92.219
954	422.258	5019.05	92.456	1011	414.327	5089.49	91.993
955	422.835	5020.54	92.002	1012	413.597	5094.08	91.748
956	421.577	5024.52	92.001	1013	413.398	5094.43	91.967
957	419.751	5029.41	92.046	1014	416.09	5095.76	91.541
958	416.879	5034.72	92.062	1015	417.125	5090.93	91.458
959	414.422	5038.82	92.146	1016	417.807	5086.04	91.297
960	411.58	5043.53	92.258	1017	419.257	5077.82	91.131
961	410.195	5046.95	92.298	1018	421.041	5070.09	90.835
962	412.078	5047.87	92.078	1019	423.333	5061.64	90.688
963	415.137	5042.64	91.954	1020	425.311	5053.11	90.732
964	417.966	5037.64	91.812	1021	428.319	5045.43	90.568
965	421.195	5032.02	91.705	1022	431.767	5038.72	90.481
966	423.31	5026.13	91.675	1023	432.769	5036.2	90.478
967	424.757	5022.9	91.646	1024	433.593	5031.95	90.559
968	429.224	5026.11	91.121	1025	434.917	5030.55	90.379
969	427.365	5029.31	91.262	1026	442.751	5037.28	89.229

Point	X	Y	Z	Point	X	Y	Z
1027	440.825	5042.34	89.336	1084	462.502	5132.5	87.264
1028	438.331	5049.52	89.402	1085	461.479	5133.97	87.424
1029	435.201	5058.36	89.514	1086	460.283	5135.84	87.892
1030	432.649	5066.79	89.67	1087	462.988	5127.98	87.283
1031	429.951	5076.55	89.807	1088	463.672	5124.74	87.06
1032	426.997	5085.77	90.303	1089	464.089	5120.57	86.717
1033	423.911	5094.54	90.646	1090	464.334	5113.52	86.481
1034	422.213	5097.5	90.812	1091	464.537	5104.85	86.533
1035	421.071	5099.43	91.13	1092	463.981	5095.59	86.72
1036	420.268	5100.52	91.644	1093	464.48	5086.97	86.706
1037	432.045	5108.16	89.879	1094	465.498	5076.35	86.454
1038	431.03	5110.2	90.353	1095	466.812	5067.72	86.384
1039	435.904	5104.1	89.596	1096	469.038	5059.98	86.285
1040	438.336	5096.07	89.296	1097	478.121	5067.15	85.382
1041	440.362	5087.08	88.976	1098	477.293	5076.6	85.391
1042	443.064	5076.88	88.759	1099	476.288	5087.19	85.383
1043	445.35	5066.55	88.453	1100	475.196	5097.11	85.511
1044	448.591	5056.5	88.226	1101	475.339	5104.38	85.417
1045	451.619	5050.45	88.144	1102	474.548	5112.19	85.434
1046	453.894	5047.02	87.877	1103	473.379	5119.7	85.616
1047	456.557	5049.46	87.519	1104	473.176	5126.2	85.879
1048	454.71	5053.19	87.819	1105	472.685	5131.42	86.425
1049	452.705	5061.18	87.757	1106	472.02	5135.23	86.618
1050	451.33	5070.51	87.805	1107	469.861	5140.35	86.626
1051	450.4	5081.51	87.958	1108	469.133	5142.39	87.123
1052	449.747	5089.93	88.124	1109	477.466	5151.28	86.579
1053	448.428	5099.42	88.264	1110	477.831	5148.84	86.164
1054	447.432	5107.12	88.365	1111	478.993	5142.57	86.131
1055	447.409	5111.78	88.437	1112	479.782	5136.75	86.084
1056	447.406	5116.53	88.638	1113	481.083	5129.2	85.709
1057	445.9	5121.35	88.781	1114	483.332	5129.24	85.657
1058	444.683	5122.83	89.283	1115	481.84	5135.38	85.947
1059	448.427	5125.04	88.608	1116	483.105	5122.95	85.479
1060	447.992	5126.07	89.117	1117	479.753	5122.1	85.488
1061	450.768	5120.71	88.5	1118	481.452	5113.05	85.203
1062	451.058	5117.33	88.431	1119	484.792	5113.38	85.056
1063	451.488	5110.29	88.293	1120	482.56	5104.27	84.998
1064	451.771	5101.26	88.227	1121	483.797	5094.51	84.747
1065	452.356	5091.72	88.129	1122	485.163	5083.96	84.651
1066	452.983	5082.43	87.986	1123	486.236	5076.88	84.61
1067	453.906	5074.4	87.847	1124	486.703	5074.25	84.559
1068	455.388	5065.48	87.677	1125	492.698	5079.33	84.013
1069	456.403	5059.55	87.639	1126	492.27	5082.55	84.112
1070	457.388	5054.52	87.57	1127	491.055	5088.13	84.156
1071	458.184	5051.02	87.402	1128	489.872	5095.76	84.227
1072	462.547	5054.46	86.955	1129	490.109	5103.74	84.373
1073	463.278	5057.8	86.832	1130	489.925	5111.3	84.754
1074	460.657	5058.47	87.1	1131	487.261	5110.91	84.781
1075	459.79	5064.59	87.075	1132	486.73	5116.86	85.089
1076	458.676	5073.29	87.185	1133	489.543	5116.96	85.139
1077	457.588	5083.62	87.366	1134	489.393	5124.36	85.36
1078	456.934	5092.85	87.489	1135	486.424	5124.17	85.314
1079	456.758	5102.43	87.458	1136	486.457	5130.59	85.444
1080	456.331	5111.75	87.483	1137	489.399	5130.65	85.498
1081	456.041	5119.29	87.702	1138	489.206	5139.09	85.561
1082	455.567	5122.9	87.927	1139	485.206	5138.65	85.641
1083	453.267	5129.64	88.17	1140	483.976	5146.51	85.756

Point	X	Y	Z	Point	X	Y	Z
1141	489.143	5147.56	85.589	1198	498.891	5088.87	83.374
1142	489.7	5155.41	85.66	1199	500.664	5085.25	83.106
1143	485.437	5152.97	85.774	1200	502.014	5086.12	83.253
1144	483.579	5157.48	85.815	1201	501.53	5086.69	83.51
1145	482.413	5159.75	86.254	1202	500.161	5089.7	83.6
1146	489.364	5160.13	85.698	1203	499.038	5095.28	83.734
1147	485.36	5161.57	85.875	1204	498.554	5101.76	83.84
1148	486.715	5164.41	85.728	1205	500.271	5108.72	84.038
1149	490.306	5162.6	85.641	1206	502.689	5114.58	84.159
1150	492.743	5165.76	85.406	1207	501.732	5114.96	83.98
1151	491.483	5163.12	85.651	1208	504.022	5119.05	83.991
1152	490.955	5160.53	85.865	1209	504.847	5118.74	84.13
1153	491.078	5154.69	85.989	1210	507.05	5125.2	84.115
1154	491.212	5148.41	85.993	1211	506.064	5125.48	84.026
1155	491.366	5139.08	85.965	1212	508.76	5132.14	84.042
1156	491.571	5132.35	85.981	1213	509.549	5131.99	84.117
1157	491.667	5124.75	85.862	1214	510.96	5136.44	84.038
1158	491.788	5118.17	85.704	1215	510.206	5136.74	83.962
1159	492.085	5111.5	85.145	1216	510.781	5138.06	83.991
1160	492.265	5103.48	84.756	1217	511.296	5138.13	84.175
1161	492.386	5094.94	84.563	1218	511.487	5137.55	83.735
1162	492.749	5087.88	84.36	1219	511.618	5139.14	84.137
1163	493.639	5082.87	84.248	1220	511.887	5139.86	84.019
1164	495.482	5081.59	83.672	1221	511.274	5140.05	83.994
1165	496.064	5083.65	83.666	1222	511.799	5142.04	83.96
1166	497.475	5082.6	83.43	1223	512.533	5141.8	84.04
1167	495.324	5085.59	83.669	1224	512.653	5142.51	83.578
1168	494.854	5091.85	83.689	1225	513.001	5142.42	82.678
1169	494.937	5098.54	83.735	1226	514.287	5142	82.545
1170	494.514	5106.74	84.109	1227	514.302	5141.66	83.47
1171	494.678	5113.62	84.553	1228	514.386	5142.38	83.485
1172	494.235	5122.34	85.059	1229	515.92	5142	83.275
1173	494.152	5130.09	85.165	1230	515.77	5141.42	83.267
1174	493.84	5138.91	85.227	1231	515.777	5141.74	82.525
1175	494.061	5134.21	85.204	1232	517.878	5141.34	82.275
1176	493.702	5144.65	85.213	1233	517.782	5141.04	82.925
1177	493.619	5150.56	85.205	1234	517.835	5141.56	82.963
1178	492.666	5158.85	85.32	1235	520.481	5140.69	82.126
1179	492.417	5162.32	85.354	1236	520.422	5140.33	82.506
1180	492.003	5174.56	85.778	1237	520.399	5140.34	82.481
1181	491.031	5176.05	86.214	1238	520.56	5141.1	82.524
1182	496.669	5181.03	85.687	1239	522.621	5140.01	82.065
1183	495.743	5183.09	86.29	1240	522.496	5139.5	82.462
1184	499.875	5176.37	85.214	1241	522.682	5140.52	82.2
1185	501.593	5169.19	84.999	1242	522.737	5140.78	82.44
1186	501.658	5161.86	84.855	1243	523.44	5140.91	82.39
1187	500.922	5153.91	84.86	1244	523.539	5140.21	81.764
1188	500.265	5146.32	84.824	1245	523.633	5139.45	82.425
1189	499.748	5138.27	84.709	1246	524.289	5141.06	82.376
1190	499.278	5131.18	84.655	1247	524.431	5140.51	81.761
1191	499.187	5124.74	84.492	1248	524.654	5140.15	82.361
1192	499.188	5118.15	84.292	1249	525.378	5141.04	81.293
1193	499.133	5118.14	84.283	1250	525.281	5140.82	82.117
1194	498.612	5111.05	83.974	1251	525.453	5141.5	82.293
1195	497.635	5104.73	83.735	1252	525.894	5141.99	82.504
1196	497.507	5098.03	83.59	1253	526.544	5140.73	81.644
1197	497.913	5093.01	83.528	1254	526.137	5140.22	81.659

Point	X	Y	Z	Point	X	Y	Z
1255	526.279	5140.56	81.164	1312	586.09	5120.93	79.296
1256	527.292	5139.8	80.943	1313	578.087	5120.8	79.252
1257	527.177	5139.48	81.465	1314	577.609	5122.82	79.154
1258	527.734	5140.14	81.439	1315	571.346	5122.38	79.081
1259	528.911	5139.26	81.014	1316	571.395	5120	79.225
1260	530.068	5139.28	80.752	1317	564.819	5119.15	79.134
1261	532.083	5138.79	80.508	1318	564.114	5121.23	79.077
1262	532.416	5139.28	80.843	1319	559.026	5119.8	79.015
1263	532.056	5138.33	80.764	1320	559.312	5117.76	79.097
1264	513.197	5146.21	83.992	1321	555.301	5116.57	79.011
1265	511.956	5146.77	83.976	1322	554.851	5118.23	78.929
1266	513.085	5150.36	84.012	1323	550.21	5116.35	79.018
1267	514.535	5149.73	83.984	1324	550.698	5114.68	79.016
1268	515.454	5149.49	84.362	1325	547.071	5113	79.06
1269	518.723	5155.08	84.347	1326	546.349	5114.49	79.063
1270	518.038	5155.69	84.018	1327	540.949	5111.82	79.26
1271	514.393	5157.54	84.183	1328	541.298	5109.86	79.279
1272	510.272	5159.93	84.446	1329	534.772	5108.22	79.48
1273	508.834	5151.17	84.371	1330	535.435	5106.33	79.485
1274	522.309	5159.55	84.485	1331	529.785	5102.47	79.951
1275	521.551	5160.26	84.056	1332	528.724	5103.87	80.003
1276	517.353	5163.65	84.16	1333	528.725	5103.88	80.003
1277	513.201	5166.89	84.415	1334	523.543	5100.06	80.501
1278	517.296	5172.2	84.424	1335	524.449	5098.49	80.495
1279	521.786	5167.91	84.126	1336	518.091	5093.72	80.956
1280	525.652	5164.19	83.982	1337	516.799	5095.14	81.053
1281	526.324	5163.42	84.408	1338	510.189	5089.66	81.549
1282	529.267	5165.33	84.13	1339	511.002	5088.01	81.576
1283	528.833	5165.83	83.943	1340	504.227	5082.49	82.115
1284	525.206	5170.31	84.102	1341	502.814	5083.84	82.19
1285	519.591	5175.34	84.498	1342	496.623	5078.99	82.778
1286	513.624	5181.76	84.86	1343	497.67	5077.38	82.761
1287	507.31	5188.08	85.183	1344	490.165	5071.25	83.528
1288	506.355	5192.28	85.344	1345	488.457	5072.49	83.546
1289	505.385	5194.15	85.867	1346	481.132	5066.62	84.321
1290	517.25	5199.92	85.745	1347	482.27	5065.08	84.31
1291	521.31	5194.23	84.727	1348	500	4925.64	79.951
1292	523.683	5189.73	84.744	1349	504.589	4913.36	80.033
1293	526.573	5184.4	84.671	1350	504.549	4913.49	79.246
1294	528.862	5178.95	84.419	1351	558.995	4964.95	76.07
1295	532.075	5173.68	84.075	1352	650.148	5022.08	73.479
1296	533.413	5171.42	83.949	1353	650.221	5022.23	73.84
1297	534.628	5169.78	83.968	1354	397.873	4976.75	95.893
1298	500	4925.63	79.955	1355	403.851	4995.27	95.243
1299	499.961	4925.74	79.711	1356	402.474	4996.79	95.277
1300	500.007	4925.63	79.95	1357	407.898	5001.42	94.688
1301	499.997	4925.75	79.709	1358	409.313	4999.77	94.628
1302	650.223	5022.21	73.85	1359	412.632	5002.74	94.213
1303	609.875	5122.02	79.201	1360	410.971	5004.61	94.214
1304	609.725	5120.16	79.162	1361	414.546	5007.71	93.709
1305	604.624	5120.51	79.295	1362	415.777	5006.21	93.597
1306	604.502	5122.51	79.295	1363	419.023	5009.79	92.941
1307	599.235	5122.65	79.404	1364	418.342	5010.72	92.978
1308	598.905	5120.75	79.302	1365	421.633	5011.67	92.586
1309	592.94	5120.84	79.349	1366	420.212	5013.31	92.569
1310	592.552	5122.94	79.331	1367	425.367	5018.89	91.792
1311	586.222	5122.83	79.259	1368	426.722	5017.09	91.763

Point	X	Y	Z	Point	X	Y	Z
1369	427.168	5017.55	91.334	1426	542.001	5176.74	84.049
1370	426.021	5019.37	91.332	1427	545.232	5180.03	84.188
1371	430.549	5023.57	90.514	1428	544.771	5184.75	84.415
1372	431.843	5022.17	90.472	1429	544.004	5192.05	84.801
1373	436.681	5026.62	89.672	1430	544.235	5197.84	84.984
1374	435.711	5028.2	89.66	1431	543.855	5201.97	85.021
1375	440.75	5032.91	88.801	1432	543.716	5204.31	85.635
1376	442.267	5031.42	88.841	1433	549.641	5206.7	85.523
1377	447.851	5036.36	88.128	1434	550.602	5204.17	84.997
1378	446.849	5038.11	88.058	1435	552.543	5197.1	84.967
1379	451.365	5041.97	87.542	1436	553.82	5190.04	84.531
1380	452.831	5040.62	87.533	1437	555.009	5181.19	84.05
1381	457.811	5044.84	86.831	1438	554.709	5175.31	83.835
1382	456.829	5046.61	86.835	1439	553.868	5169.76	83.291
1383	464.978	5050.89	86.042	1440	552.657	5164.23	82.482
1384	464.117	5052.67	86.097	1441	547.661	5160.49	82.144
1385	469.03	5056.99	85.47	1442	546.43	5159.74	82.412
1386	470.556	5055.44	85.501	1443	542.121	5157.86	82.446
1387	478.887	5062.4	84.622	1444	537.094	5155.08	82.362
1388	477.67	5064.02	84.645	1445	531.353	5149.49	82.382
1389	481.943	5067.3	84.242	1446	529.18	5146.6	82.495
1390	483.115	5065.96	84.233	1447	528.745	5145.98	82.178
1391	488.692	5070.13	83.69	1448	526.924	5143.43	82.3
1392	487.406	5071.74	83.672	1449	526.564	5143.16	82.513
1393	493.529	5076.69	83.128	1450	524.332	5139.72	82.373
1394	494.771	5074.99	83.107	1451	521.822	5135.36	82.446
1395	524.826	5162.28	84.444	1452	519.616	5130.45	82.45
1396	524.47	5163.43	84.003	1453	518.279	5125.67	82.416
1397	522.493	5165.55	84.04	1454	518.439	5126.56	82.464
1398	520.594	5170.14	84.241	1455	517.443	5119.71	82.362
1399	519.532	5176.65	84.544	1456	516.96	5115.58	82.321
1400	518.466	5183.24	84.77	1457	516.926	5110.86	82.23
1401	516.372	5189.02	84.82	1458	517.299	5105.8	82.202
1402	514.197	5194.65	85.041	1459	518.327	5101.87	82.131
1403	513.582	5198.15	85.575	1460	519.555	5100.08	81.995
1404	520.727	5201.05	85.951	1461	518.778	5099.38	81.687
1405	522.609	5197.15	84.918	1462	517.441	5101.03	81.843
1406	525.842	5193.16	84.633	1463	516.298	5104.59	81.925
1407	529.064	5189.81	84.814	1464	515.601	5108.04	81.989
1408	534.788	5183.63	84.472	1465	515.71	5113.11	82.139
1409	538.586	5179.83	84.251	1466	516.386	5119.25	82.214
1410	542.887	5176.47	84.051	1467	517.148	5124.55	82.285
1411	542.187	5175.95	84.336	1468	518.078	5128.48	82.343
1412	539.909	5173.62	84.339	1469	519.877	5133.42	82.41
1413	538.517	5171.85	84.274	1470	522.104	5136.77	82.389
1414	536.078	5170.12	84.288	1471	520.153	5139.03	82.475
1415	533.48	5168.08	84.264	1472	525.327	5142.25	82.338
1416	531.211	5166.93	84.266	1473	527.51	5145.4	82.237
1417	530.409	5166.29	84.114	1474	529.861	5148.69	82.228
1418	529.24	5165.37	84.098	1475	533.104	5152.6	82.264
1419	527.956	5164.53	84.389	1476	537.741	5156.41	82.312
1420	527.564	5165.3	83.971	1477	541.124	5158.83	82.337
1421	531.152	5167.71	83.95	1478	544.403	5159.19	82.372
1422	534.76	5169.93	83.963	1479	545.797	5159.78	82.371
1423	536.674	5171.61	83.973	1480	545.346	5163.07	82.569
1424	538.228	5172.46	83.994	1481	543.846	5167.09	83.196
1425	539.509	5174.33	83.981	1482	539.624	5164.57	83.055

Point	X	Y	Z	Point	X	Y	Z
1483	533.352	5160.28	82.94	1540	540.615	5124.78	80.449
1484	528.472	5155.82	82.809	1541	542.439	5131.74	80.513
1485	523.67	5151.18	82.918	1542	545.91	5138.45	80.622
1486	519.553	5145.49	83.001	1543	550.412	5144.88	80.781
1487	517.914	5142.4	83.038	1544	555.062	5150.86	81.284
1488	516.311	5138.37	82.999	1545	560.335	5156.58	81.916
1489	514.77	5133.36	82.941	1546	566.296	5162.3	82.673
1490	513.043	5127.03	82.857	1547	571.666	5167.12	83.278
1491	511.459	5121.3	82.858	1548	584.861	5177.38	84.027
1492	510.249	5116.65	82.894	1549	590.896	5181.52	84.126
1493	510.387	5105.23	82.536	1550	595.503	5184.55	84.084
1494	510.985	5098.63	82.412	1551	600.527	5188.46	84.176
1495	511.719	5093.99	82.353	1552	602.036	5189.83	83.762
1496	515.53	5096.86	82.039	1553	604.397	5193.62	83.764
1497	513.461	5112.23	82.29	1554	605.926	5195.87	83.541
1498	515.074	5119.64	82.31	1555	607.997	5198.31	82.907
1499	516.029	5127.17	82.438	1556	601.008	5203.9	83.619
1500	518.215	5133.54	82.463	1557	598.806	5200.84	84.356
1501	520.588	5139.25	82.463	1558	597.37	5198.76	84.409
1502	522.928	5142.61	82.368	1559	592.022	5192.35	83.964
1503	525.604	5145.81	82.238	1560	586.155	5187.06	83.907
1504	529.145	5150.08	82.278	1561	578.854	5183.65	83.85
1505	534.745	5155.8	82.367	1562	573.417	5177.97	83.591
1506	539.66	5159.63	82.432	1563	569.601	5174.19	83.42
1507	540.993	5168.43	83.45	1564	565.303	5170.37	83.055
1508	542.395	5172.57	83.808	1565	560.35	5165.94	82.478
1509	543.085	5175.2	83.962	1566	555.939	5160.99	81.972
1510	539.926	5171.82	83.814	1567	551.521	5155.15	81.394
1511	539.864	5170.55	83.716	1568	546.509	5148.63	80.851
1512	538.605	5169.37	83.666	1569	542.541	5141.5	80.466
1513	534.927	5165.73	83.439	1570	539.599	5134.08	80.29
1514	534.202	5166.98	83.685	1571	535.368	5127.2	80.281
1515	530.173	5164.6	83.678	1572	533.326	5118.13	80.304
1516	531.018	5163.24	83.38	1573	532.826	5112.79	80.282
1517	524.086	5159.14	83.614	1574	532.09	5108.57	80.379
1518	525.366	5157.93	83.345	1575	526.871	5105.03	80.901
1519	518.938	5152.6	83.615	1576	525.902	5109.1	80.879
1520	520.115	5151.68	83.351	1577	525.041	5114.14	81.116
1521	515.804	5146.86	83.603	1578	525.167	5116.17	80.98
1522	517.229	5145.95	83.36	1579	526.138	5122.48	80.832
1523	513.056	5137.78	83.482	1580	528.279	5129.67	80.748
1524	510.682	5130.95	83.532	1581	531.155	5136.86	80.761
1525	511.804	5130.35	83.239	1582	535.742	5145.29	81.126
1526	508.546	5124.88	83.525	1583	540.621	5151.44	81.368
1527	507.064	5119.29	83.443	1584	545.245	5157.52	81.871
1528	504.562	5115.67	83.663	1585	540.725	5155.78	81.927
1529	506.9	5114.86	83.28	1586	535.619	5152.1	81.886
1530	502.708	5110.81	83.554	1587	531.78	5147.39	81.756
1531	500.155	5104.42	83.452	1588	529.197	5144.71	81.684
1532	499.952	5099.62	83.394	1589	527.01	5141.66	81.926
1533	500.373	5093.34	83.268	1590	528.712	5141.05	81.402
1534	501.596	5089.17	83.16	1591	525.39	5138.73	81.685
1535	502.862	5086.87	83.089	1592	522.615	5133.76	81.731
1536	536.734	5113.07	80.272	1593	520.523	5129.2	81.828
1537	536.812	5111.69	80.061	1594	521.936	5128.71	81.544
1538	537.434	5115.09	80.491	1595	520.658	5124.52	81.57
1539	538.683	5117.85	80.514	1596	519.352	5124.62	81.841

Point	X	Y	Z	Point	X	Y	Z
1597	518.554	5119.35	81.87	1654	420.827	4959.96	94.877
1598	520.057	5119.26	81.578	1655	414.36	4963.82	95.347
1599	519.442	5113.49	81.628	1656	407.415	4967.72	95.353
1600	518.125	5113.72	81.848	1657	397.154	4974.08	95.451
1601	518.29	5108.72	81.763	1658	386.414	4982.3	95.161
1602	519.727	5108.83	81.57	1659	379.76	4993.48	95.394
1603	519.008	5104.13	81.69	1660	374.858	5003.69	95.286
1604	520.441	5104.67	81.506	1661	370.782	5014.46	95.37
1605	520.607	5100.61	81.571	1662	368.583	5026.59	95.222
1606	522.646	5102.01	81.316	1663	370.219	5041.54	95.003
1607	523.164	5112.49	81.236	1664	371.955	5054.7	95.059
1608	601.834	5139.61	80.665	1665	379.129	5065.64	96.004
1609	596.337	5140.25	80.55	1666	391.39	5080.21	96.205
1610	589.628	5140.09	80.272	1667	401.253	5095.81	95.676
1611	581.127	5139.3	79.876	1668	422.387	5116.21	95.275
1612	574.371	5138.59	79.664	1669	440.854	5135.86	94.652
1613	568.194	5137.63	79.6	1670	455.618	5149.01	93.262
1614	561.852	5135.89	79.593	1671	466.107	5159.37	92.641
1615	556.168	5134.25	79.575	1672	481.035	5179.2	90.872
1616	549.836	5132.44	79.642	1673	492.885	5193.36	89.171
1617	603.772	5122.4	79.288	1674	509.091	5204.07	88.054
1618	603.466	5120.43	79.32	1675	526.274	5208.99	87.736
1619	611.802	5120.11	79.08	1676	542.428	5212	88.003
1620	612.017	5122	79.162	1677	557.517	5214.18	86.96
1621	620.571	5121.47	78.746	1678	557.415	5208.22	85.335
1622	620.504	5119.6	78.734	1679	557.208	5204.08	84.941
1623	627.931	5119.18	78.447	1680	557.204	5200.58	85.016
1624	628.118	5120.99	78.421	1681	557.241	5196.97	84.93
1625	635.123	5120.9	78.241	1682	557.626	5191.18	84.571
1626	634.96	5118.92	78.174	1683	558.013	5183.99	84.132
1627	641.128	5118.65	77.916	1684	558.043	5177.61	83.835
1628	641.387	5120.45	77.966	1685	557.467	5171.54	83.423
1629	648.27	5096.35	78.527	1686	520.448	5172.7	84.344
1630	649.009	5094.89	78.376	1687	513.098	5168.92	84.422
1631	650.248	5092.75	77.717	1688	503.923	5164.86	84.761
1632	634.13	5081.92	78.963	1689	507.865	5156.87	84.522
1633	632.632	5084.03	79.793	1690	499.936	5155.85	84.909
1634	621.129	5077.11	81.048	1691	497.333	5167.95	85.161
1635	622.117	5075.74	80.564	1692	574.266	5209.62	86.195
1636	622.981	5074.32	80.069	1693	576.986	5203.79	84.934
1637	612.261	5065.67	80.892	1694	690.035	5024.39	71.607
1638	610.534	5067.95	81.772	1695	676.994	5037.23	73.163
1639	605.901	5063.41	81.94	1696	641.949	5056.44	73.265
1640	607.156	5059.89	80.878	1697	618.199	4991.02	73.46
1641	596.054	5053.87	82.022				
1642	589.048	5048.05	82.29				
1643	580.027	5041.2	82.727				
1644	570.697	5030.71	82.328				
1645	559.803	5023.4	82.802				
1646	545.787	5017.19	83.824				
1647	531.226	5009.15	84.851				
1648	517.307	5001.82	85.979				
1649	492.959	4986.22	88.724				
1650	477.255	4977.32	90.785				
1651	461.527	4966.64	92.2				
1652	447.913	4954.08	91.863				
1653	428.027	4957.86	94.557				

D. 5 Dysons 2008 cross section data (parallel to central channel)

Cross ectional data Dyson's 1986 survey surface (Approx. parallel to channel)							
Point	Easting Grid Reference	Northing Grid Reference	Elevation (AHD)	Point	Easting Grid Reference	Northing Grid Reference	Elevation (AHD)
1	718705	8563618	88.6051	31	718796	8563650	81.6193
2	718708	8563619	88.3402	32	718800	8563651	81.5483
3	718711	8563620	88.1563	33	718804	8563653	81.4818
4	718712	8563620	88.0767	34	718805	8563653	81.4731
5	718717	8563622	87.7308	35	718808	8563654	81.4481
6	718721	8563623	87.2975	36	718812	8563656	81.422
7	718723	8563624	87.0496	37	718817	8563657	81.4
8	718725	8563625	86.8213	38	718817	8563657	81.3994
9	718729	8563626	86.3485	39	718821	8563659	81.4016
10	718733	8563628	85.8241	40	718825	8563660	81.4095
11	718735	8563628	85.7053	41	718829	8563662	81.4192
12	718737	8563629	85.4731	42	718829	8563662	81.4221
13	718742	8563631	85.1386	43	718833	8563663	81.4473
14	718746	8563632	84.8238	44	718837	8563665	81.468
15	718746	8563632	84.7805	45	718840	8563666	81.4776
16	718750	8563634	84.5387	46	718842	8563666	81.4851
17	718754	8563635	84.2762	47	718846	8563668	81.5025
18	718758	8563636	83.9602	48	718850	8563669	81.5115
19	718758	8563637	83.9487	49	718852	8563670	81.5037
20	718762	8563638	83.6945	50	718854	8563671	81.5006
21	718767	8563640	83.4243	51	718858	8563672	81.5014
22	718770	8563641	83.1874	52	718863	8563674	81.4957
23	718771	8563641	83.1182	53	718864	8563674	81.4879
24	718775	8563642	82.7786	54	718867	8563675	81.4734
25	718779	8563644	82.3534	55	718871	8563677	81.4254
26	718782	8563645	82.1858	56	718875	8563678	81.357
27	718783	8563645	82.0697	57	718876	8563678	81.3446
28	718787	8563647	81.8665	58	718879	8563680	81.2386
29	718792	8563648	81.7208	59	718883	8563681	81.1542
30	718793	8563649	81.6789	60	718884	8563681	81.1372

D. 6 Dysons 2008 cross section data (orthogonal to central channel)

Cross ectional data Dyson's 2008 survey surface (Approx. parallel to channel)							
Point	Easting Grid Reference	Northing Grid Reference	Elevation (AHD)	Point	Easting Grid Reference	Northing Grid Reference	Elevation (AHD)
1	718775	8563711	84.719	26	718812	8563654	79.3918
2	718776	8563709	84.6279	27	718812	8563653	79.3545
3	718777	8563708	84.5772	28	718815	8563649	79.0483
4	718779	8563704	84.3446	29	718815	8563649	79.0698
5	718780	8563703	84.3093	30	718818	8563645	79.6192
6	718782	8563699	84.0523	31	718818	8563644	79.8892
7	718783	8563699	84.0443	32	718820	8563641	80.5354
8	718785	8563695	84.1657	33	718822	8563639	80.6578
9	718786	8563694	83.9944	34	718823	8563636	80.8017
10	718788	8563691	83.2328	35	718825	8563634	80.9394
11	718789	8563689	82.8991	36	718826	8563632	81.0101
12	718791	8563687	82.5926	37	718828	8563629	81.1982
13	718792	8563684	82.0916	38	718828	8563628	81.2241
14	718793	8563682	81.8675	39	718831	8563624	81.4524
15	718796	8563679	81.3075	40	718831	8563624	81.4697
16	718796	8563678	81.2199	41	718834	8563620	81.7424
17	718799	8563674	80.7498	42	718835	8563619	81.8017
18	718799	8563674	80.7238	43	718837	8563616	82.0085
19	718801	8563670	80.4259	44	718838	8563614	82.1372
20	718802	8563669	80.2736	45	718839	8563611	82.2685
21	718804	8563666	79.8443	46	718841	8563609	82.3112
22	718805	8563664	79.7271	47	718842	8563607	82.3933
23	718807	8563662	79.619	48	718844	8563604	82.4132
24	718809	8563659	79.5702	49	718845	8563603	82.4182
25	718810	8563657	79.542	50	718847	8563600	82.482

D. 7 One dimensional consolidation model data and time specific settlement results

mv =	0.00104				
t (years)	**0**	**0.055**	**1.595**	**1.65**	**6.215**
q (kPa)	180.375	180.375	180.375	180.375	180.375
z = 0	180.375	0	0	0	0
z = 1	180.375	180.375	26.956	26.058	13.569
z = 2	180.375	180.375	52.116	52.116	26.899
z = 3	180.375	180.375	77.275	74.916	40.230
z = 4	180.375	180.375	97.717	97.717	52.871
z = 5	180.375	180.375	118.159	115.152	65.512
z = 6	180.375	180.375	132.588	132.588	77.082
z = 7	180.375	180.375	147.018	144.212	88.652
z = 8	180.375	180.375	155.836	155.836	98.872
z = 9	180.375	180.375	164.654	162.565	109.092
z = 10	180.375	180.375	169.295	169.295	117.804
z = 11	180.375	180.375	173.936	172.660	126.516
z = 12	180.375	180.375	176.024	176.024	133.683
z = 13	180.375	180.375	178.113	177.466	140.849
z = 14	180.375	180.375	178.909	178.909	146.537
z = 15	180.375	180.375	179.704	179.433	152.225
z = 16	180.375	180.375	179.957	179.957	156.579
z = 17	180.375	180.375	180.210	180.117	160.934
z = 18	180.375	180.375	180.276	180.276	164.149
z = 19	180.375	180.375	180.343	180.316	167.365
z = 20	180.375	180.375	180.356	180.356	169.655
z = 21	180.375	180.375	180.370	180.364	171.945
z = 22	180.375	180.375	180.372	180.372	173.517
z = 23	180.375	180.375	180.374	180.373	175.090
z = 24	180.375	180.375	180.375	180.375	176.130
z = 25	180.375	180.375	180.375	180.375	177.170
z = 26	180.375	180.375	180.375	180.375	177.834
z = 27	180.375	180.375	180.375	180.375	178.497
z = 28	180.375	180.375	180.375	180.375	178.905
z = 29	180.375	180.375	180.375	180.375	179.313
z = 30	180.375	180.375	180.375	180.375	179.554
z = 31	180.375	180.375	180.375	180.375	179.795
z = 32	180.375	180.375	180.375	180.375	179.932
z = 33	180.375	180.375	180.375	180.375	180.069
z = 34	180.375	180.375	180.375	180.375	180.145
z = 35	180.375	180.375	180.375	180.375	180.220
z = 36	180.375	180.375	180.375	180.375	180.259
z = 37	180.375	180.375	180.375	180.375	180.299
z = 38	180.375	180.375	180.375	180.375	180.319
z = 39	180.375	180.375	180.375	180.375	180.339
z = 40	180.375	180.375	180.375	180.375	180.349
z = 41	180.375	180.375	180.375	180.375	180.359
z = 42	180.375	180.375	180.375	180.375	180.363
z = 43	180.375	180.375	180.375	180.375	180.367
z = 44	180.375	180.375	180.375	180.375	180.369
z = 45	180.375	180.375	180.375	180.375	180.371
z = 46	180.375	180.375	180.375	180.375	180.371
dummy	180.375	180.375	180.375	180.375	180.371
Settlement	**0.000**	**0.094**	**0.799**	**0.813**	**1.588**

Note: Settlement in meters

mv =	**0.00104**				
t (years)	**14.025**	**15.300**	**16.980**	**17.040**	**22.020**
q (kPa)	180.375	180.375	180.375	180.375	180.375
z = 0	0.000	0.000	0.000	0.000	0.000
z = 1	9.021	8.986	8.532	8.532	7.497
z = 2	17.972	17.972	17.065	17.005	14.994
z = 3	26.923	26.819	25.478	25.478	22.410
z = 4	35.666	35.666	33.891	33.774	29.826
z = 5	44.409	44.240	42.071	42.071	37.082
z = 6	52.815	52.815	50.250	50.081	44.339
z = 7	61.221	60.997	58.091	58.091	51.362
z = 8	69.179	69.179	65.932	65.717	58.385
z = 9	77.136	76.865	73.343	73.343	65.109
z = 10	84.551	84.551	80.755	80.502	71.834
z = 11	91.965	91.659	87.662	87.662	78.201
z = 12	98.767	98.767	94.569	94.289	84.569
z = 13	105.568	105.238	100.916	100.916	90.534
z = 14	111.710	111.710	107.263	106.965	96.499
z = 15	117.851	117.510	113.013	113.013	102.025
z = 16	123.311	123.311	118.764	118.457	107.550
z = 17	128.770	128.429	123.901	123.901	112.614
z = 18	133.546	133.546	129.038	128.731	117.676
z = 19	138.323	137.992	133.562	133.562	122.264
z = 20	142.437	142.437	138.086	137.788	126.850
z = 21	146.551	146.238	142.015	142.015	130.959
z = 22	150.039	150.039	145.943	145.660	135.066
z = 23	153.527	153.238	149.306	149.306	138.702
z = 24	156.437	156.437	152.669	152.406	142.335
z = 25	159.347	159.087	155.506	155.506	145.513
z = 26	161.736	161.736	158.343	158.104	148.686
z = 27	164.126	163.897	160.702	160.702	151.425
z = 28	166.057	166.057	163.061	162.848	154.157
z = 29	167.987	167.789	164.993	164.993	156.480
z = 30	169.521	169.521	166.924	166.737	158.794
z = 31	171.055	170.887	168.481	168.479	160.727
z = 32	172.253	172.253	170.035	169.873	162.646
z = 33	173.451	173.311	171.265	171.262	164.214
z = 34	174.368	174.368	172.489	172.350	165.765
z = 35	175.285	175.170	173.436	173.429	166.990
z = 36	175.972	175.972	174.369	174.251	168.196
z = 37	176.658	176.564	175.066	175.053	169.099
z = 38	177.156	177.156	175.738	175.636	169.981
z = 39	177.653	177.576	176.206	176.186	170.578
z = 40	177.996	177.996	176.634	176.544	171.151
z = 41	178.340	178.275	176.883	176.857	171.454
z = 42	178.554	178.554	177.079	176.995	171.731
z = 43	178.769	178.713	177.108	177.079	171.744
z = 44	178.872	178.872	177.079	176.995	171.731
z = 45	178.975	178.923	176.883	176.857	171.454
z = 46	178.975	178.975	176.634	176.544	171.151
Dummy	178.975	178.923	176.206	176.186	170.578
Settlement	**2.388**	**2.392**	**2.526**	**2.530**	**2.892**

Note: Settlement in meters