

# SPECIFICATION FOR COASTAL RECLAMATION

## 1.0 SCOPE OF WORKS

The areas to be reclaimed are as shown in the drawings consisting mainly:

- (a) Parcels A (comprising of A1 & A2), Parcel B (comprising of B1 & B2) and Parcel C and C1.
- (b) Land reclamation generally along the Jelutong Expressway alignment.

The filling operation shall be by hydraulic pumping method and shall follow the recommended EIA guidelines.

It is expressly stated that the Contractor shall be fully responsible to investigate, identify sand borrow sources, and secure necessary permit or approval for supply of fill materials all at his own costs.

## 2.0 SEABED CLEARING

This work shall consist of wreck clearing (whether visible or hidden) unless of historical value, large obstruction/debris clearing, existing jetty structures and fishtraps clearing.

Incombustible material, including where appropriate the remains of burning, shall be disposed of in a safe and tidy manner at solid waste dumps approved by the Local Town Council but outside the Site, unless otherwise approved or directed by the Engineer. The Contractor shall be solely responsible for making the necessary agreements, and paying expenses and claims arising from the use of such solid waste dumps whether on Government or private land.

## 3.0 SUPPLY, DELIVERY AND STORAGE OF FILL MATERIALS

The Contractor shall make his own investigation prior to Tendering to ascertain the most suitable borrow sources. Full details of such information shall be submitted to the Engineer for approval for the hydraulic fill material (sand) and non-hydraulic fill material. The Contractor shall also determine the most suitable mode of delivery of fill materials from the proposed borrow sources to the site, including type of plants, vessels and methods to be used.

If the delivery of sand fill material involves pumping via a pipeline, the entire length of the pipeline shall be visually monitored at all times during operation for evidence of breaks or leakages. In the event a leak is detected, pumping shall be stopped as soon as practicable and shall not be started again until the leakage is repaired to the satisfaction of the Engineer.

## 4.0 SAND FILL MATERIALS FOR RECLAMATION

Fill materials for the reclamation works shall be sand obtained from Contractors borrow sources as mentioned above. The fill material shall be free from organic or other deleterious matters and shall contain less than 10% fines. The acceptable range of fill materials is given in the sieve envelope of Figure 1 of Appendix A herein. Materials marginally deviated from the above shall only be accepted with written approval of the Engineer

The Contractor shall carry out trial dredging to identify areas where suitable fill material can be obtained. For this purpose, Particle Size Distribution Tests for coarse grain soils in accordance to BS1377 (1990) shall be carried out on samples obtained from such trial dredging. The results

indicating the grading of sand obtained from such trial dredging shall be submitted to the Engineer for his approval prior to the reclamation works.

The strength tests shall be carried out also:

1. Compaction tests.
2. Shear box tests.

And the minimum effective shear strength of  $c'= 0$  and  $\phi'= 30^\circ$  shall be achieved unless otherwise agreed by the Engineer.

Once placed, the fill material shall be sampled and tested at regular intervals not less than once every placed 5,000 cubic metres as directed by the Engineer to determine its uniformity/conformity with the source samples. Materials found not conforming with the approved samples shall be removed from the Site and replaced at the Contractor's own costs.

The frequency of laboratory testing on the fill material samples shall be as directed by the Engineer, depending on the uniformity of sand fill materials at source and as delivered to the site by the Contractor.

The original soil at the reclamation area is of relatively low strength. The filling procedure which the Contractor intends to adopt shall take cognisance of this and shall avoid inducing slips, slides, mudwaves, erosion or displacement of the original soil and the rates and prices entered in the Bill of Quantities are deemed to allow for carrying out the work in such a manner. The Contractor should also submit a full detailed method statement of the reclamation for the Engineer's approval.

It is of importance that the procedure should allow for depositing the hydraulic fill uniformly over the site in thin layers with height agreed by the Engineer and with sufficient interval between successive increases in the depth of fill so as to ensure that the underlying soil does not fail. Under no circumstances should the first layer of fill result in abrupt differences in surface elevations or more than 0.6m anywhere over distances of less than 6.0 metres.

#### **4.1 Compaction**

Compaction of hydraulic fill below water level or +1.8m CD whichever is higher shall be by tidal flooding with sea water or with sea water ponding as applicable.

Compaction shall be by mechanical means for above water where practicable in accordance to Clause 2.6. The Contractor shall submit his proposals for compaction for the approval of the Engineer.

Hydraulic fill material placed at approximately the top 2 metres of the reclamation shall be densified to achieve an in-situ density 90% of the maximum possible density (4.5kg hammer) derived from compaction tests according to B.S. 1377 Part 4: 1990.

### **5.0 HYDRAULIC FILLING WORKS**

#### **5.1 Filling Procedure**

- (a) Prior to commencement of actual construction, the Contractor shall submit to the Engineer for his approval the proposed construction method.
- (b) The filling procedures that the Contractor intends to adopt shall take cognisance of the soil condition and marine environment at the Site and shall avoid inducing slips, slides and excessive mud waves.
- (c) The Contractor shall indicate the intended sequence of filling from the starting

point and the direction which the filling is expected to progress until completion.

(d) Whatever method initially proposed by the Contractor, a 'trial section' is to be carried out to prove his feasibility.

## 5.2 Methods to be Approved

- (a) The Contractor shall submit to the Engineer for his approval:
- (i) A detailed sequence and programme of operations complying with requirements of the Contract;
  - (ii) Pre-reclamation Survey drawings showing the extent of proposed reclamation works under this Contract and a detailed survey plan;
  - (iii) The general layout, and detailed design of all temporary works including bunds, drains, sluices, pipelines, culverts, access roads and bridges, docks, jetties, sumps, etc. which the Contractor intends to establish for handling and placing the reclamation fill.
  - (iv) Drawings showing the location, dimensions and elevations of any stockpiles of material which the Contractor intends to establish on the Site;
  - (v) Details of the plants, equipment and machinery to be employed and its capacity and how they are to be deployed on the Site; and
  - (vi) Such other information as the Engineer may require for the proper control and supervision of the Works.
  - (vii) All settlement markers and rod settlement gauges if so desired by the Contractor shall be set in position and level just prior to filling and the details recorded and shown on a drawing of 1:200 shall be subject to the approval of the Engineer.
  - (viii) Field (In-situ) testing method to determine the strength profile of the subsoils during staged construction. The locations and frequency of testing shall be discussed and agreed by the Engineer.
- (b) These submissions shall be made at least three (3) weeks before the intended date for commencement of the reclamation works in order that any modification which may be required by the Engineer be given effect to. No claim for delay in commencing the reclamation works can be entertained arising from these requirements. The cost of preparing and submitting the above to the Engineer and of making whatever modifications may be required by the Engineer before giving his approval shall be deemed to have been allowed for in the Contract Sum.
- (c) Approval of the Contractor's proposed Method of Construction shall not in any way relieve the Contractor of his responsibilities under the Contract. Nor can the Contractor claim any loss in time and money, if his proposed method is not successful in actual construction, even though prior approval has been obtained.

## 5.3 Loss of Fill

The Contractor shall allow in the Contract Sum for all risks and for any loss of fill which may occur during the course of the works including but not limited to marine erosion and loss of fill around the seaward perimeter, wind erosion, drainage, losses due to any settlement which may not be disclosed by the method of measurement specified. No claims for payment for filling other

than in accordance with the Specifications and in the Preamble to the Bills of Quantities will be allowed.

#### **5.4 Tolerances During Filling**

The fill shall be placed to within a tolerance of 150 mm above or below the levels profiles or thickness required by the filling procedure or shown on the Drawings. This tolerance does not apply to the finished work nor to the method of measurement which are elsewhere specified.

Add all temporary and permanent slope profiles gradient shall not exceed 1:5 unless the design drawing specified otherwise.

#### **5.5 Resting Period**

Resting period is the time required for the subsoil to gain strength after each stage of filling. Contractor shall not be allowed to proceed to next stage of filling until the following have been submittal and approved by the Engineer:

- (a) In-situ tests: Results from in-situ test carry out on subsoil.
- (b) Monitoring: Readings from all the instrumentation.

#### **5.6 Adjoining Property and Drains**

- (a) Methods shall be adopted and care taken so as not to cause flooding to adjoining property and that no materials are deposited thereon from the Works.
- (b) Should any siltation of the drains in the vicinity occur as a result of the Works, it shall be cleared forthwith by the Contractor at no additional cost to the Contract.
- (c) The insurance provided under the Contract shall provide full coverage against any claims for damages which may arise in these respects from parties having an interest of any kind in the adjoining lands and drains.

### **6.0 NON-HYDRAULIC FILLING**

#### **6.1 General**

Non-hydraulic filling may be performed after the underwater filling at the reclamation area has been completed to a stage above the water level if approved and directed by the Engineer. Non-hydraulic fill may be placed within the tidal range provided the work is performed during periods of non-submergence and only with the approval of the Engineer.

Non-hydraulic filling materials shall be obtained from borrow areas approved by the Engineer. All fill materials under this category shall be deposited in layers as determined from trial compaction tests. Each layer shall be compacted layer and shall be maintained at all times with a sufficiently even surface in order to drain away the surface water.

All fill materials shall be compacted as soon as practicable after being placed and spread. Compaction shall be undertaken to the requirements of this Section by equipment approved by the Engineer. All compaction requirements shall be controlled by means of field density measurements.

#### **6.2 Compaction Trials**

The B.S. 1377 compaction Test (4.5kg rammer method) shall be used in determining the

moisture versus density relation of soil.

The compacted soil samples (sufficient samples shall be prepared) shall be subjected to Isotropically Consolidated Undrained Triaxial Test ( CIU ) and shear box tests to determine the shear strength of the soil. The minimum effective shear strength of  $c'=0$  and  $\phi'=30^\circ$  shall be achieved unless otherwise agreed by the Engineer. If the compacted samples can not achieve the specified shear strength, the borrowed materials will be considered not suitable and other borrow sources shall be proposed by the Contractor. The Contractor will not be allowed to claim for extension of time and additional cost for the sourcing of new borrow materials due to the above failure. The range of particle size distribution of the soil samples to be used shall also be submitted to the Engineer for approval prior to the trials.

The Contractor shall submit to the Engineer for his approval the proposed method of compaction for each main type of material to be used. This shall include the type of compaction equipment and number of passes to achieve the desired compaction. The maximum compacted thickness of fill for these trials shall be limited to 300mm unless otherwise approved by the Engineer. The Contractor shall carry out field compaction trials supplemented by any necessary laboratory investigations as required by the Engineer. The method of compacting shall be exactly the same as that proposed for the permanent filling. Each trial area shall not be smaller than 8m x 15m. All expenses incurred shall be deemed to have been included in the rates and prices entered in the Bill of Quantities.

### 6.3 Degree of Compaction

Based on the in-situ density measurements, the materials shall be compacted to not less than 90% of the maximum dry density determined in accordance to B.S. 1377 Compaction Test (4.5kg rammer method).

The earthfill shall be processed as necessary to bring its moisture content to a uniform level throughout the material, suitable for compaction. The optimum moisture content as determined by the B.S. 1377 Compaction Test (4.5kg rammer method) shall be used as a guide in determining the proper moisture content at which each soil type shall be compacted.

Field density tests on each layer of compacted earthfill as specified elsewhere and at a minimum rate of once in every 200 sq.m. shall be carried out using the sand replacement method in accordance with B.S. 1377 or other means of testing of comparable accuracy approved by the Engineer.

Work on subsequent layers shall not proceed until satisfactory compaction of the preceding layers have been confirmed by the Engineer. The Contractor shall supply all samples to the Engineer from locations and depths as directed for the necessary tests.

## 7.0 PRE- AND POST-RECLAMATION SURVEYS

The Contractor shall be responsible for the setting out of the whole reclamation works under the Contract. He shall engage the services of a competent survey team approved by the Engineer to set out and level all the works including instrumentation, so as to enable the Engineer to carry out design cross-checking and adjustments where necessary.

The following surveys shall be carried out:-

- (a) Survey of the Site before commencement of the reclamation works (Pre-Reclamation Survey).
- (b) Survey of the Site on completion of the reclamation works (Post-Reclamation Survey)
- (c) Interim Surveys when required in connection with interim payments.

All surveys to be used as basis for progress payment shall be carried out jointly between the Contractor's competent surveyor and the Engineer's representative. The Contractor shall give notice (minimum one week) to the Engineer and shall send approved Licensed Surveyor with all necessary equipment to carry out the joint survey. All readings shall be mutually verified by the Contractor and the Engineer representative to the agreement of both parties.

Notwithstanding sub-paragraph 6.3 above, the Engineer may when he requires the joint survey to be carried out, give notice to the Contractor or his authorised agent/representative, who shall forthwith attend or send a qualified agent and an approved competent surveyor to carry out the survey jointly with the Engineer or his representative. Should the Contractor not attend, or neglect/omit to send such agent and neglect/omit to send such competent surveyor, then the survey made by the Engineer or approved by him shall be taken to be correct and be used for the measurement.

The Contractor shall confirm the correctness of the Site with the Engineer before proceeding with the setting out and reclamation works. Notwithstanding whatever assistance or checks on the surveys/setting out by the Engineer or his representative, the Contractor shall not be relieved of his responsibility for the correctness of the setting out and levelling. The Contractor shall remedy any work wrongly performed as a result of incorrect setting out or levelling at his own costs.

The surveys and the location, number and construction of bench marks and survey points shall be carried out and completed as directed and to the satisfaction of the Engineer, and the survey plans executed to his approval. All surveys relating to the beach nourishment works shall be reduced to Chart Datum (ACD).

## **8.0 PRE-RECLAMATION SURVEY**

The pre-nourishment survey shall be carried out before commencement of the beach nourishment works by a Licensed Surveyor to be approved by the Engineer and the survey of the site shall be plotted to a scale of 1:500 or to other scale approved by the Engineer.

Survey lines shall be set out spaced at 20m intervals. Levels shall be taken at not more than 10m intervals along the survey lines; these levels shall be recorded on the Survey Drawing. Additional levels shall be taken where there are significant changes in level or gradient or for the purpose of identifying ground features. Cross-sections of the reclaimed land profile shall be plotted as directed by the Engineer and shall extend up to at least 100 metres beyond the toe of the sandfill.

The limit of reclamation may be pegged out and used as base line for the Survey. Grid references, bearing, lines of sight and reduced levels of survey stations and bench marks shall be shown on the Survey plan. All existing roads, tracks, structures, drains and other salient features within the construction limits shall also be shown.

The Pre-reclamation Survey drawings shall be submitted to the Engineer for approval at least three (3) weeks prior to the intended date of commencement of filling works. The limits and extent of the reclamation areas shall be determined and confirmed by the Engineer after examining the pre-reclamation survey plans.

In all cases, NO filling work under this Contract can commence until the complete Primary Survey drawings have been submitted to the Engineer and his approval, which shall not be withheld unreasonably, has been obtained.

## **9.0 INTERIM SURVEYS**

Interim surveys of the reclaimed site shall be carried out jointly between the Contractor's competent surveyor and Engineer's representative in connection with interim monthly payments or as and when directed by the Engineer.

## **9.1 Post-Reclamation (Final) Survey**

The post-reclamation survey shall be carried out by a Licensed Surveyor on completion of full or part areas for the purpose of taking over. The survey shall be plotted on the same scale and covering the same areas as in the pre-reclamation survey. The survey shall show the levels and profile of the completed reclamation works.

## **10.0 SURVEY RECORDS AND PLOTTING**

All survey results shall be properly booked, computed and plotted to the required scale as directed by the Engineer.

All field books and drawings shall be carefully documented and handed over to the Engineer for his use.

## **11.0 TAKING OVER OF COMPLETED WORKS**

The whole or part of the reclamation works shall only be considered as complete for taking over purpose when all the following criteria have been achieved :

- The said whole or part of the reclamation areas has been filled to the design level or such other level approved by the Engineer within the tolerance of +150mm.
- The reclamation edge has satisfied the specified limits lines and slopes.
- The subsoil has achieved the 95% degree of consolidation unless otherwise specified by the Engineer.

The above completion shall be verified by the monitoring results and joint post-reclamation survey.

## **12.0 DIVERSION AND CARE OF WATER DURING CONSTRUCTION**

### **12.1 General**

- (a) The Contractor shall construct and maintain all diversion and protective works which are necessary for construction and to prevent surface, drainage and ground water from entering the various parts of the Works and shall furnish all materials and equipment required therefore, in accordance with the requirements of this Clause.
- (b) It is pointed out to the Contractor that high water levels can be expected in the rivers, streams and drains and adjacent swamp or non-swamp areas during rainy season and at other times following heavy rain. The Contractor shall take note of this and other information made available to him to construct and maintain diversion and protection works so that the river or drainage discharge may be safely controlled without overtopping any part of the embankment or other constructional work.
- (c)
  - (i) Diversion and protection works shall comprise, but are not necessarily limited to cofferdams, levee banks, channels, flumes, conduits, drains and when required, settling ponds.
  - (ii) Where diversion and protection works constructed by the Contractor are not required as components of the Permanent Works, they shall be removed and disposed of or levelled to give a sightly appearance and so as not to interfere with the operation or usefulness of the Permanent Works as approved by the

Engineer.

## **12.2 Maintenance of Existing Irrigation and Drainage System**

(a) During the construction period, the Contractor shall, at his own cost, unless the Contract otherwise provides, take all steps to ensure that there is no disruption or interference in the use or in the flow of water in the natural water courses, existing irrigation and/or drainage system owing to any factors within his control.

(b) Where interference with existing drains and natural watercourses is necessary to permit the proper construction of the works, the Contractor shall submit Drawings and Specifications of proposed diversion or protective works to the Engineer for approval prior to their construction. In general, such diversion or protective works shall have at least equal discharge capacity to the existing drains and watercourses.

(c) Where construction of the works, including spoil disposal will result in interference with local run off flow paths, the Contractor shall construct diversion drains generally running around the spoil disposal areas and connecting to the drains or to the river channel.

## **12.3 Dewatering**

(a) The Contractor shall furnish, install, maintain and operate all necessary pumping and other equipment for dewatering and maintaining the various parts of the Works free from water during construction and, as required, for inspection and safety and for any reason determined to be necessary by the Engineer after any part of the Works is completed.

(b) All diverted and pumped water shall be discharged at location on the surface from which it cannot re-enter the works and in a manner which does not cause erosion, pollution or nuisance to landowners, other contractors employed by the Employer or other persons within or adjacent to the Site.

## **12.4 Pollution**

The Contractor shall construct, maintain and operate suitable settling ponds, bunded areas, separating plant or other works necessary to prevent any discharge into rivers, streams or existing drainage systems of water containing polluting matter or visible suspended materials.

## **12.5 Responsibility for Works**

The Contractor shall be fully responsible for any damage or delay to the Works caused by failure of the dewatering, diversion and protective works during diversion. All damage to the foundations and other parts of the works shall be repaired by the Contractor, at his own expense.

## **13.0 SOIL FAILURE**

Should slips, slides or displacements occur the Contractor shall do everything necessary to rectify the defect and stabilise the ground to the satisfaction of the Engineer and shall bear all expenses and with no claim for extension of time, including replacing at his own expense any fill lost or rendered unsuitable as a consequence of the defect or providing any additional fill which would not have been necessary had the defect not occurred.

No claim shall be allowed for rectification of slips and displacements and the rates and prices entered in the Bill of Quantities and the Contractor Programme and the Completion Times

entered in the Tender are deemed to provide for all costs, expenses and delays which may be incurred.

#### **14.0 SILT : SEA POLLUTION**

The Contractor shall take whatever measures as required to prevent the escape of silt and fines into the Sea.

In this connection advantage may be taken for tidal working and for using the changes in the direction of the stream.

#### **15.0 MUD WAVE**

Filling shall be carried out in an approved manner so as to ensure the minimum loss of the original ground and to avoid, as far as possible, the formation of a mud wave due to the displacement of the original ground. In this connection the advancing face of the fill should be restricted in height and kept as flat as possible.

Should such a mud wave develop, the Engineer may direct the removal of the excess material and the cost of so doing shall be borne by the Contractor and the expense incurred shall be deemed to have been allowed in the rates and prices entered in the Bill of Quantities.

#### **16.0 EROSION**

When placing hydraulic fill care shall be taken not to erode or wash out the existing soil. Should this occur the cost of replacing the eroded material shall be borne by the Contractor.

#### **17.0 BUNDS AND DRAINS**

The Contractor shall provide such bunds, silt traps, settling ponds, drains and sluices and other temporary works, including temporary access roads and bridges, as may be necessary for the proper execution of the work and in fulfilment of his obligations under the Contract.

#### **18.0 REHANDLING (RECLAMATION) UNITS**

The attention of the Contractor is drawn to Clause 2.13 of the Specification in so far as the requirements of that item may affect the use of systems of reclamation employing bottom dump barges and redredging pumping units or other methods requiring the spoil to be rehandled in the sea.

Such equipment and methods may be permitted only in accordance with EIA requirements if suitable arrangements are made to contain the escape of silt and to avoid pollution. The Contractor shall give details of his proposals with his tender though acceptance of his proposals shall not in any way relieve the Contractor of his obligation to comply with the requirements of Clause 2.13 of the Specification and his obligations and responsibilities under the Contract.

#### **19.0 SURCHARGING**

Where indicated in the Drawings, the Contractor shall fill to the levels and outlines of the surcharge areas or as directed by the Engineer. Such surcharge shall be placed and compacted all in accordance with Clauses 2.4 and 2.5 hereof as appropriate.

When settlement designed for has taken place the surplus surcharge materials shall be removed and placed elsewhere on the site as and when directed by the Engineer. The site after removal

of surcharge materials shall be trimmed to the required finished levels, properly compacted and graded all to the satisfaction of the Engineer. This however, shall be carried out only when it is within the completion period.

## **20.0 GROUND IMPROVEMENT USING PREFABRICATED VERTICAL DRAINS**

### **20.1 General**

Where shown on the Drawings prefabricated vertical drains shall be installed after partial placement of the drainage layer or from levels as stated in the Drawing.

### **20.2 Installation of Prefabricated Vertical Drains**

The prefabricated vertical drains shall be installed after partial placing of the drainage layer to the spacing shown in the Drawings. The drains shall be of sufficient length to penetrate the full depth of the drainage layer, the geotextile sheet (if any) and the underlying compressible layer and shall be equipped with an end shoe to prevent damage to the drain faces.

Installation of the drains shall be by the displacement method preferably using a **static** machine of sufficient capacity to install the drain within a mandrel through the different levels and subsequently to retract the mandrel. Vibro driven machines may be needed in certain locations. All machines shall be approved by the Engineer.

Installation of the drains and retraction of the mandrel shall be carried out in a single downward and single upward stroke and no alternative raising and lowering of the mandrel will be permitted. The installation procedure shall be such as to ensure that the vertical drains are not damaged, kink or distorted.

Prior approval of the Engineer shall be obtained on the suitability of the type of mandrel to be used.

The size and shape of the mandrel shall be as close as possible to the size and shape of the drains in order to minimise disturbance to the soil. The length of the mandrel shall be not less than the maximum length of the drain. The mandrel shall be capable of making a clean puncture through any geotextile if necessary.

The drains shall be installed with a tolerance of  $\pm 100$ mm in plan from the proposed location and to a vertical tolerance of 1 in 75.

Splicing of drains may be allowed subject to the approval of the Engineer. Wherever splicing is allowed the Contractor shall ensure an overlap of at least 1.5m of inner core of the drain enclosed within the filter. In no case shall external laps be permitted. The details of the method and frequency of splicing shall be submitted by the Contractor prior to the actual splicing for the approval of the Engineer.

The installation of the drains shall be terminated at the depths indicated in the Drawings or where refusal is met, if lesser, but after the Engineer has been satisfied that the drains have successfully penetrated the underlying soft compressible layer.

After installation of the drains, the debris around the drain position shall be cleaned away and not allowed to contaminate the fill material.

### **20.3 Fill**

Fill shall be placed and properly compacted according to the rate and height of each stage of filling to be agreed by the Engineer according to the design.

Extra fill shall be placed to thickness specified on the Drawings as surcharge to speed up rate of embankment settlement depending on the design. Surcharging fill shall be maintained for a period of time indicated in the Drawing and shall be removed only with the approval of or when instructed by the Engineer.

## 20.4 Material

Prefabricated vertical drains shall be from an approved manufacturer and consist of an polymer core and an external non-woven filter membrane, and shall comply with the requirements as indicated on the Drawing and Table 1.

Property		Unit	Specified Requirements	Remarks
Material	Core			Continuous plastic drain core
	Filter			Wrapped in non-woven geotextile material
Dimension of drain	Width	Mm	100 ± 2	
	Thickness	Mm	3 to 4	
Coefficient of permeability of drain filter		M/s	$> 5 \times 10^{-5}$	
Discharge capacity of drain		M <sup>3</sup> /s	$25 \times 10^{-6}$	
Soil retention capacity		Microns	75	
Tensile strength of entire drain	Dry	kg/10cm	> 100	
	Wet	kg/10cm	> 100	
Tensile strength of filter	Dry	Kg/cm	> 3	At elongation minimum 2% maximum 10%
	Wet	Kg/cm	> 3	Tested at 1% strain/mm after saturation in water at 10° for 48hrs
Elongation of entire drain		%	< 10	At 100kg/10cm width
Elongation of filter	Dry	%	< 10	At 3kg/cm
	Wet			

TABLE 1

## 21.0 INSTRUMENTATION AND MONITORING

### 21.1 General

Instrumentation shall be installed to measure horizontal and vertical displacement or structures

and water pressures in the soil. Instrumentation is part of the permanent works and shall remain in good condition and operational both during and after the construction contract, unless as agreed by the Engineer.

The Contractor shall be responsible for and shall follow the instructions of the manufacturer and the requirements of this specification in the installation, calibration and testing of all measuring instruments and equipment, which shall be carried out under the direct supervision of the Engineer. The Contractor shall inform the Engineer at least 2 day prior to undertaking installation of the equipment. The Contractor shall make due allowances in his construction programme for delays which may arise on account of the installation of the instruments and of their maintenance.

## **21.2 Protection and Maintenance of Instruments**

The Contractor shall take all necessary precautions to protect the instruments and maintain the instruments in good working order after commissioning. For all instruments which project through and above the ground, special precautions shall be taken to provide protection from vehicles and plant including substantial and readily visible barriers at a distance of 750mm around each instrument. Heavy compaction equipment shall not approach within 1.5m of projecting instruments. Damaged instruments shall be replaced or repaired by the Contractor at his own expense within seven days unless otherwise agreed by the Engineer.

## **21.3 Stabilising Electronic Readout Devices**

All electronic readout devices and transducers shall be shaded from direct sunlight during use. Probes which are used inside access tubes shall be placed inside the tube and allowed to come to a stable temperature for at least 10 minutes before use. Zero or starting values shall only be taken once temperature stabilisation is complete.

## **21.4 Labelling and Marking of Instruments**

All instruments shall be labelled with their reference number at the location where readings or measurements are taken. The labelling shall be permanent using a method or material to be agreed with the Engineer.

For instruments which are located beneath a drainage blanket where vertical drains are later to be installed, their locations and the locations of any connecting tubes or cables shall be marked using 1.6m lengths of 20mm diameter steel bar. The bars shall be driven vertically 0.9m into the ground as close as practicable to the instrument before the drainage blanket is placed. The tops of the steel bars shall be painted in bright colours, with a colour coding if necessary. During placing of the drainage blanket around the bars the Contractor shall ensure that the bars remain vertical, and clearly visible on completion of the drainage blanket.

## **21.5 Survey Equipment and Temporary Benchmark**

All surveying equipment used in conjunction with the monitoring of instrumentation, including measuring tapes, precise levels and theodolites shall be maintained and calibrated as required by the manufacturers. Certificates of calibration for all equipment shall be submitted to the Engineer and approved by the Engineer prior to carry out the field work. Levels shall be checked for horizontality of the line of sight every four weeks.

The temporary benchmarks shall be installed at the nearby structure or remote from the reclamation area and marked on an end bearing pile or similar structure. The levels for all TBMS shall be checked/survey every three months or sooner as instructed by the engineer.

## **21.6 BOREHOLES FOR INSTRUMENTS**

Boreholes for instruments may be drilled by approved method provided that it results in a clean and stable hole of the required diameter to the correct depth. Boreholes shall be cased to their full depth unless strata are sufficiently competent for the hole to stay open under dry conditions. Boreholes shall be drilled using clean water. Drilling mud or polymer additives shall only be used with the approval of the Engineer. In the case of installation of piezometers, drilling mud or polymer additives shall not be permitted.

During drilling care shall be taken to ensure that minimum material is lost from outside the casing. Surging of casing shall not be allowed, and flushing of drilling water up the outside of the casing shall be minimised.

The method of forming boreholes, including the procedure for advancing casing, shall be submitted to the Engineer for approval before commencement of the works.

## **21.7 GROUTING OF BOREHOLES**

For all instruments placed in boreholes, grouting is required of part or all of the borehole during installation. The grout shall be a bentonite : cement mixture with sufficient water to achieve a pumpable mix. The proportions of the mix shall be such as to imitate as closely as possible the strength or consistency of the natural soils present. The Contractor shall conduct trials on different mixes of bentonite : cement (from 4:1 to 8:1) to ascertain the relationship with strength. Specimens shall be cured and stored, then tested in undrained triaxial compression after 1 day, 2 days, 7 days, 14 days, 1 month and 3 months. 3 specimens shall be tested on each occasion, and the sources of bentonite and cement shall be the same as used for eventual installation. On the basis of these trials, the Engineer shall decide on the bentonite : cement proportions to be used, which may be varied depending on the application. Grout shall be poured or pumped into boreholes using a tremie pipe.

For inclinometer installed in the wall, the annulus between inclinometer access tube and wall shall be filled up with neat grout of grade 35.

## **21.8 Installation and Monitoring**

### **21.8.1 Settlement Markers**

Details of settlement markers shall be as shown in the drawings. The contractor shall install settlement markers in locations indicated in the drawing or as directed by the Engineer. For each layer of fill, the Contractor must survey, relocate, transfer and reinstall the settlement markers to the next level. The Contractor must take readings on the settlement markers prior to relocation to the next level. Base readings are to be taken on all relocated settlement markers immediately after relocation. The period and frequency of monitoring shall follow the requirements as stipulated by the Engineer.

Levels of the top of the rods of settlement markers shall be measured using standard levelling techniques. The datum used shall preferably require only one set up of the level, and levelling shall be closed back to the datum.

### **21.8.2 Rod Settlement Gauges**

Rod settlement gauges shall be as shown in the Drawings and the Contractor shall be responsible for installation of all gauges at locations specified by the Engineer as work proceeds. The base plate and first length of rod shall be placed before any significant filing (including any drainage blanket) has been placed. Extension lengths shall be installed when the level of compacted embankment is 250mm below the top of the preceding lengths.

Should a rod settlement gauge be damaged or should the Contractor fail to extend the gauge when required, he shall stop all filling in the vicinity of the gauge until the necessary remedial works have been carried out. The Contractor shall be liable for any delay in his programme, or any additional work that has to be done as a result of such damage.

Should any rod settlement gauge be damaged in such a way as to make it useless for its purpose, the Engineer shall assess the settlement for measurement purposes and this assessment shall be accepted by the Contractor as final.

Rod settlement gauges shall be monitored by precise levelling techniques. Levels shall be taken of the top of the rod itself and the fill adjacent to the gauge on each occasion. The datum used shall preferably require only one set up of the level, and levelling shall be closed back to the datum. When rods are extended, levels shall be measured immediately before and immediately after adding the extension.

### 21.8.3 Inclinerometers

The Contractor shall install inclinometer at locations, and with depths and details as specified by the Engineer.

Inclinometer access tube shall consist of broached PVC tubing with four keyways set at right angles to each other and shall be supplied in 3.0m lengths with 0.3m long couplings and end caps. The spiral twisting of the keyways shall not exceed 0.75 degrees per metre length of the tubing. Where necessary, the Engineer may instruct the Contractor to obtain spiral metric measurements of the keyways in the inclinometer tubing after installation. After assembly joints and rivets shall be coated in sealing mastic and wrapped in sealing tape. The tube shall be coated with thick grease over its upper part when it passes through compressible subsoils. The assembled tube shall be lowered into a 125mm diameter borehole backfilled with a suitable bentonite : cement grout mix. Alternatively the tube may be placed in an open borehole and grout placed afterwards. In granular material, the backfill may be sand or pea gravel. The keyways shall be orientated such that movements are measured parallel to and right angles to the embankment/slope axis.

Where the access tube passes through upper stiff crusts or fill material, it shall be sleeved by a larger diameter tube so that it can pass freely through these materials as settlement takes place. Where the access tube passes through fill which is being placed, the access tube and outer sleeve shall be extended in lengths which are multiples of 0.5m as filling progresses. The top of the access tube, and the larger diameter sleeve where present, shall be protected with a suitable cover.

Angular movements shall be measured by an inclinometer torpedo which shall be a biaxial type with a gauge length of 500mm, and the system shall be capable of measuring lateral deformation to an accuracy of  $\pm 10\text{mm}$  over a depth of 30m. The casing of the inclinometer probe shall be constructed of stainless steel and the probe shall be fully waterproof and corrosion proof. The inclinometer probe shall be supplied with a rigid carrying case fully lined with shockproof padding. The cable supplied for use with the inclinometer shall be a polyurethane sheathed cable with a minimum length of 40m, incorporating a central kelvar straining wire. The cable shall be graduated in intervals of 500mm and shall be supplied complete with a portable cable reel.

The inclinometer data logger unit shall display the readings from the inclinometer torpedo on an alphanumeric display. The readout unit shall be powered by a re-chargeable battery with a minimum life of 12 hours continuous use between charges. A suitable automatic battery charger shall be supplied with the readout unit. The readout unit shall incorporate an RS232C port and a solid state data storage unit with the capacity to store at least 30000 readings directly from the inclinometer probe together with time and date of reading. The following facilities are also required within the readout unit :

- a. Scan stored data.
- b. Display of face errors as readings are being obtained.

- c. Display of mean deviation and cumulative deviation of any one set of readings.
- d. Graphical display of displacement profile between any two sets of readings.
- e. Backlit LCD display.

A calibration frame shall be supplied to enable the inclinometer calibration to be checked at vertical and 10 degrees either side of vertical.

Immediately before or after taking a series of readings, the level of the top of the access tube shall be measured by standard levelling techniques. Before passing the torpedo down the access tube, a dummy torpedo should be lowered to the base of the tube and pulled up to check for obstructions or constrictions. The inclinometer torpedo shall then be lowered to the base of the access tube and raised taking readings every 0.5m until the torpedo reaches the top. The readings shall be read by and stored in the data logger. The procedure shall be repeated on the opposite face following the manufacturer's method and sign convention.

#### 21.8.4 Magnetic Extensometer

Magnetic extensometers provide a method of measuring settlement or heave at a point or a series of points below the ground surface. The Contractor shall install magnetic extensometers at locations and with depths and details as specified by the Engineer.

The magnetic extensometer shall consist of an access tube and a series of magnetic targets which are free to slide down the tube, together with a datum magnet which is fixed to the tube near its base. The access tube shall be a rigid PVC tube 33.5mm o.d. and 24.5mm i.d. with threaded ends which provide both an internal and external flush coupling. A rigid PVC endcap shall be fixed to the lower end of the series of tubes. Compression/extension tubes shall be provided where required by the Engineer. All joints shall be sealed with a suitable PVC solvent cement.

The compression/extension tubes shall allow axial movement of access tubes to minimize distortion due to vertical strain. The tubes shall have treaded ends to provide an internally and externally flush coupled joint. The smaller diameter end tubes are fitted with 'O' rings or equivalent, and are free to slide within the larger diameter central cylinder. The minimum allowable compression and extension length shall not be smaller than 0.6m and 1.0m respectively.

A datum ring magnet shall be fixed approximately 2m above the lower end of the tube. Spider magnets shall be used within the subsoil, and plate magnets within fill where magnets can be placed during construction.

The tubes and magnets shall be assembled prior to installation in such a way that the magnets remain in the correct position in relation to the tube. The tube shall be coated with a thick grease over its upper part where it passes through compressible subsoils. It shall then be lowered together with all magnets and necessary accessories fixed in position into a 100mm diameter borehole backfilled with a suitable bentonite : cement grout mix of equivalent strength of the surrounding soil. Once in position the spider magnets shall be released.

Where the access tube passes through upper stiff crusts or fill material, it shall be sleeved by a larger diameter tube so that it can pass freely through these materials as settlement takes place. Where the access tube passes through fill which is being placed, the access tube and outer sleeve shall be extended as filling progresses. The top of the access tube, and the larger diameter sleeve where present, shall be protected with a suitable cover with facility for locking.

The readout device shall consist of a nickel plated brass probe containing a reed switch encapsulated in silicone rubber. The probe shall be connected via a nylon coated steel tape to a reel buzzer.

Magnetic extensometers shall be monitored by passing the probe down to the base of the access tube. The probe shall then be pulled upwards measuring the position of each magnet

from the top of the tube. The position of each magnet shall be measured twice, once while moving upwards and once while moving downwards towards the magnet. Immediately before or after taking a series of readings, the level of the top of the access tube shall be measured by standard levelling technique.

### **21.8.5 Combined Inclinometers and Magnetic Extensometers**

Combined inclinometers and magnetic extensometers provide a method of measuring both vertical settlement and horizontal displacement at a series of points below the ground surface.

The Contractor shall install combined inclinometers and magnetic extensometers at locations, and with depths and details as specified by the Engineer.

This specification should be read in conjunction with the specifications for inclinometers and magnetic extensometers; and only specifies requirements where they differ from the individual systems.

The access tube shall be telescopic inclinometer access tube, and magnetic targets shall be suitable for use with this tube .

The magnets shall be positioned in relation to sleeved joints such that they can move downwards without obstruction sufficiently to monitor the expected settlement. The borehole shall be 150mm diameter or size agreed by the Engineer.

### **21.8.6 Pneumatic Piezometers**

Pneumatic piezometers are used to measure water pressures at specific depths within variety of soil types. The Contractor shall install pneumatic piezometers at locations, and with depths and details as specified by the Engineer. 'Push-in installation method shall be used.

Pneumatic piezometer tips shall be of high air entry ceramic type with an average pore diameter of 1 micron using marine brass or stainless steel bodies. The piezometer system shall be capable of measuring water pressures to an accuracy of  $\pm 0.2$ m head of water in the range 0 - 100m head of water.

The piezometers shall be connected to tubing comprising suitably coded twin 1.9mm i.d. and 3.2mm o.d. nylon tubes and covered with a polythene sheath 1mm thick. Joints in the tubes other than at the piezometer tip or at the terminal panel shall not be permitted. The tubes from individual piezometers shall be colour-coded and marked every 3m. The tubing shall be connected either to suitable quick release couplings or a terminal panel which shall be housed in a lockable steel cabinet.

The arrangement of the equipment and the three methods of installation are shown in the Drawings.

Installation shall be by pushing into the base of the borehole method. A 100mm diameter borehole shall be terminated 0.3m above the required position of the piezometer tip. The piezometer tip with cable attached shall be pushed into the base of the borehole to the required depth using an arrangement of sufficiently stiff tubes. The borehole shall then be sealed with bentonite pellets and bentonite: cement grout as shown on the Drawings.

The piezometer leads shall either be connected to quick release couplings set inside a suitable cover, or be taken to a terminal panel fixed inside a lockable steel cabinet. The cabinet shall be set on a concrete plinth typically 0.6x1.0x0.3m thick (plan dimensions may be adjusted to suit the cabinet size). Where cables are laid in trenches the backfill shall be sand. The cable shall be laid with sufficient slack to take up any lateral movements that are expected to occur due to settlement of embankments or structures.

The pneumatic readout unit shall be capable of storing 500 readings and shall incorporate an electronic pressure transducer, backlit digital display, RS232C interface and cable link, rechargeable battery providing at least 12 hours continuous are between charges, a rechargeable gas reservoir bottle, a reservoir pressure gauges, return + flow indicator, flow control valve and quick release self sealing leads for connection to the supply and return manifolds of the terminal panel. The readout unit shall be housed in a rigid weatherproof case with carrying handles and shall be capable of resolving readings to 1 kPa. An automatic charger for the readout unit battery shall be supplied suitable for 240V, 50Hz electricity supply. The Contractor shall make facilities available for recharging the gas reservoir with nitrogen.

Before installation and taking initial readings the Contractor shall pressure test the pneumatic piezometer tip in a container of water after connection to the tubing with a pressure of 500 kPa to check for leaks or poor connections. The ceramic element shall be deaired under vacuum and precautions shall be taken to ensure that it remains saturated during installation. During installation readings shall be taken when the piezometer tip is lowered down the borehole, when it is pushed in or placed in the sand pocket and at various times after installation to check the response of the piezometer and help find the static pressure value before the initial base readings are taken.

Readings shall be taken by and stored on the readout device. Care shall be taken to ensure that the flow and return leads are connected correctly.

## **21.9 Instrumentation Records**

### **21.9.1 Commissioning and Base Readings**

After installation the functioning of each instrument shall be demonstrated to the Engineer, including the recording of measured values using the appropriate readout device. As part of the commissioning three sets of readings shall be taken and compared. When instruments are installed before earthwork starts, then these three sets of readings shall also be taken before earthwork starts. If there are significant differences or anomalies, then further readings shall be taken. Once three sets of comparable readings have been taken, these shall be averaged to form the base readings, representing conditions before earthwork starts.

In cases where instruments are installed during earthworks, three sets of readings shall be taken in quick succession and the results compared. These results shall be used to provide base readings in a manner to be agreed with the Engineer.

### **21.9.2 General Information on All Records**

All records of instrumentation, either installation, readings or monthly summaries, shall contain the following information :-

- Project name
- Contract name and number
- Instrument reference number and type
- Dates of installation, reading or summary
- Times of installation or reading
- Chainage and Offset (or coordinates if appropriate)
- Personnel responsible
- Relevant comments or remarks
- Reduced level

### 21.9.3 Installation Records

The Contractor shall prepare an installation record sheet for each instrument installed. The format of the sheet shall be prepared by the Contractor and submitted to the Engineer for approval at least one week before installation commences. The record sheet shall include the following information in addition to the general information required:

- Existing ground level at the time of installation
- Planned location in plan and elevation
- Planned orientation
- Planned lengths, widths, diameters, depths and volumes of backfill
- Plant and equipment used, including diameter and depth of any drill casing used
- Spaces for necessary measurements or readings required during installation to ensure that all previous steps have been followed correctly, including acceptance tests
- A simplified log of ground conditions (obtained during rotary wash boring)
- Type of backfill used
- As-built location in plan and elevation
- As-built orientation
- As-built lengths, widths, diameters, depths and volumes of backfill
- Weather conditions
- A space for notes, including problems encountered, delays, unusual features of the installation, and any events that may have a bearing on instrument behaviour
- A record of commissioning information and readings
- Any colour coding used

The Contractor shall submit to the Engineer the specified number of copies of each installation report within one working day of completion on the installation, including taking of base readings.

### 21.9.4 Installation Report

The Contractor shall submit an installation report once installation of all instruments is completed. Submission shall be within two weeks of completion including taking of all base readings. The report shall include :

- A text describing the scope of work, the site, the work carried out and the types of instrument installed
- All installation record sheets
- Plans and cross section drawings at a scale of 1:200 or other agreed scale showing the locations, elevations and details of all instruments
- Photographs of all the instruments used, illustrating installation and method of reading
- Values of all base readings taken together with any subsequent readings up to the time of submission

### 21.9.5 Readings

On each occasion that readings are taken from an instrument or set of instruments, the measured values shall be recorded on a record sheet. The format of the record sheet for each type of instrument shall be prepared by the Contractor and submitted to the Engineer for approval at least one week before readings commence. For readings that are recorded on data loggers, a record sheet shall be required giving references to the data stored. A computer system including interfaces, plotter, printer and software shall be available to make the data transfers, listings and plots required.

The format of plotted results shall be submitted to the Engineer for approval. Details of information and values to be stored on each record sheet in addition to the general information

required are given below :

<u>Instrument</u>	<u>Data required</u>
Settlement marker	- reduced level of top of rod (mRL) - change in reduced level of top of rod relative to base readings and previous reading (mm)
Displacement	- distance from fixed point (m) marker (details to be given)
Survey station	- offset, coordinates and reduced level of top of rod (m)
Deep datum	- reduced level of datum (mRL) - reduced level of toe (fixed point) (mRL)
Rod settlement	- reduced level of top of rod gauge (mRL) - original ground level at gauge location (mRL) - reduced level of ground adjacent to gauge (mRL) - record of fill placed (m) - total thickness of fill (m) - record of extensions (m) - settlement of plate relative to base readings and previous reading (mm)
Inclinometers	- reduced level of top of access tube (mRL) - reduced level of ground adjacent to access tube (mRL) - horizontal movements of top of access tube by survey - file name of data stored in data logger - file name of data after transfer to floppy disk - listing of deflection values and face errors every 0.5m - graph and listing of horizontal movement of access tube relative to base readings against depth - status of fill height
Standpipe piezometer	- time and date - reduced level of top of tube (mRL) - reduced level of ground (mRL) - depth of water from top of piezometer tube (m) - water pressure readings (m water) - change of water head relative to base readings (m) - water pressure readings (m water) - daily weather chart
Magnetic Extensometer	- reduced level of top of access tube extensometers (mRL) - reduced level of ground adjacent to access tube (mRL) - distance of each magnet from top of tube (m) - reduced level of each magnet (mRL) - settlement of each magnet relative to base readings (mm)
Combined magnetic extensometer and inclinometer	- as for magnetic extensometer and inclinometers
Pneumatic piezometers	- water pressure readings (m water) - file name of data stored in data logger - file name of data after transfer to floppy disk - reduced level of piezometer tip as installed (mRL) - estimated or measured settlement of piezometer tip (m)

- water head (mRL)
- change in water head relative to base readings (m)

The Contractor shall submit to the Engineer the specified number of copies of each record sheet with necessary listings and graphs within one working day of taking the readings unless otherwise directed by the Engineer.

### 21.9.6 Frequency of Measurement

The frequency or the interval of measurement is dependent on the rate of settlement of a subsoil. Close intervals are used during and shortly after fill has been laid. The intervals are increased with increase in the duration of lapse time. The following can be used as a guide.

- a) During filling
  - Every morning before subsequent filling commences.
- b) After a formation is reached
  - i) For first three months
    - Every alternative day
  - ii) For fourth and subsequent months
    - Between twice a week to once a fortnight depending on the rate of settlement as shown in the Appendix B or as instructed by the Engineer, the time interval should allow reasonable settlement to be plotted.

### 21.9.7 Anomalous Readings

Whenever sets of data are measured, they shall be compared to previous sets of data. If anomalous readings are present which differ from the expected value or trend, then further readings shall be taken immediately and the Engineer shall be informed. If the anomalous values persist, then the Engineer shall be informed and an investigation shall be carried out to find the reasons for the anomalous readings.

### 21.9.8 Monitoring Report

The Contractor shall submit a report at the end of each calendar month of monitoring but fortnightly for treated areas with vertical drains. A proposal for the format of the report shall be submitted to the Engineer including all graphical presentations for approval at least one month before submission of the first monthly report. Each monthly report shall include:

- a description of monitoring works which have been in operation during the preceding month
- information on reading anomalies or corrections, and factors which may influence measured data
- observations or remarks
- diagrams showing installed locations of instruments (taken from installation report)
- data tabulations or plots of instrument readings as given below. The Contractor shall have available suitable software for generating the required plots and tabulations. Zero time to be used in all plots and tabulations shall be agreed with the Engineer. The time axis shall be days from "day zero", and an indication of date or months shall be included on the axis. The plots and tabulations presented each month shall be an update of the previous plots and tabulations, giving a complete record starting from the time of installation.

Instrument

Plots and Summaries required

Settlement marker	-	settlement v. time (tabulation and plot)
Rod settlement gauge	-	thickness of fill and settlement of plate v. time (tabulation and plot)
Displacement marker	-	displacement vs time indicating direction of movement (tabulation and plot)
	-	displacement profile with distance from wall (tabulation and plot)
Survey station	-	coordinates and reduced level (tabulation)
Deep datum	-	reduced level (tabulation)
Inclinometer	-	file name of data on floppy disk
	-	latest graph of horizontal movement of access tube relative to base readings against depth
	-	maximum horizontal movement relative to base readings v. time (tabulation and plot)
Magnetic extensometer	-	settlement of each magnet vs time (tabulation and plot)
	-	settlement of each magnet vs depth for 4 latest sets of readings (tabulation and plot)
Combined magnetic extensometer and inclinometer	-	as for magnetic extensometers and inclinometers
Standpipe piezometer	-	water head (mRL) vs time (tabulation and plot)
	-	water level profile with distance from wall (tabulation and plot)
	-	changes of water head (tabulation and plot)
	-	water head with depth for latest 4 sets of readings (tabulation and plot)
	-	Important activity like excavation or ground water pumping should be highlighted in the graph.
Pneumatic piezometer	-	excess water head v. time (tabulation and plot - all instruments in a profile plotted on the same graph)
	-	excess water head v. depth for latest set of readings (plot)
	-	excess water head v. height of fill (plot)

All plots where time is the horizontal axis shall have the same scale for the time axis. Where fill thickness, settlement and excess water head are all available at the same location, the plots shall be combined on the same sheet where possible. Final layouts, scales and details shall be agreed with the Engineer at the time of submitting the format.

The Contractor shall submit the required number of copies of the monthly monitoring report to the Engineer within 7 working days of the end of the month being reported. If there are anomalies or sudden significant changes in the results, the Engineer should be informed within 1 day after monitoring.

## 21.9.9 Presentation of Reading in Graphic Format

The Contractor will have to submit to the Engineer for comment on the graphic presentation of the monitored readings. The presentation will have to be agreed by the Engineer prior to the field work. Hand plotted graphs are not acceptable.



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