1.0 GENERAL

1.1 Scope

This Specification covers the requirements for supply and installation of **prefabricated vertical drains** (PVD) plus the associated works.

The Contractor shall provide all necessary resources including skilled labour, proper machine/tools and materials to complete all the scope of works for the installation of PVD in accordance to the details shown on the Drawings and this Specification.

1.2 Site Investigation (SI) Report

SI report shall be made available at the S.O./Engineer's office for the Contractor's information. The report is intended solely as a guide and neither the completeness nor the accuracy of the information provided is guaranteed. No responsibility is assumed by the S.O./Engineer for any opinion or conclusion given in the soil report. The Contractor shall study the given soil report and make his own interpretation of the information provided and to make due allowance for the effects of site conditions on his construction operations.

Piezocone Test (CPTU) may be carried out to verify the subsoil profile and properties of the subsoil to be treated using PVD drains if necessary or as directed by the S.O./Engineer. The CPTU shall be carried out according to ASTM D5778 and at least until few meters beyond the design depth of PVD as specified or as instructed by the S.O./Engineer. The CPTU results shall be submitted to the S.O./Engineer for design verification purpose prior to the commencement of work.

1.3 Method statement

The Contractor shall prepare and submit method statement of installation of PVD drains and the associated works as shown in the Drawings to the S.O./Engineer for prior written approval by at least 7 working days before the commencement of works. The method statement shall include, but not limit to the following scope/details:

- **Introduction**

Introduction should include:

(a) Brief statements about the **project name**, **scope of works** to be included and carried out (number of points of PVD/spacing of PVD/termination criteria for depth of PVD to be installed,

(b) **Brief site conditions** (boundary/topo/access conditions; any headroom restrictions; any nearby structures/buildings/services; any nearby construction activities & any environmental hazards),

(c) **Brief subsoil conditions**/borehole & test results (interpreted soil profiles; undrained shear strength & soil strata description; piezometric levels of groundwater & its variations; presence of any localized penetration resistance such as thick sand fill/tree roots/boulders/gravel/sand/silt/ cemented materials), and

d) **Special construction requirements, if any**.

Site/location plan and Drawings showing the layout of PVD with sand blanket/separator non-woven geotextile/surcharge details, instrumentation details, summarized SI results/profiles, plus a list of PVD projects completed within the last 3 years, etc., should be included as **Appendix A**.

- **List of specific machine/equipment/tools to be mobilized**

List of specific installation rigs/machines (types/make/model/size/weight/max pushing force & configuration), mandrel (dimensions & length plus tip details), electronic data logger (type/model/capacity/output printout) with catalogues/ photos to be used/mobilized to execute the works as specified and to complete the works within the specified work program shall be clearly stated. Refer Clause 3.2a and 3.2b for machine and mandrel requirements.

Catalogues/photos/drawings showing the details of the PVD installation rig/machine, electronic data logger & mandrel details/specifications should be included as **Appendix B**.

- **List of specific materials/products to be used**

List of specific materials/products **with brief descriptions** about their respective trade names, manufacturers, characteristic properties to show compliance with the requirements specified in Clause 2 shall be included. How the materials are to be stored at site shall also be given.

Catalogues/photos/drawings showing the PVD drain product, anchor plate, spliced PVD sample and the relevant test certificates by independent ISO 17025 accredited laboratory, etc., should be included as **Appendix C.**

- **List of manpower/key operator and technician to be engaged**

List of specific **manpower/key personnel** (site manager, QC manager, operators & skilled workers) with names and their respective **job designation/duty** and brief C.V. shall be included for S.O./Engineer or CRE/RE's review and approval. Work permit for foreign workers, if relevant, should be included.

Detail C.V., personnel details & work permits if relevant can be included as **Appendix D**.

- **Sequence of works**

Important sub-activities such as **site inspection**, **working platform preparation** (with justifications & details/method)/sand blanket construction, setting up/ tolerance of position or PVD spacing/position marking, rate of pushing-in of PVD, criteria of depth termination, mitigations/precautions against possible site problems and PVD damage before & after installation, splicing/jointing (method & quality checks), removal of extruded soft clay before filling, protection of exposed PVD from being damaged by construction traffic, placement of surcharge, instrumentation & settlement monitoring, etc., shall be included with descriptions and machine/equipment layout in diagrammatic presentation, etc.
Details on installation records by electronic data logger shall be proposed, but it shall comply with Clause 3.2 (i).

Works program and details of necessary temporary works such as working platform preparation with necessary justifications/calculations about bearing capacity for the machine by qualified P.Eng should be included as **Appendix E**.

Statements such as "suitable PVD installation machine will be deployed to push-in PVD to suitable depth or experienced operators will be engaged or high-quality PVD materials will be used" are too general and not specific and are totally unacceptable.

- **Output of works**

The estimated **daily output** of works (average time/hours taken to complete each point of PVD and how many points of PVD can be completed per working day per rig/machine or how many meters of PVD can be pushed-in by per rig/machine per day) shall be indicated to ensure the works can be completed within the scheduled work program.

- **QC tests/checks**

Specified methods for of quality control tests such as trial PVD (Clause 3.2e), format for recording (Clause 3.2i) and checks/mitigations/precautions against PVD damages before and after installation, machine tilting due to inadequate bearing capacity, etc., with respect to frequency plus their respective **acceptance criteria** shall also be included in the method statement, and

- **Remedial measures** shall also indicate in the method statement in cases where the acceptance criteria cannot be complied with.

In brief, the method statement shall clearly prescribe how the PVD installation work shall be carried out in compliance with the approved drawings and this Specification, with particular reference to specific requirements for resources, sequence of works, realistic work output, quality controls, etc.

1.4 Safety facilities for access to site

Facilities/means of access to site and working platform shall be properly installed to enable the workers to work and SO/Engineer or his representative to examine closely the PVD installation works. Identifiable protection fences and barriers shall be provided and maintained for the work areas during the construction period.

2.0 MATERIALS

2.1 Prefabricated Vertical Drains (PVD)

a) General Requirements

Prefabricated vertical drain (PVD) shall be of newly manufactured materials from an approved ISO 9001 certified/accredited manufacturer.

PVD shall comprise of a durable plastic/polymer ribbed/corrugated drainage core wrapped around with an external non-woven geotextile and seamed to itself. The non-woven geotextile (spun-bond/thermally-bond or approved equivalent) shall act as a regular/even structure filter jacket and perform like a permeable filter to provide regular hydraulic flow capacity by allowing excess pore water to move into the PVD while retaining soil particles from entering and clogging the PVD.

PVD shall comply with the technical requirements as specified in the **Table 1a and Table 1b.**

Factory visit by the S.O./Engineer shall be arranged by the Contractor to inspect the process of production and QC facilities. Visual inspections for defect/damage such as visible creases, tears, holes, etc., shall be made regularly as part of the production quality control. Test certificates by independent ISO 17025 certified laboratory shall be readily available for inspection.

The PVD core and the non-woven geotextile filter jacket shall be capable of resisting all bending, puncturing and tensioning subjected during the installation and design life of the drain and also in compliance with the minimum requirements specified in Table 1b.

The core shall be made of continuous plastic material fabricated to facilitate drainage along the axis of the vertical drain.

The prefabricated vertical drain shall be resistant against rotting, mildew, bacterial action, insect, salts, acids, alkalis, solvent and other constituents in ground water.

b) Transportation and Storage

All the PVD drain materials supplied and delivered to site shall be labelled or tagged for project/sample identification and other quality control purposes. Each pallet shall be identified by the manufacturer name/logo and lot number, individual roll number, date of manufacture, manufacturer and product identification of the filter jacket and core.
All PVD delivered to site shall be recorded in site diary and/or in file with delivery note/order readily for inspection by the S.O. in the format approved by the S.O.

All PVD shall be properly covered and protected by heavy-duty plastic sheet from sunlight, mud, dirt, dust, debris and other detrimental substances during transport and on-site storage. The Contractor shall ensure that the PVD is in good condition and properly stored in a covered area at the worksite. In the event of any damage or deterioration of the PVD, the Contractor shall be liable to replace the affected materials at his own cost.

All materials which are defective or damaged during transportation, handling or storage and do not meet the minimum requirements of the PVD drain specifications shall be rejected by the S.O./Engineer. No payment of any kind shall be made on the rejected product.

c) Quality Control and Testing

The actual PVD drain to be used shall be at the option of the contractor subject to the compliance with technical requirements (Table 1a & 1b) and approval of the S.O./Engineer based on the **submitted test results by independent ISO 17025 accredited laboratory attached samples.**

The Contractor shall submit the **method statement** (Clause 1.2) and PVD samples plus Catalogue with test certificates to S.O./Engineer for verification of the physical, mechanical and hydraulic properties of the PVD drain and approval prior to delivery to site.

d) Routine Sample Testing

In addition to QC testing based on testing frequency stated in Table 1b, S.O./Engineer reserves the right to take any additional individual samples at any time for any tests (in Table 1b) by independent ISO 17025 accredited laboratory whenever the PVD is suspected to be defective.

Individual sample shall be not less than 15 meters in length. Samples submitted for tests shall indicate the linear meters of drain and manufacturer's identifications represented by the sample.

Should any individual sample selected at random fail to meet the specification, then that roll shall be rejected and two additional samples shall be taken at random from two other rolls representing the same batch on 100,000 metres. If either of these two additional samples fails to comply with the specification, then the entire batch of vertical drains represented by the samples shall be rejected and removed from the site.

All the tests shall be carried out in accordance with the Codes of Practices and Test Standards provided within this Specification. All cost associated with the tests and preparation of report shall be borne solely by the Contractor.

e) Technical requirements of PVD

The prefabricated vertical drain (PVD) shall meet the following requirements in Table 1a and Table 1b:

Table 1a: Geometrical Dimension of Prefabricated Vertical Drain (PVD)

Property		**Test Designation**	**Specified** Requirements
Dimension of PVD Drain	**Width**	**-**	**100 ± 3 mm**
	Thickness	**ASTM D5199**	**3 to 8 mm**

Table 1b: Properties of Prefabricated Vertical Drain (PVD)

Property	**Test Method**	**Proposed Values**	**Testing frequency**
Tensile Strength (full width of PVD)	ASTM D4595	>2.5 kN	100,000 m
Elongation at 1.0 kN (full width of PVD)	ASTM D4595	≤ 10%	100,000 m
Discharge capacity of new straight PVD at 240 kPa & hydraulic gradient of 1	ASTM D4716	> 50 x 10^{-6} m^3/sec	500,000 m
Discharge capacity of kink PVD at 240 kPa & hydraulic gradient of 1	ASTM D4716	> 35 x 10^{-6} m^3/sec	500,000 m
Tensile strength of filter jacket*	ASTM D4595	>3 kN/m	200,000 m
Apparent opening size of filter jacket (O_{95})	ASTM D4751	< 90 um	200,000 m
Coefficient of permeability of filter jacket	ASTM D4491	>1x10^{-4} m/s	500,000 m
Seam strength of filter jacket	ASTM D4884	>1 kN/m	200,000 m

*For installations deeper than 25 m or in difficult soil conditions, a minimum tensile strength of **6 kN/m** in the longitudinal direction for filter jacket may be adopted. (BS EN 15237:2007).

Test results (ASTM D4595) on spliced/joined PVD by independent ISO/IEC 17025 accredited laboratory shall be included, if relevant.

S.O./Engineer reserves the right to take any additional individual samples at any time for tests by independent ISO 17025 accredited laboratory whenever the PVD is suspected to be defective.

2.2 Non-woven Geotextile Separator

a) General Requirements

All geotextiles shall be from an approved ISO 9001 accredited manufacturer and shall be manufactured from polypropylene or other approved suitable polymer. Geotextiles shall be sufficiently durable and resistant to naturally occurring chemicals. Geotextile shall be free of any flaws which may have an adverse effect on the physical properties of the geotextiles.

Geotextile fabrics shall be non-woven needle-punched fiber geotextile in accordance with the Specification and shall be used as shown and described in the Drawing or as directed by S.O./Engineer.

Geotextile shall be stabilized against ultra-violet radiation to the degree that one month's exposure of the geotextile to sunlight shall not reduce its strength to less than 70% of the specified strength rating in the Specification.

Unless otherwise shown on the Drawing, the non-woven geotextile separator shall comply with the properties as listed in Table 2. Minimum roll width shall be 4.0 meters.

b) Technical requirements

Unless otherwise specified in the Drawing, the non-woven geotextile separator shall be NW 15. Important technical requirements for non-woven geotextile are as shown in Table 2.

Table 2: Properties of Non-woven Geotextile Separator

ITEM	PROPERTIES	TEST METHOD	TYPES of NON-WOVEN (NW) GEOTEXTILE		
			NW 11	NW 15	NW 20
1	Wide width tensile strength	ISO 10319/ASTM D4595	>11 kN/m	>15 kN/m	>20 kN/m
2	Elongation at break	ISO 10319/ASTM D4595	> 35 %		
3	CBR puncture resistance	IS0 12236/ASTM D6241	>1750 N	>2000 N	>2900 N
4	Cone drop	ISO 13433	<45 mm	< 23 mm	<18 mm
5	Permeability at 50mm head	ISO 11058/ASTM D4491	> 75 l/m^2/s	>60 l/m^2/s	> 50 l/m^2/s
6	Effective opening size, O_{90}	ISO 12956	< 120 um	< 100 um	< 90 um
7	UV resistance	ASTM D4355 / EN12224	% retained after 500 hours > 70%		

The Contractor shall in additional provide the following information, for the approval of S.O./Engineer, for the acceptance of the geotextile fabric for the works.

- **Manufacture's Certificate** which shall include: Name of manufacturer, Product name and type, Accreditation from international Institutes.
- **Test Certificates** by independent ISO accredited laboratory which shall include: Mass Per Unit Area, Wide Width Tensile Strength (longitudinal/transverse), Elongation (Longitudinal /transverse), Effective opening size (O_{90}) or Apparent Pore Size (O_{95}), CBR Puncture Resistance, Cone drop, Permeability and UV resistance.

The tests shall be carried out in accordance with the Codes of Practices and Standards as provided within this Specification, unless otherwise approved by S.O./Engineer.

Prior to installation and at the discretion of SO/Engineer samples of each 100,000 m^2 of geotextile fabric shall be selected for routine tests (wide width tensile strength tests) at approved ISO accredited testing laboratories.

The properties to be tested shall comprise index properties including unit mass, mechanical properties including tensile strength, CBR Puncture Resistance and hydraulic properties including pore size and permeability. Where the individual samples fail to satisfy the requirements of this Specification on the geotextile fabric, the roll from which the sample is obtained shall be rejected. Two additional samples shall then be selected from two other rolls from the same batch of geotextile fabric. If either of these two additional samples fails to comply with the requirements, the entire batch represented by the samples shall be rejected.

c) Geotextile Packaging & storing

The geotextile rolls shall be furnished with suitable wrapping for protection against moisture, and extended ultra-violet exposure prior to placement. Each roll shall be labelled or tagged to provide product identification sufficient for field identification as well as inventory and quality control purposes. If stored outdoors, they shall be elevated and protected with a waterproof cover.

2.3 Drainage Blanket

The sand drainage layer shall consist of hard/clean sand or gravel/crushed rock with less than 10% of fine content passing the 75um sieve.

Unless otherwise specified in the drawing, sand blanket shall have a grading with the limits specified in Table 3 below.

Table 3: Properties of Sand Blanket

B.S Sieve Size	Percentage by weight passing
10 mm	100
5.0 mm	90 to 100
1.18 mm	45 to 80
300 um	10 to 30
150 um	2-10

The sand blanket drainage material for depositing in water shall be deposited without the associated use of compaction plant.

The sand drainage layer shall be built up evenly in horizontal layers each of not more than 300mm thick. Filling shall commence from the lowest level, and each layer shall cover the full area of the intended total fill area at that level before deposition of the subsequent layer commences.

3.0 INSTALLATION

3.1 Preparation of working platform

The Contractor shall check and prepare the temporary working platform to support the PVD installation machine to ensure in stable and safe conditions, especially when there are nearby buildings, flowing traffic, overhead cables, etc.

Temporary metal deck or steel plate or approved equivalent may be needed in case the provided drainage sand blanket is inadequate in bearing capacity to support the installation rig. Justifications/calculations to show the temporary working platform is safe to support the PVD installation rig/machine **shall** be validated by suitably qualified P Eng.

3.2 Installation of Prefabricated Vertical Drain (PVD)

a) Machine for PVD installation

Prefabricated Vertical Drain (PVD) shall be installed with approved modern equipment/machine of a type which shall have adequate capacity (>**133 kN** downward force) to push-in to the depth specified using **constant load or constant rate of advancement method and will cause a minimum of disturbance of the subsoil** during the installation operation and maintain the mandrel in a vertical position.
Machine for installing PVD shall be **plumbed prior to installing each PVD** drain and shall not deviate from the vertical more than **1 in 50** during installing of any drain.

PVD machine shall be equipped with electronic data logger to record the required information as specified in Para 3.2 (i).

b) Mandrel

PVD shall be installed using a mandrel or sleeve and shall be inserted (i.e. pushed or vibrated) into the ground using constant load or constant rate of advancement method. The mandrel shall protect the PVD material from tears, cuts, and abrasion during installation, and shall be retracted after each PVD drain is installed to the specified depth.

The size and shape of the mandrel or sleeve shall be adequate stiff and as close as possible to the size and shape of the PVD drains in order to minimize disturbance to the soil. Unless otherwise approved by the S.O./Engineer, **the cross-sectional area of the mandrel and anchor plate combination shall not be greater than 6,450 mm^2** (10 sq. inch) so as to reduce disturbance and to reduce smear effect. The length of the mandrel shall be not less than the maximum length of the specified PVD drain. The mandrel shall be capable of making a clean puncture through any non-woven geotextile if necessary.

The mandrel or sleeve shall be provided with an anchor plate (PVD shoe) or similar arrangement at the bottom to prevent the soil from entering the bottom of the mandrel during the installation of the PVD drain and to anchor the drain tip at the specified depth at the time of mandrel withdrawal.

The dimension of the anchor shall conform as closely as possible to the dimensions of the mandrel so as to minimize soil disturbance. The S.O./Engineer shall determine the acceptability of the anchorage system and procedure.

c) Method statement

One week prior to the beginning of trial of PVD installation, the Contractor shall submit method statement (**Clause 1.3**) with full details of the PVD materials, equipment, sequence and method proposed for PVD installation plus details of recording to SO/Engineer for review and approval. Approval by the SO/Engineer of installation sequence and methods shall not relieve the Contractor of his contractual obligation to install PVD drains in accordance with the Drawings and Specifications.

d) Splicing

Splicing of PVD is only allowed if the manufacturer has the details of splicing and the proposed splice has the same tensile strength as the unspliced PVD drain by test results from independent ISO 17025 accredited laboratory.

Only one (1) splice per PVD drain installed can be permitted.

e) Trial PVD

Prior to the installation of working PVD, the Contractor shall demonstrate that the proposed equipment, method, anchor plate and PVD materials can produce a satisfactory installation in accordance with the Drawings and Specifications. For this purpose, the Contractor shall be required to install at least 3 trial PVD drains of the same specified depth at locations designated by S.O./Engineer and in accordance to the approved method statement by S.O./Engineer. One of these 3 trial PVD drains shall have one approved splice/joint below ground level. After installation, the installed trial PVD drains shall be extracted by careful low water pressure wash rotary boring machine using SI open casing with internal diameter of at least 175mm or other approved equivalent for checking the PVD conditions after installation. The Contractor shall amend/change the PVD material, installation equipment/procedures and method statement for another additional 3 trial PVD drains, if the installed PVD drains are found defective/damaged after installation.

f) Approval by S.O./Engineer of the method or equipment used to install the trial drains shall not constitute, necessarily, acceptance of the method for the remainder of the project. If, at any time, the S.O./Engineer considers that the method of installation does not produce satisfactory PVD, the Contractor shall alter his PVD material/method and/or equipment as necessary to comply with the Drawings and Specifications.

g) Installation procedure

PVD shall be located, numbered and pegged out by the Contractor using a baseline and benchmark indicated by the S.O./Engineer. The Contractor shall take all reasonable precautions to preserve the pegs and is responsible for any necessary re-pegging. The as-installed location of the PVD shall not vary by more than **150mm** from the plan locations designated on the drawings.

PVD that are deviated by more than **150mm** from the design plan location or are damaged or improperly installed with machine swinging up and down, will be rejected and abandoned in place.

PVD shall be installed from the working surface to the depth shown on the drawings, or to such depth as directed by S.O./Engineer who may vary the depths, spacing, or the number of drains to be installed, and may revise the plan limits for this work as necessary.

During PVD installation, the Contractor shall provide the S.O./Engineer with suitable means of determining the depth of the advancing drain at any given time and the length of drain installed at each location/zone by using electronic data logger.

PVD shall be installed using a continuous push using static weight.

Installation techniques using driving will not be permitted. Jetting techniques or pre-boring will be permitted only after receiving written approval from the SO/Engineer.

The installation shall be performed, without any damage to the PVD drain during advancement or retraction of the mandrel. In no case will alternate raising or lowering of the mandrel during advancement be permitted. Raising of the mandrel will only be permitted after completion of an installation to the required depth.

The mandrel penetration rate should be between 150mm and 600mm per second.
The completed PVD shall be cut off neatly **at least 300mm** above the working grade, or as otherwise specified on the drawings.

The Contractor shall observe precautions necessary for protection of any field instrumentation devices.

The Contractor shall replace, at his own expense, any instrumentation equipment that has been damaged or become unreliable as a result of his operations prior to continuing with drain installation or other construction activities.

h) Pre-augering/Obstructions
The Contractor shall be responsible for penetrating any overlying material as necessary to install the drains.

Where obstructions are encountered below the working surface which cannot be penetrated by the installation equipment, the Contractor shall complete the drain from the elevation of the working surface to the obstruction and notify the S.O./Engineer prior to installing any more drains.

At the direction of the S.O./Engineer and under his review, the Contractor shall attempt to install a new drain within 600mm horizontally from the obstructed drain. A maximum of two attempts shall be made as directed by the S.O./Engineer. If the drain still cannot be installed to the design tip elevation, the drain location shall be abandoned and the installation equipment shall be moved to the next location, or other action shall be taken as directed by the S.O./Engineer.

The Contractor shall be responsible for penetrating overlying fill material as necessary to satisfactorily install the PVD. Satisfactory installation may require clearing obstructions

defined as any man-made or natural object or strata that prevents the proper insertion of the mandrel and installation of the PVD.

The Contractor may use augering, spudding, or other approved methods to loosen the soil and any obstruction material prior to the installation of PVD. The obstruction clearance procedure is subjected to the approval of the S.O./Engineer; however, such, approval shall not relieve the Contractor of his responsibility to clear obstructions in accordance with the specification.

If augering is the selected method, the augers shall have a minimum outside diameter equal to the largest horizontal dimension of the mandrel, shoe or anchor, whichever is greater.

i) Installation Record of PVD

The Contractor shall submit to the S.O./Engineer at the end of each working day a summary of the PVD installed on that day. The summary shall be checked and signed by the Contractor's site supervisor and countered signed by the S.O./Engineer's representative.
The installation rig for PVD shall be provided with a fully automatic electronic data logger/recorder. The following parameters should be recorded:

- Brief project name & zone;
- drain identification number & coordinates for each PVD point;
- date and time;
- depth of installation;
- accumulated amount of installed drain length;
- verticality and location;
- tea/lunch break,
- any obstruction/abnormality/hard strata encountered, &
- Name of operator & site supervisor/IOW.

3.3 Geotextile Separator

Prior to the laying of the geotextile fabric, site clearance shall be carried out in accordance with the Specification and Drawing or as directed by the S.O./Engineer. All voids shall be filled with suitable material and the area cleared of large stones and exposed tree root systems or other such like protrusions.

Geotextile fabric shall be installed to the shape and requirements as specified herein or as shown and described on the Drawings. The geotextile shall be unrolled smoothly on the prepared ground as approved by the Engineer and generally in a direction perpendicular to the edge of the platform, embankment or area of fill as approved by the S.O./Engineer. Adjacent geotextile rolls shall be overlapped and sewn in accordance with this Specification. On curves and corners geotextile may be folded or cut to conform to the direction as approved by the S.O./Engineer. Adjacent geotextile rolls shall be overlapped and sewn in accordance with this Specification. On curves and corners geotextile may be folded or cut or conform to the direction as approved by the S.O./Engineer. Overlapping of geotextiles without sewn connections shall only be allowed by the S.O./Engineer.

Geotextile fabrics shall be placed just in advance of placement of the specified overlying fill material. Geotextiles so placed shall be covered by the relevant fill within 7 days of being placed. Installation proposals and trials as deemed required shall be carried out for approval by the S.O./Engineer prior to the acceptance of the placement method for the main works. The installation trials shall include the placement operations of the overlying fill materials, including excavation of such materials thereafter for examination of the geotextile fabric installation and fill materials placement method with respect to the prevailing ground conditions and constraints.

The geotextile fabric shall be joined using an approved portable industrial sewing machine and by sewing a double chain stitch with 'J' or 'prayer' seam (minimum lap of 50mm) with high tenacity polyester thread and a minimum of 3 stitches per 25mm shall be required. The thread shall have a breaking lead of not less than 160N.

Exposure of geotextile to natural elements between placement and cover shall be an aggregated period to a maximum of seven (7) days to minimize damage. The counting for this foresaid seven (7) days shall commence immediately upon the geotextile being exposed from its protective wrapping.

The specified overlying fill material on the geotextile fabric shall be placed in accordance with the requirements shown and described in the Drawings or as directed by the Engineer. These fill materials shall be deposited in layers not exceeding 300mm loose depth and shall be spread simultaneously with the dumping in a manner to prevent any localized distress or failure of the ground.

In water logged or swampy areas, the geotextiles shall be sunk after jointing by ballasting with sufficient sandbags. To control the location of the mattress, buoys shall be fixed with ropes on the edges of the geotextile. As soon as possible after positioning, the mattress shall be ballasted.
No traffic shall travel directly on the geotextile and there shall be no sudden stops, starts or turns on the fill materials by the construction equipment or other such actions which may cause damage to the geotextile.

3.4 Fill Surcharge
Fill shall be placed and properly compacted according to the rate of filling indicated in the Drawings.

Extra fill shall be placed to thickness specified in the Drawings as surcharge to speed up rate of embankment settlement.
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.

The fill be capable of being compacted to the requirements as indicated on the drawing and shall not comprise of: -

- material from swamps, marshes and bogs;
- peat, logs, stumps, perishable and toxic material;
- material susceptible to spontaneous combustion;

- clay of liquid limit exceeding 80% and/or plasticity index exceeding 55%;
- organic content greater than 2.5% by weight on ignition.

4.0 INSTRUMENTATION

4.1. General

The Contractor shall install instruments to enable measurements (monitoring) of vertical movements and pore water pressure and carry out measurements (monitoring) of the movements and water pressures and water levels during the currency of the works.
The depths and locations of all instruments shall be determined by the SO/Engineer on site.

Provisional quantities are provided in the Bills of Quantities for supply and installation of instrumentation plus necessary monitoring, etc.

The Contractor shall be responsible for and shall follow the instructions of the manufacturer 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 SO/Engineer at least 2 days prior to undertaking installation of the equipment or taking measurements. The Contractor shall make due allowances in his construction programme for delays which may arise on account of the installation of the instruments and their maintenance.

4.2. Settlement Gauges

Settlement gauges shall be provided and installed vertically by the Contractor in the positions directed by the S.O./Engineer for the purpose of measuring settlement taking place under the embankments. Settlement gauges shall be located at position as indicated by the SO/Engineer and the Contractor shall be responsible for installation of all gauges as work proceeds.

The Contractor shall take all necessary measures to protect settlement gauges from damage by the plant and vehicles and shall repair any such damage to the satisfaction of the S.O./Engineer at his own expense. The Contractor shall erect substantial and readily visible barriers/barricades of about 1m high and at a distance of 750mm around each gauge.

The Contractor shall replace any damaged settlement gauges within five days, at his own expense should any settlement gauge be damaged in such a way as to make it useless for its purpose.

4.3. Permanent Settlement Reference Stations

The Contractor shall be responsible for establishing permanent settlement reference stations in locations selected by the Engineer. The permanent settlement reference stations shall be located on stable ground.

4.4 Method of Monitoring

Monitoring of vertical movements of settlement gauges shall be by precise levelling with respect to the permanent settlement reference stations. Measurement of settlement shall be by the use of a precise level with an accuracy of 0.5mm. (Refer Appendix A).

4.5. Installation

The method of installation shall be the most advantageous method recommended by the manufacturer and shall be subject to the approval of the SO/Engineer.

The Contractor shall install settlement gauges and reference settlement stations before the commencement of earthworks.

4.6. Frequency of Measurement

Settlement Gauges – refer to Appendix A.

4.7. Protection of Instruments

All instruments shall be protected against damage during the currency of the Works and the Period of Maintenance. Instruments damaged during the above shall be immediately replaced by the Contractor at his own cost.

4.8. Instruments Not Functioning

All instruments shall be designed to ensure proper functioning over the required period of monitoring. Instruments not functioning during the period of monitoring shall be immediately replaced by the Contractor at his own cost. The SO/Engineer's decision as whether an instrument is functioning or not **shall be final.**

APPENDIX A
PERFORMANCE MONITORING/MEASUREMENT OF SETTLEMENT OF SUBSOIL AND FILL

1. SETTLEMENT OF SUBSOIL

Settlement of subsoil due to fill and/or surcharge is to be measured by means of settlement gauges/plates as shown in Drawings. Settlement gauges/plates are positioned before the fill is laid. Settlement shall be measured by precise levelling.

2. LOCATION AND PROTECTION OF SETTLEMENT PLATES

The settlements gauges/plates shall be placed at locations indicated on the drawing or as directed by SO/Engineer. They shall be located in areas that are least affected by construction vehicles and plant. They shall be properly protected with wooden barricades, 1m high and labeled with visible reference numbers. Heavy compaction plant 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.

3. FREQUENCY OF MEASUREMENT

The frequency or the interval of measurement is dependent on the rate of settlement of the subsoil. Unless otherwise specified in the Drawings or instructed by the SO/Engineer, frequency of measurements shall be as follows:

During filling: Every morning before subsequent filling commences.
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 example or as instructed by the SO/Engineer, the time interval should allow reasonable settlement to be plotted.

4. SUPPLY, INSTALLATION AND MONITORING OF SETTLEMENT STATIONS

Installation of precise instrument involves the supply and installation of the instruments at positions as indicated by the SO/Engineer.

- **Temporary Bench Marks:** The temporary bench marks will be installed at the nearby stable structure or remote from the reclamation area and marked on an end bearing pile or similar structure.
- **Settlement Plates:** The **precise level** settlement measurements shall be referenced to the temporary bench marks. The measuring instruments shall be a precise level, capable of allowing readings to be read to 0.5mm.

5. PLOTTING

The results should be plotted during the period of measurement for graphs of height of fill against time and settlement against time.