

**MOKOLO AND CROCODILE
WATER AUGMENTATION PROJECT
PHASE 2 (MCWAP-2)**

TENDER NO 054/2024/PMID/MCWAP2/RFB

**PART C3.1
SPECIFICATION**

SECTION 16

EMBANKMENT CONSTRUCTION

PART C3.1 SPECIFICATION

SECTION 16 EMBANKMENT CONSTRUCTION

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SECTION 16

EMBANKMENT CONSTRUCTION

16.1 SCOPE

This Section covers the requirements for the construction of small earth dams / embankments of height up to 15 m as defined by the International Commission on Large Dams (ICOLD). It covers excavation, and the selection, placing, and compacting of materials in the various zones of the embankment. It specifically includes for the subsoil drainage system and the preparation of the surface for the lining.

This Section specifically does not cover the following:

- Opening up, operating and reinstatement of borrow pits and quarries;
- Drilling and grouting;
- Dam lining;
- Concrete works as part of dam / embankment; and
- Landscaping and vegetating of the embankments.

16.2 SUPPORTING SECTIONS

The following technical Sections shall be read in conjunction with this Section 16:

- Section 1 – General;
- Section 5 – Survey and setting out;
- Section 7 – Clearing Site;
- Section 8 – Dealing with Water;
- Section 9 – Bulk Surface Excavations and Trenching;
- Section 12 – Blasting;
- Section 14 – Spoil, Borrow and Excavated Materials;
- Section 17 – Reservoir membranes and linings;
- Section 20 – Concrete works (Structural);
- Section 47 – Landscaping and Rehabilitation; and
- Section 48 – Tests on Completion.

The reference to the sections above does not preclude the use of any relevant Section of the Specification.

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16.3 DEFINITIONS, ABBREVIATIONS AND REFERENCES**16.3.1 Definitions**

For the purpose of this Section, the definitions and abbreviations given in the Sections listed above in Clause 16.2 and the following definitions shall apply:

- a) **“Dam basin”** the part of the catchment area that is upstream of a dam wall and that lies below the full supply level of the dam.
- b) **“Dispersive soil”** a material that consists of clayey particles of colloidal size in a state in which they can easily go into suspension in water.
- c) **“Drainage zone”** A zone that acts mainly to conduct water safely through the dam to the downstream area. This function is also attributed to filter and transition zones.
- d) **“Filter material”**
 - i) A material that has a grain size distribution such that the voids between grains are smaller than the finest grains of adjoining material on one hand and with a grain size that is larger than the interstices of adjoining material on the other hand; or
 - ii) A material such as a fine aggregate, a sandy material, or a woven or a non-woven fabric (geotextile) having pore sizes that are fine enough to prevent the migration of soil particles from a soil mass adjoining it.
- e) **“Optimum moisture content (OMC)”** The moisture content at which the maximum dry density occurs in the test for Proctor density.
- f) **“Proctor density”** The maximum dry density determined at OMC in accordance with the method given in ASTM D 698.
- g) **“Riprap”** a surface layer of approved rockfill material placed to a specified controlled thickness.
- h) **“Transition zone / Riprap bedding”** Layers or zones that are located between the earthfill materials and the riprap.
- i) **“Approved laboratory”** A material laboratory suitably equipped and staffed for purposes of earthworks and aggregate testing and approved by the Engineer.
- j) **“Relative Density”** The state of compactness of a soil with respect to the loosest and densest states at which it can be placed. This is applicable to non-cohesive materials which do not have well-defined moisture / density curves. (ASTM D4254).
- k) **“Slope protection”** The outer zone of an embankment which can either consist of topsoil and grass or transition layers and riprap.
- l) **“Zone (of an embankment)”** A section of an embankment that is wholly constructed with material that conforms to a particular set of physical characteristics that are different from those of the material of an adjoining section.
- m) **“Deviation”** The difference between the actual (i.e. measured) size or position and the specified size or position.
- n) **“Permissible deviation”** The specified limits of deviation.

16.3.2 Abbreviations

ICOLD	:	International Commission on Large Dams
OMC	:	Optimum Moisture Content
PD	:	Permissible Deviation

16.3.3 References

When reference is made to a Code of Practice, Specification or Standard, the reference shall be taken to mean the latest edition or replacement at time of tender of the Code, Specification or Standard; including addenda, supplements, modifications and revisions thereto. Where a previous version is intentionally used, it will be indicated as such. Where reference is made to a Code, Specification or Standard that has subsequently been withdrawn and not replaced, the intended content will remain relevant unless confirmed otherwise in writing by the Engineer.

16.4 MATERIALS

16.4.1 General

Materials for construction of the zones of an embankment shall only be obtained from the designated borrow pits or quarries shown on the Drawings or from the selective use of material from excavations or from other sources as directed or approved by the Engineer.

The materials used in filter zones, drains, transition layers and riprap shall where applicable be obtained by means of controlled blasting techniques, crushing, screening, blending, washing or by such other methods as the Engineer may from time to time approve. Where materials are blended the Contractor shall provide the means, to the approval of the Engineer, for the required batching and the blending itself. The methods and durations of mixing of the materials shall all be subject to the approval of the Engineer prior to commencing and also during the execution of the work. The Contractor shall perform such tests as the Engineer may approve or subsequently order to develop a satisfactory blending technique and such additional routine tests as to ensure that the desired uniformity of quality is maintained.

The water used for washing or compacting embankment materials shall be free from silt or other suspensions that might detrimentally affect the material properties.

The material being placed in any layer of any particular zone shall be homogeneous, uniformly graded and at all times conform to the specified grading and other properties. The Contractor's methods of transporting, placing, spreading, mixing and compacting the materials shall not cause excessive degradation or segregation and the finally placed and compacted material shall conform to the specified requirements. Where grading envelopes have been specified the mass of material actually retained in any size fraction shall be within the limits defined by the grading envelope curves unless otherwise approved by the Engineer.

The quality of the materials placed in an embankment and the methods of procuring and processing the materials shall at all times be subject to the approval of the Engineer who shall be at liberty to instruct the Contractor from time to time, to obtain materials from specific approved sources of supply. Any stockpiled material no longer conforming to the specified requirements or able to yield a uniform product shall be reprocessed by the Contractor to the satisfaction of the Engineer.

16.4.2 Classification for Excavation Purposes

16.4.2.1 Method of Classifying

The Contractor may use any method he wishes to excavate any class of material, but his chosen method of excavation shall not determine the classification of the excavation. The Engineer will decide on the classification of the materials. The classification will be based on inspection of the material to be excavated and on the criteria given in Clause 16.4.2.2.

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In the event of disagreement between the Contractor and the Engineer it shall be the responsibility of the Contractor, if so instructed and subject to the terms of Clause 16.5.1, to make available at his own expense such mechanical equipment as is specified in Section 9 - Bulk Surface Excavations and Trenching, in order to demonstrate the classification of the material to be assessed. The decision of the Engineer on the classification shall then, subject to the provisions of the Contract, be final and binding.

16.4.2.2 Classes of Excavation

The excavation of material will be classified as follows for purposes of measurement and payment:

(a) Soft Excavation

See Section 9 – Bulk Surface Excavations and Trenching.

(b) Hard Rock Excavation

See Section 9 – Bulk Surface Excavations and Trenching.

(c) Boulder Excavation Class A

See Section 9 – Bulk Surface Excavations and Trenching.

(d) Boulder Excavation Class B

See Section 9 – Bulk Surface Excavations and Trenching.

16.4.3 Classification for Placing Purposes

Refer to Annexure 16/1 for definition of Zones.

16.4.3.1 Zone 1: Selected Earthfill Material (Impervious)

Selected earthfill material used as earthfill:

- a) Shall be free of stumps, trees, rubbish, organic matter, and other deleterious materials;
- b) Shall conform to the size limits and grading boundaries and physical properties given on the Drawings for the various embankment zones;
- c) Shall be compactable to the density specified; and
- d) May contain isolated individual stones and boulders of maximum dimension up to two-thirds of the compacted layer thickness, provided that the volume of the stones and boulders does not exceed 15% of the volume of the layer.

16.4.3.2 Zone 2: Unselected Earthfill Materials

Unselected earthfill material shall consist of miscellaneous mixtures of clay, silt, sand, gravel, cobbles, and rock fragments to 200 mm maximum dimension. The materials shall be obtained from

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excavations for permanent construction required for the Works and from borrow areas. Boulders and rock fragments larger than 200 mm maximum dimension shall be removed from otherwise approved unselected earthfill material, either at the site of excavation or after the material has been placed in the embankment, but before the material is compacted. Such oversize boulders and rock fragments shall either be used as rockfill material, or spoiled.

16.4.3.3 Zone 3: Rockfill Material for Embankment

Rockfill used in the embankment and as riprap shall:

- a) Be hard, dense, durable material that is free from weathering; and
- b) Conform in mass and size limits to the values given below.

The rockfill material shall be obtained from other required excavations, or from a quarry. The rockfill shall consist of rock fragments reasonably well graded between 200 and 1000 mm (varies for different purposes and material sizes) in maximum dimensions of the individual fragments. The rockfill may contain materials less than 200 mm size provided that the quantities do not exceed the amount required to fill the voids in the larger rock. Individual rock fragments larger than 1000 mm may be embedded in the rockfill within 2 m of the downstream slope.

16.4.3.4 Zone 4: Filter, Drain and Transition Zone Materials

Sands and gravels required for use in drains and filters shall:

- a) Be clean and contain no organic material;
- b) Contain no soft friable particles;
- c) Consist of hard, durable, and well-shaped particles; and
- d) Have a grading between the limits given on the Drawings.

Where necessary aggregates shall be washed with approved washing Plant to ensure that the grading and other quality requirements are complied with.

The coarse aggregates shall meet the minimum requirements of stone for concrete as specified in SANS 1083 and shall not have any property which, in the opinion of the Engineer, could adversely affect the functioning of the filter, drain or transition zone. Should the Contractor be unable or elect not to produce the materials as crusher run then the coarse aggregate shall be separated and separately stockpiled in applicable sizes of stone. The coarse aggregate shall meet the prescribed requirements of the 10% FACT value for a concrete not subject to surface abrasion. The coarse aggregate shall be tested for the following properties:

- Shape (as indicated by voids content). Testing shall be conducted in accordance with SANS 5846 and the voids content shall not exceed 48%;
- Soundness. When tested in accordance with ASTM C88 (sodium and magnesium sulphate method), the coarse aggregate shall not indicate a loss in mass of more than 8%;
- Abrasion resistance. The abrasion resistance, when tested in accordance with SANS 5846, shall not exceed 48; and
- Flakiness index. The testing shall be carried out in accordance with SANS 5847 and the flakiness index shall not exceed 35%.

In addition, all the non-soluble deleterious materials, including materials of low density, in each size fraction shall not exceed 3% by mass.

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The fine aggregates used in filters shall meet the requirements of sand for concrete in SANS 1083 unless otherwise approved by the Engineer and shall have no property which, in the opinion of the Engineer, could adversely affect the functioning of the filters.

The fine aggregate may be of either class specified in Table 1 of SANS 1083 or may be a blend of both classes. The specified filter grading shall be achieved by the blending of at most two types of sand. Different types and classes of sand shall be separately stockpiled.

The fine aggregate shall be tested for the following properties:

- Content of material of low density;
- Soundness. When tested in accordance with SANS 5847 (sodium sulphate method), the fine aggregate shall not indicate a loss of more than 8%; and
- Other impurities.

In addition, all the non-soluble deleterious materials, including materials of low density, in any size fraction shall not exceed 2% by mass.

In general and unless otherwise approved by the Engineer these materials shall comply with the requirements for concrete aggregate in SANS 1083 with the following modifications:

- The dry 10% FACT value shall not be less than 110kN; and
- The wet 10% FACT value shall be at least 75% of the determined dry value.

The Contractor shall construct storage facilities that:

- Provide adequate capacity to ensure no interruption to the construction;
- Provide separate storage areas for different types and sizes of material;
- Ensure there is no intermixing nor contamination by deleterious matter;
- Ensure there is no segregation; and
- By restricting the height of the stockpiles, ensure that no breakdown of particles takes place.

16.4.3.5 Zone 5: Riprap

All stone for riprap shall be of rock of a petrographic type approved by the Engineer and shall be quarry or excavation run processed only to remove excess fines or to remove or degrade oversize particles and shall meet the following requirements:

- a) Be hard, dense, durable quarried rock that is free from weathering, cracks, seams and other defects that will cause rapid or excessive deterioration or degradation during service;
- b) Conform to the grading given on the Drawings (see Clause 16.8.10) and the requirements stated in Clause 16.4.1;
- c) Contain no more than 5% by mass in total of impurities (or undesirable material) such as individual pieces of riprap which do not meet the quality requirements as specified and which can be visually differentiated from satisfactory pieces, plus dirt, sand, clay, rock fines and material of low density;
- d) The specific gravity of the individual particles shall be greater than 2.60;
- e) The dry 10% FACT value determined in accordance with SANS 5842 shall not be less than 110 kN;
- f) The wet 10% FACT value determined in accordance with SANS 5842 shall not be less than 75% of the determined dry value; and
- g) The loss after 5 cycles measured by the sodium sulphate soundness test (see Clause 16.8.9) shall not be greater than 8%.

16.4.3.6 Zone 6: Pervious Backfill

The materials to be used for pervious backfill shall be selected pervious mixtures of sand, gravel and cobbles, reasonably well graded to a maximum size of 150 mm, except that occasional larger fragments may be used if well distributed in the backfill. The pervious backfill shall not contain more than 5 percent, by mass, of material passing a 75 micron sieve. The materials shall be furnished from an approved source, selected from necessary excavation for the Works, or recovered from an approved borrow area.

16.4.3.7 Zone 7: Rock Backfill

The material used for rock backfill shall be selected angular rock fragments, reasonably well graded, from 75 mm to 200 mm in minimum and maximum dimensions; and shall be obtained from the same type of rock source, and be of the same quality, as required for riprap in Clause 16.4.3.5; selected from rock materials from required excavations, or obtained from an identified borrow area. The rock backfill shall contain no more than 5 percent, by mass, of material passing a 75 micron sieve. Materials less than 75 mm in maximum size may be used in an amount only sufficient to fill the voids in the coarser material.

16.4.3.8 Zone 8: Gravel for Downstream Face Protection

Gravel used for downstream face protection shall comply with the following requirements:

- Gravel shall comprise hard, clean rock particles;
- Gravel shall have a maximum particle size of 75 mm, shall be continuously graded and have a maximum of 5% passing the 75 micron sieve;
- Gravel shall be clean and shall conform to the grading given on the Drawings and the requirements stated in Clause 16.4.1. Where necessary aggregates shall be washed with approved washing Plant to ensure that the grading and other quality requirements are complied with;
- Gravel shall meet the minimum requirements of stone for concrete as specified in SANS 1083 and shall not have any property which, in the opinion of the Engineer, could adversely affect the functioning of the filter, drain or transition layer; and
- Gravel shall meet the prescribed requirements of the 10% FACT value for a concrete not subject to surface abrasion.

16.4.3.9 Zone 9: Gravel Capping

Gravel capping material shall have:

- a) A minimum CBR of 45% at 95% of modified AASHTO maximum density;
- b) A maximum CBR swell of 0,5% at 100% of modified AASHTO maximum density;
- c) A plasticity index of not less than 6 and not more than 12;
- d) A maximum particle size of 50 mm; and
- e) Between 30% and 40% of the material shall be retained on a 13.2 mm sieve.

16.4.3.10 Zone 10: Transition layer / Riprap Bedding

The materials for the transition layer / riprap bedding shall comprise a pervious mixture of sand, gravel and cobbles reasonably well graded from 5 mm to 150 mm in maximum dimensions, but may contain materials smaller than 5 mm in quantities not to exceed the amount required to fill the voids between the materials larger than 5 mm; provided that the material shall contain no more than 5 percent, by weight, of material passing a 75 micron sieve.

Should cobbles and boulders having dimensions of more than 150 mm be found in otherwise approved materials, they shall be removed by the Contractor either at the Site of excavation or after being placed. Such oversize cobbles and boulders shall be placed in Zone 5 or 6 or spoiled, as directed by the Engineer.

16.4.4 Selection**16.4.4.1 General**

Where a zoned embankment is shown on the Drawings, the Contractor shall ensure that the material is correctly selected and placed in the correct zone in the embankment.

16.4.4.2 Topsoil

Topsoil removed from any borrow area within the dam basin shall be stockpiled and used as directed. Topsoil removed from any borrow area above the full supply level of the dam shall be preserved for reinstatement of the borrow area.

16.4.4.3 Fill Materials

Fill material for the construction of the embankment shall be obtained from the dam basin (where suitable material is available), from borrow pits or from within the boundaries shown on the Drawings. Suitable fill material from excavations on Site shall be stockpiled for later use or used directly in the embankment fill and rockfill materials.

The sources from which filter and rockfill materials are supplied shall be subject to approval.

16.5 EQUIPMENT**16.5.1 Excavation Equipment**

Although particular items of equipment are specified in Clause 9.2, for the classifying of excavations, the Contractor is not obliged to provide or use those particular items of equipment for carrying out the work. However, should those items of equipment not be freely available in good working order on the Site, the Engineer will be entitled to decide the classification of materials and types of excavation on the basis of the good-working-order-performance of the items of equipment provided by the Contractor, pro-rata to the theoretical performance of the items specified (See Clause 16.4.2.1).

The Contractor shall employ all such other or additional equipment as may be necessary to ensure adequate and efficient procuring, processing, loading, hauling, dumping, spreading, mixing, scarifying, watering, compaction, levelling and such other operations as may be incidental to the

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construction of an embankment to the specified dimensions, methods and standards, all to the satisfaction of the Engineer.

16.5.2 Crushing and Screening Equipment

If required, the Contractor shall supply and erect, in a position approved by the Engineer, a suitable crushing facility to produce the material required for the filters, drains and transition layers. The capacity of the facility shall be such that it can meet the Contractor's peak production requirements and required rate of production of aggregates for the concrete works. The screening unit shall be capable of producing the different grading specified for each type of material. Grizzlies to process riprap shall be of a design and layout approved by the Engineer.

16.5.3 Batching Plant for Filters, Drains and Transition Zones

Where aggregates are to be combined to produce material conforming to the specified grading, the Contractor shall provide an approved batching system which is efficient and accurate. Materials that do not bulk when moist may be measured by mass or volume. Fine aggregate fractions that bulk when moist shall be measured by mass. The measuring equipment shall ensure that the batched amount of each constituent is within 5% of the required quantity. The Contractor shall carry out all necessary calibrations and regular checks to the approval of the Engineer to ensure that this degree of accuracy is maintained throughout the Contract. Regular checks shall be carried out before commencing every new shift and, or at least at the start of each day on which materials for filters, drains and transition layers are being batched. The layout of the facility and its mode of operation shall ensure that the materials are kept uncontaminated throughout the batching process and that changes in moisture content do not occur between measurements made to adjust for moisture content when using mass batching. In addition, adequate safeguards shall be provided that ensure ingredients are not omitted or duplicated. The measuring system installed shall be capable of ready adjustment of the proportions whenever this is found to be necessary.

16.5.4 Mixing or Blending Equipment for Filters, Drains and Transition Zones

The type and capacity of the mixing or blending Plant used to combine aggregates shall be such that the output is suitable for the programmed production rate of materials. The Plant shall ensure a uniform distribution of the ingredients and that the mixed or blended batch is not segregated on completion. The Contractor shall agree with the Engineer on the mixing or blending time to be used for the type of Plant employed and this shall not be varied without the prior approval of the Engineer.

16.5.5 Loading and Transport Equipment

The equipment used to load and transport material from the quarries, borrow pits and batching facility shall be of adequate capacity to ensure that the grading of each load conforms as nearly as is practicable to the average grading of the material in the particular zone being placed. The loading equipment used in quarries may be mounted either on crawler type tracks or pneumatic tyres provided that it is always operated in such a way that will ensure a minimum amount of degradation in the quarries subject to meeting the specified grading requirements for the particular zone being loaded. The Contractor may use either special rock loading buckets or pass the material over a grizzly or use such other acceptable means as the Engineer may approve to remove some or all of the fines from the quarried rock when necessary to produce quarry-run rock for use as riprap. Tracked vehicles shall not be used on the embankment if these are found to cause a degradation of any of the placed materials. The equipment used by the Contractor shall at all times be designed and operated to keep wastage of the materials to a minimum.

The transporting equipment shall be such that the Contractor can at all times place any of the zones shown on the Drawings when the layers are being placed in strips either parallel to or at right angles to the crest of the embankment.

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If transport equipment is required to operate on public roads, it shall meet the requirements of the appropriate road traffic regulations.

16.5.6 Spreading Equipment

The equipment used on the embankments for spreading material such as bulldozers, graders and ploughs shall be of sufficient capacity to ensure that adequate inter-mixing of the various loads of dumped material is obtained without segregation, and without bridging of the larger particles with consequent large voids in the spread material.

Adequate spreader boxes and formwork where necessary shall be provided on Site for placing and spreading filter or drain materials without segregation or contamination. The equipment used shall at all times be subject to the approval of the Engineer.

Whenever, in the opinion of the Engineer, the Contractor's placing, spreading and mixing techniques on the embankments are such as to cause degradation or segregation of the material the Contractor shall immediately take approved corrective measures.

16.5.7 Compaction Equipment

The Equipment used for applying the dynamic load, controlling the moisture content, and grading or mixing shall be capable of achieving the compaction specified (without over-compaction) with the materials available for the construction of the Works.

The selection of compaction equipment to be used for foundation preparation, fill, filter and drain construction shall be based on the type of material to be compacted, its location, the required density and the performance of the equipment when compacting the materials required for the Works. The selection shall be confirmed during the construction of the trial embankment. Impact rollers will not be allowed.

Compaction equipment used against a concrete (or masonry) structure shall be capable of compacting material against a near vertical face, i.e. the edge of the roller must reach the concrete face.

16.6 CONSTRUCTION**16.6.1 General**

The Contractor shall programme his work such that wherever possible suitable material obtained from excavations is transported directly into its final place in the embankment.

The phasing of drilling, water testing, the construction of grout caps and grouting, core trench excavation and foundation preparations and the placing of core material shall be in accordance with the requirements as shown on the Drawings or as directed by the Engineer. No core materials shall be placed or foundation preparations performed in an area where the Engineer has not given his specific approval of that particular portion of foundation.

The embankment shall be constructed to the lines, levels and slopes shown on the Drawings, with adequate allowance for settlement during construction as required in terms of Clause 16.6.4.5. The Contractor shall include in his embankment construction Method Statement, the manner in which this will be achieved.

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Surface or subsurface water, which is encountered during the progress of the work, shall be dealt with by the Contractor entirely at his own cost in terms of Section 8 – Dealing with Water.

At weekly intervals the Contractor shall submit to the Engineer details of his programme of construction for the succeeding week, including borrow pits to be worked and areas and volumes of embankment to be placed.

The Engineer may order the Contractor to remove any material which is unsuitable, improperly laid, watered or compacted.

16.6.2 Precautions

16.6.2.1 Safeguarding of Excavations

- a) The Contractor shall appoint, in writing competent persons to inspect bracing and shoring as required by Section 2 and the Occupational Health and Safety Act (Act No 85 of 1993) and its regulations.
- b) Where the depth of an excavation exceeds 1 metre or the nature of the material excavated renders the sides of the excavation liable to movement that might endanger the Works or the workmen engaged on the excavation;
 - i) The sides of the excavation shall be supported by suitable timber or other sheeting adequately strutted and braced, all being assembled properly and having sufficient strength and stiffness to prevent movement in the materials supported; or alternatively;
 - ii) The Contractor may, subject to the approval of the Engineer, so reduce the slope of the excavated face or faces that any danger to the Works or to the said workmen is removed.
- c) Depending on circumstances, the Engineer may or may not approve a change of slope in a cut-off trench (see Clause 16.6.4.2(b)).
- d) The Contractor shall make good any fall of rock or earth due to rain, flooding, insufficient timbering, or other cause, and any cavities so formed shall be filled in at his own expense, as directed or by using approved means.
- e) Without relieving the Contractor in any way of his responsibilities, the Engineer may order additional lateral support for, or the sloping or reduction of the slope of, the sides of any excavation.
- f) During the progress of each excavation, the Contractor shall report to the Engineer the presence of bedding planes inclined towards the excavation, seepage water, and any other feature that may affect the stability of the excavation, as soon as the presence of such feature(s) is known.
- g) All timbering and sheeting shall be removed from the excavation before the completion of the work, unless the written permission of the Engineer allowing any portion to remain is obtained.

16.6.2.2 Explosives

Should blasting be necessary, the Contractor shall take every precaution to protect the Works and persons, animals, and property in the vicinity of the Site. The Contractor will be held responsible for any injury or damage caused by any blasting operations and shall, at his own expense, make good such damage.

The provisions of Clause 2.9.12 are relevant for the use of explosives.

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The blasting process shall be executed in terms of the provisions of Section 12 - Blasting. When blasting to specified profiles, the Contractor shall so arrange the holes and charges that the resulting exposed surfaces are as sound as the nature of the material permits. The Contractor shall make good at his own expense any additional excavation resulting from the shattering of rock in excess of any overbreak allowance shown on the Drawings or specified in the project specification.

Where rock excavation by non-explosive methods is scheduled and ordered, the Contractor shall not use explosives. Should the Contractor fail to carry out such an order he shall bear the cost of making good any resultant over-excavation including its replacement with concrete or selected material, as instructed.

16.6.2.3 Surfaces Damaged by Equipment

Should any mobile equipment of any type operated by the Contractor damage any finished surface of an area normally open to the public, the Contractor shall repair such surface as a matter of urgency and at his own expense.

16.6.3 Trial Embankment Construction and Tests

The Engineer may order the construction of a trial embankment to test the properties and compaction characteristics of the earthfill material.

The trial embankment shall be constructed on a cleared section of ground after stripping the surface of topsoil and clearing objectionable material.

The trial embankment shall be constructed for each type of material with the aim of determining:

- a) The optimum and/or maximum thickness of the layers to be placed;
- b) The number of passes required with the compaction equipment to obtain the specified percentage of maximum Proctor Density for a particular thickness of the layer;
- c) The type and mass of the compacting equipment to be used;
- d) The behaviour of the material when placed and compacted at its specified moisture content range and the effect of over-compaction on the material; and
- e) The correlation obtained between density and moisture content by means of the wax density, Sand Displacement Method, Core Cutter density methods and the Hydro densimeter.

The Engineer may instruct trial embankment for each type of material as and when conditions require such action.

16.6.4 Methods and Procedures**16.6.4.1 Clearing and Stripping of Site****(a) Clearing**

The Contractor shall clear the foundation area of the embankment. This shall consist of:

- i) The removal and disposal of all trees, bushes, and other vegetation (complete with roots), rubbish, fences, and all other material that may interfere with the construction of the embankment, spillway, and ancillary works;

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- ii) The removal and disposal of structures that encroach upon or may otherwise obstruct work on the areas covered by (a) above, and that can be cleared by means of a bulldozer of mass approximately 20 t and flywheel power approximately 130 Kw. Structures that cannot be so cleared shall be broken down in accordance with the requirements for the removal and disposal of structures given in Section 7 – Clearing Site;
- iii) The removal and stockpiling of riprap, rocks and boulders of size up to 0,15 m³ that are lying on the surface including those that are exposed during the clearing operations; and
- iv) Where fences have to be taken down, the sorting, coiling, and stacking of the material at a designated place within 0.5 km of the Engineer's Site office.

The moving of a certain amount of soil or gravel may be inherent in or unavoidable during the process of clearing. No extra payment will be made for the removal of such soil or gravel.

(b) Topsoil

If there is suitable topsoil within the limits of the area to be cleared, the Contractor shall, if so instructed, remove and conserve the topsoil together with any grass or other acceptable vegetation. If it is not used immediately or if it is not stockpiled in windrows clear of the working areas, the topsoil shall be conserved for later use in the manner specified in Section 7 for finishing of the embankment or as directed.

The Contractor will not be required to remove topsoil from any area in which the average depth of topsoil is less than 150 mm.

(c) Clearing Dam Basin

In addition to clearing and stripping the embankment and spillway sites and removing and using topsoil as specified in Clauses 16.6.4.1 (a), (b) and (c), and where so scheduled in the Bill of Quantities or to the extent required on the Drawings or when so instructed by the Engineer, the Contractor shall remove trees and bush from the dam basin.

16.6.4.2 Excavation**(a) Foundation**

After the foundation area has been stripped in terms of Clause 16.6.4.1, excavation shall be carried out to the depths given on the Drawings or to such greater depths as may be instructed by the Engineer to ensure a satisfactory foundation.

All excavated surfaces shall be trimmed to ensure that there is no projection into the excavation profile that is:

- i) Greater than the tolerance specified in Clause 16.7.2.1, as relevant; or
- ii) Inside the excavation payment-line shown on the Drawings, as applicable.

Any extraordinary feature such as fossils, unexpected groundwater, or an unexpected geological feature shall be reported to the Engineer before it is removed or covered.

(b) Preparation of Exposed Surfaces**(i) Rock Surfaces**

Except as specified otherwise in Clause 16.6.4.3, all rock surfaces exposed in the cut-off trench or foundation shall be prepared as specified in Clause 16.6.4.2 (b)(i).

Rock surfaces exposed in the cut-off trench or embankment and spillway foundation areas shall be excavated to sound rock and washed clean using air and water jets.

Abrupt changes in section, for example benches on the abutment slopes, shall be avoided. Surfaces against which material is to be placed shall be excavated to slopes not steeper than 1:1.

No surface treatment, including joint and crack grouting, shall commence until all the required blasting within 100 m of the area to be treated has been completed.

All loose and partly detached blocks of rock shall be removed. All knobs, projections, and overhangs of rock shall be removed by barring and wedging or light blasting. In order not to open up joints or otherwise disturb the rock surface, the amount of blasting shall be kept to a practicable minimum. No blasting shall be done on surfaces that have been grouted or slush-grouted.

Joints and cracks that are exposed in the excavation shall be cleaned to a depth of not less than three times their width at the surface. Such joints and cracks shall then be filled with an approved grout. Where possible, a pipe shall be set at the bottom of a joint or crack and grout shall be pumped in until the joint or crack is completely filled. Grout shall then be broomed and brushed across the top of the joint or crack to ensure that the contact with the core or other zone material will be tight and non-erodible. Except in the case of small cracks, the brushing of slush grout to fill a crack is not acceptable.

Grout used for the purpose of filling cracks shall be highly plastic and buttery. The maximum size of aggregate in grout used for filling a crack shall not exceed one-third of the width of the crack.

Depressed areas, potholes, and similar irregularities shall be filled with a plastic mix of 20 MPa / 40 mm concrete vibrated into place. Small ribs and similar irregularities shall be filleted to produce a slope not steeper than 1:1.

The final rock surface shall have smooth contours against which soil can be compacted by heavy equipment.

(ii) Soil Surfaces

Except as specified otherwise in Clause 16.6.4.3, all soil foundation surfaces shall be prepared as specified in this section (Clause 16.6.4.2 (b)(ii)).

Before each soil foundation is inspected by the Engineer, the Contractor shall ensure that all loose material is removed from the foundation. After the foundation has been approved, the soil shall be ploughed to a depth of 150 mm, wetted or dried, as applicable, and then compacted to at least 95% of the Proctor density (see Clause 0) except that where the presence of dispersive soil has been proved by the Engineer, the density shall be at least 98% of the Proctor density. After the soil has been compacted, the surface shall be scarified to a depth of 25 mm to ensure bonding with the fill material and, immediately after that, the embankment fill shall be placed directly on the prepared surface.

(c) Borrow Pits

When the Contractor is instructed by the Engineer to open up borrow pits to obtain additional or selected excavated material from designated sites, the Contractor shall first clear the surface of the sites in accordance with the applicable requirements of Section 14 - Spoil, Borrow and Excavated Materials. Topsoil and overburden shall be stripped and stockpiled separately. The Contractor shall so maintain borrow pits that they do not become a danger to persons and livestock.

The Contractor shall so plan and operate borrow pits as to obtain maximum use of the materials. Haulage and access roads shall be kept to a minimum and the Contractor shall inform the Engineer fully of any proposed routes for haulage and access roads to and from the borrow areas. The management of borrow pits shall be done according to Section 14 - Spoil, Borrow and Excavated Materials.

(d) Disposal

The Contractor shall not spoil, stockpile, or waste any material without approval. In addition to complying with the requirements of Clause 16.6.4.2 (c) for the disposal of unused material from borrow pits; he shall dispose of surplus and unsuitable material in areas designated spoil areas or as shown on the Drawings.

16.6.4.3 Preparations of Receiving Surfaces

The final receiving surfaces which are to be accepted and approved by the Engineer shall be treated and prepared as follows:

(a) Zone 1: Selected Earthfill Materials (Impervious)

After excavation (see Clause 16.6.4.2), all loose blocks shall be removed from the contact area. All knobs and overhangs shall be removed using barring and wedging. If light blasting is required, the prior approval of the Engineer will be required.

In areas of rock surface foundations, all fissures such as crevices, seams or joints shall be raked out to remove all unsuitable material for as deep as possible (but not less than 3 times the width at its widest point) and then cleaned with air / water jets. Fissures with an average width of less than 25 mm shall be filled with cement grout having a water: cement ratio of not more than 0.67. Fissures between 25 mm and 75 mm wide shall be filled with a cement mortar rodded into position with steel bars. The mortar shall comprise sand and cement in the same proportions as used for a grade Class 25 concrete. Wider features shall be filled with a Class 25/19 concrete. Grout shall be broomed and brushed across the top of all filled crevices and seams to ensure that the contact with the core material will be tight and non-erodible. Where directed by the Engineer, small cracks may be treated by brushing of slush grout having a water: cement ratio of not more than 0.67.

Depressed areas and other irregularities in the rock surface shall be filled with a Class 25/19 or Class 25/38 concrete vibrated into place. Small ribs and similar irregularities shall be filled to produce a slope not steeper than 1(V):2(H). The final rock surface after treatment shall have smooth contours against which the core material can be compacted to specification by heavy equipment.

In areas of cohesive and non-cohesive core foundation materials, the foundation preparation as described in (a) above for the embankment shells shall apply mutatis mutandis (with respective differences taken into consideration).

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(b) Zone 1: Selected Earthfill Materials (Semi-Pervious)

In areas of cohesive foundation materials, the in-situ material shall be scarified to a depth of 150 mm and conditioned to within minus 1% and plus 2% of the OMC and then compacted to a dry density of nowhere less than 95% of the Proctor density.

In areas of non-cohesive foundation materials the in-situ material shall be compacted with vibratory rollers conforming to the specified requirements. The number of passes for the specified rollers will be determined on Site by the Engineer and will vary in accordance with the thickness of the material to be compacted and until a relative density of at least 70% is attained.

If so instructed by the Engineer, the Contractor shall water the foundation materials, both cohesive and non-cohesive, in the amount and in accordance with the requirements specified by the Engineer. Such watering shall be carried out immediately prior to compaction or during late afternoon and/or evening preceding early morning compaction on the following day, whichever the Engineer decides, and in a manner to reduce moisture losses to a minimum. Watering of the foundation shall be carried out uniformly over the whole area to be compacted. If, in the opinion of the Engineer, the Contractor unnecessarily delays compaction operations after water has been applied to the foundation or wastes water in this operation, the Contractor shall add more water to the foundation until specified requirements are met before compaction is commenced.

This work shall be performed over short lengths of the foundation to prevent subsequent loosening up and any areas that become loose due to any cause whatsoever shall be re-compacted by the Contractor. Consecutive passes of vibratory and impact rollers shall be adjacent to each other and shall overlap only sufficiently to ensure full coverage of the surface by each pass. A "pass" for a double drum impact roller is defined as two passes of the roller such that one drum of the roller during its second passage travels in the inter-drum space created by the first passage of the impact roller. An efficient method of lane marking shall be used to ensure that accurate tracking of the roller drums is maintained.

(c) Zone 2: Unselected Fill Materials

The foundation for Zone 2 materials shall be prepared by levelling, moistening, and compacting so that the surface materials will be as compact as specified for subsequent layers of the zone.

In areas of cohesive foundation materials, the in-situ material shall be ploughed to a depth of 250 mm and conditioned to the specified OMC and then compacted to a dry density of nowhere less than 98% of the Proctor density. The surface shall then be scarified to a depth of 25 to 40 mm with cut marks not further than 150 mm apart.

In areas of non-cohesive foundation materials the in-situ material shall be compacted with suitable vibratory rollers conforming to the specified requirements. The number of passes for the specified rollers will be determined on Site by the Engineer and will vary in accordance with the thickness of the material to be compacted and until a relative density of at least 70% is attained.

This work shall be performed in such a way as to prevent subsequent loosening up of the compacted foundation and any areas that become loose due to any cause whatsoever shall be re-worked, moisture conditioned and re-compacted by the Contractor.

An efficient method of lane marking shall be used to ensure that accurate tracking of the roller drums is maintained.

(d) Zone 3: Rockfill Material for Embankment

Fine and other materials unsuitable for the support of rockfill shall be removed, as directed by the Engineer. No material shall be placed until the foundation has been dewatered, stripped and suitably prepared. All cavities, depressions and irregularities shall be cleaned and filled with rockfill materials compacted as specified, or slush grouted and filled with dental concrete, as directed by the Engineer.

Areas of weathered rock shall be scarified to a depth of 150 mm and conditioned to within minus 1% and plus 2% of the OMC and then compacted to a dry density of nowhere less than 95% of the Proctor density.

(e) Zone 4: Filter, Drain and Transition Zone Materials

The provisions of Clause 16.6.4.3 (d) shall apply.

(f) Zone 5: Riprap

The embankment receiving surface for Riprap shall be well compacted and free of loose material.

(g) Zones 6 to 9

The embankment receiving surface shall be well compacted and free of loose material. The Contractor shall programme his works such that placing of core material can commence immediately after the surface has been prepared as specified above, to avoid deterioration of the material or prepared surface. If the Contractor fails to meet this requirement, any additional preparatory work required shall be carried out to the satisfaction of the Engineer.

(h) Zone 10: Transition layer / Riprap Bedding

The embankment receiving surface for riprap bedding shall be well compacted and free of loose material.

16.6.4.4 Batching, Mixing, Blending and Loading of Materials

Where deemed necessary by the Engineer, all constituents of the filters, drains and transition layers shall be batched in the proportions required to comply with the respective specific grading requirements.

The mixing or blending of materials for filters, drains and transition layers shall be conducted by an experienced operator. The sequence of charging the mixing or blending equipment shall be approved prior to commencing the earthworks operations and this sequence shall be maintained unless otherwise approved by the Engineer. The quantity of the mixed material per batch shall not exceed the rated capacity of the mixing and blending Plant. No ingredients shall be added while the mixer is stationary.

The discharge from the mixing or blending equipment shall be arranged so that there is no segregation of the materials in the mix. Mixers shall be completely emptied before being recharged.

Adequate precautions shall be taken to ensure that the materials loaded into the vehicles for placement in the embankments conform to the specified requirements and have been conditioned accordingly. The Contractor shall ensure that during the loading operation for filter and riprap material excess fines are not picked up from the quarry or stockpile floors and if special rock-loading buckets are used, the loading face shall be cleared continuously to remove the concentration of

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finer from the floor. This material shall either be spoiled or stockpiled for later use in another embankment zone requiring finer material. In the event of the Contractor using a grizzly to remove excess fines or oversize material, as the case may be, the oversize or undersize fraction shall be disposed of or used in accordance with the instructions of the Engineer, and the Contractor shall take all the necessary precautions to prevent uncontrolled mixing of materials.

In borrow pits and in the dam excavations the Contractor shall at all times avoid loading material which does not conform to specified requirements or which has become unsuitable for use in a particular zone for which it was intended. Where such material has already been transported onto the embankments the Contractor shall remove and replace.

The Contractor shall so phase and organise his operations that the material in each vehicle represents as nearly as is practicable the average grading of the particular zone being placed and where the material is being placed directly into its final position on the embankments without any mixing other than spreading and levelling the material in each load shall comply exactly with the specified requirements within the tolerances specified.

The Contractor shall selectively load all suitable materials from the dam excavations, borrow pits and quarry to prevent contamination with unsuitable overburden and unsuitable material as defined in the relevant specifications. No oversize material shall be brought onto the embankments.

16.6.4.5 Material Processing

(a) Processing

Where required, material shall be processed by screening, heavy grid rolling or bentonite processing.

(b) Screening

Before being placed, the material shall be passed through a screening Plant, with screens of the required or specified sizes, to remove the oversize fraction and unsuitable or excess fines. The screened-out material shall be removed to spoil sites and disposed of.

(c) Heavy Grid Rolling

Heavy grid rolling shall be carried out with a grid roller of mass at least 13t and travelling at a speed of at least 12 km/h. Every portion of the layer shall be covered by at least 4 passes of the roller. The material shall be windrowed to one side of the layer, shall be checked for oversize material, and the oversize material shall be removed. The material shall then be re-spread and again grid rolled as before. The process shall be repeated until all oversize material is broken down or removed.

(d) Bentonite Processing

The bentonite shall be evenly spread over the layer to be processed. Immediately after the bentonite has been applied, it shall be mixed with the layer material, for the full depth of treatment. Mixing shall be continued for as long and repeated as often as may be required to ensure a thorough, uniform and intimate mix of the material to be processed and the bentonite.

The resulting mixture shall be homogeneous. The material shall then be wetted, the water mixed in and the layer compacted.

16.6.4.6 Lines and Grades

The embankment shall be constructed to the lines, grades, and levels shown on the Drawings or as directed. The allowance for settlement given on the Drawings or specified elsewhere shall be taken into account during construction so that the final crest level shortly after construction, is at the height given on the Drawings (see Clause 16.9.2.1).

16.6.4.7 Placing and Spreading**(a) Embankment, General Requirements**

- i) Only material that:
 - Has been obtained from excavations or borrow pits, or both; and
 - Has been approved and complies with the applicable requirements of Clause 16.4.3, shall be placed in the embankment.
- ii) As far as is practicable the moisture content of the material for the embankment shall be adjusted in the borrow pits. If required, water shall be added by spraying and mixed into the material to bring it to within the specified moisture content limits and to produce a uniform moisture content in the material. Material containing excessive moisture shall be either stockpiled or harrowed.
- iii) The material of the embankment shall be placed in layers of thickness, before compaction, not exceeding 250 mm unless specified otherwise. The material shall be spread over the area of the embankment and sloped sufficiently to allow for the run-off of rainwater. Where the dam is constructed across a river, the construction level of the embankment shall be always on the same horizontal level throughout to avoid concentration of floods. Where it is economically advantageous to place the fill material at different levels during construction of the dam, the Contractor shall have advised the Engineer, before starting the work, of his intention to use such a method of construction and shall take all the special precautions that have been laid down by the Engineer in respect of the work.
- iv) Each layer shall be compacted, mainly by means of heavy compaction equipment, to at least the Proctor density specified on the Drawings for the particular zone or, where no such density is specified, to at least 95% of Proctor density, subject to the applicable tolerance specified in Clause 0.
- v) Compaction by hand-held compaction tools shall be kept to a minimum, and where they are used, such tools shall be subject to approval.
- vi) Where the presence of dispersive soil has been proved by the Engineer, the Contractor shall ensure that the specified precautionary measures are strictly adhered to.
- vii) In addition to the tests required in terms of Clause 16.8.4 the Engineer may order the Contractor to perform tests to ensure that the specified density is attained throughout the entire thickness of a layer.
- viii) Should the material of the top layer of compacted material be too wet (from rain or other cause) to allow the next layer to be placed, it shall be harrowed and allowed to dry out to the specified moisture content and re-compacted. Should the top layer of compacted material dry out and form shrinkage cracks, it shall be harrowed, rewetted, and re-compacted. The top surface of each layer shall be sufficiently rough to ensure proper bonding with the succeeding layer. The Contractor may be required, at his own expense, to scarify the surface if, in the opinion of the Engineer, the surface is too smooth to ensure proper bonding. The surface shall be scarified to a depth of 25 mm to 40 mm with 'cut marks' not further than 150 mm

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apart, to ensure bonding with the fill material and, immediately after that, the embankment fill shall be placed directly on the prepared surface.

- ix) Fill material shall be placed 500 mm wider than the relevant width shown on the Drawings to ensure proper compaction on the upstream and downstream slopes, and then cut back.
- x) End slopes and side slopes of partial fill sections in the embankment shall not be steeper than 1 vertical to 4 horizontal.
- xi) The distribution and gradation of materials in any zone shall be such that the embankment will be free of lenses, pockets, streaks, and layers of material differing markedly in texture or gradation from the surrounding material.

(b) Rockfill, Riprap, Drains and Filters, General Requirements

- i) Stone for riprap shall be so placed on the bedding layers as to produce a reasonably well-graded mass of rock with the minimum practicable percentage of voids.
- ii) The larger stones shall be well distributed and the entire mass of stones in their final position shall be roughly graded to conform to the gradation specified. The finished riprap shall be free from unacceptable pockets of small stones and clusters of large stones. Riprap shall be placed to its full course thickness in one operation and in such a manner as to avoid displacing the bedding material. The finished layer of riprap shall be a well-integrated, stable mass of rock.
- iii) No compaction will be required for riprap.
- iv) Non-vertical filter layers may, subject to approval, be connected with short vertical sections (giving a stepped effect), to suit the Contractor's method of working. The cost of extra material used for this purpose will be for the Contractor's account.
- v) Rockfill for use in the downstream toe and other portions of the embankment shall be dumped, with exposed surfaces finished off to present a neat appearance. No compaction will be required for rockfill materials.
- vi) Where any source of rockfill is designated, no guarantee is given or implied that the source will provide material that complies with Clause 16.4.3.3 as regards quality or grading limits, or that it will be adequate in quantity. Where any part or the whole of a designated source of rockfill does not comply with Clause 16.4.3.3 or is not adequate in quantity, the Contractor shall locate and obtain approval for one or more other sources of rockfill and the terms of Clause 16.6.4.2 (c) and Clause 16.6.4.14 shall apply to such material and the source(s).

(c) Zone 1: Selected Earthfill Materials

Core and shell materials shall be placed in horizontal layers throughout, to a maximum permissible compacted thickness of 150 mm and 250 mm respectively or three times the maximum particle size, whichever is the larger. The maximum compacted thickness for core and shell materials in restricted areas, such as around the tongue walls and other structures shall be limited to 100 mm and 150 mm respectively. A slight cross fall from the chimney drain in both directions to the upstream and downstream shall be maintained for draining stormwater and to prevent contamination of the chimney drain.

Whenever a layer or portion of a layer is placed to a compacted thickness of less than 50% of the maximum permissible thickness it shall be bonded to the previous layer by scarifying the latter to a depth of 25 mm or such greater depth required to ensure a combined compacted thickness of 50% of the maximum permissible thickness, provided that no layer shall be placed to a thickness less than twice the maximum particle size.

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The fill may be brought on and spread with scrapers or may be dumped in piles and spread with bulldozers and/or graders. The Contractor shall route haul vehicles and other Plant over the entire area of the fill. There shall be no unnecessary concentration of routing vehicles tending to cause ruts, laminations or uneven compaction within the fill. Where such ruts, laminations or unevenness occurs, they shall be corrected to the satisfaction of the Engineer.

The widths of the various layers and the direction of placing shall follow a regular pattern and the Contractor shall submit details of his proposed programme and layout of the layers to the Engineer for his approval before commencing with construction. In particular the Contractor shall stagger the longitudinal edges of the layers in a vertical section taken normal to these edges in order to avoid these contact areas from extending continuously over more than one layer. The contact between any two zones shall not be allowed to form a longitudinal edge of a layer. The layers and zones shall be so placed that compaction can be conducted simultaneously along or across the zones to ensure complete integration of the two zones at the contact.

Construction shall at all times be commenced at the lowest point of the foundations. The embankments shall be constructed over the full width of each zone except for fill in the vicinity of filter zones. Under no circumstances, except where limited by the foundation profile shall any layer be less than 300 m in length.

The surface of any compacted layer, including the foundation layers shall be prevented from drying out and cracking by regularly watering the surface until it can be covered by the succeeding layer. Should the surface of any layer show signs of cracking the material shall be scarified to below the level of the deepest cracks, re-watered and re-compacted. Where the cracks extend to depths greater than the maximum permitted layer thickness the Contractor shall submit proposals to the Engineer for rectifying the problem.

The top surface of each layer shall be sufficiently rough to ensure proper bonding with the overlying layer. If the surface is too smooth to ensure proper bonding the Contractor shall scarify the surface ensuring that the combined scarified thickness plus compacted thickness of the overlying layer does not exceed the maximum permitted layer thickness.

Fertiliser where specified at the outer surface of the downstream shell shall be introduced into the soil in a manner approved by the Engineer.

(d) Zone 2: Unselected Fill Materials

The material shall be placed in continuous and approximately horizontal layers, not more than 300 mm in thickness after being compacted as herein specified. The combined excavation and placing operations shall be such that the materials, when compacted in the miscellaneous fill, will be sufficiently blended to secure the best practicable degree of compaction and stability.

(e) Zone 3: Rockfill Material for Embankment

Rockfill material shall be placed in continuous, approximately horizontal layers having a compacted thickness generally not greater than 1 m. In those areas where the rockfill width is less than 3 m, the un-compacted thickness of the layer shall be reduced to a depth approved by the Engineer, or indicated on the Drawings. Successive loads of material shall be dumped so as to secure the best practical distribution of the material and minimize segregation as approved by the Engineer. The material shall be dumped and levelled in an approved manner prior to compaction.

Rockfill shall not be placed against new concrete until the concrete has been in place for at least 28 days.

(f) Zone 4: Filter, Drain and Transition Zone Materials

Material for horizontal filters and drains may be placed in heaps and then spread with graders.

Traffic shall be controlled with crossings limited to roadways which shall afterwards be removed entirely and replaced with filter material. The layers shall be placed free from contamination by fines and without segregation. Equipment shall not be allowed to operate simultaneously on horizontal filter zones and the adjacent earthfill zones. The material for horizontal filters and drains, such as the blanket drain may be placed and spread in one single layer if in the opinion of the Engineer adequate homogeneity and compaction can be achieved over the full thickness of the layer.

Inclined and/or vertical filter layers shall be placed to the full thickness as shown on the Drawings and in heights not exceeding 500 mm. They may be constructed either by:

- Placing and spreading in advance of the surrounding zones; or
- Placing and compacting the surrounding materials for the full width and then excavating through these layers in order to place the filter material.

In both cases, particular care shall be taken to ensure that any contaminated filter material is completely removed before placing the next layer of filter material.

Filter layers shall at all times be protected against contamination or clogging by materials from other zones, excavated material or material transported by surface or stormwater runoff. Material placed against irregular surfaces shall be worked into all crevices and openings to ensure that there will be no voids or cavities after compaction.

At the contact with the fill and in the case of vertical or inclined filters the adjoining fill shall be built up and compacted simultaneously with the filters over a width of at least 2.0 m to support and protect the filters. The filter layers shall be maintained at a height of between 300 mm and 500 mm above the level of the adjoining fill, except for the supporting fill which shall be gradually sloped away from the filter to prevent surface runoff from the fill from entering the filters. Where embankments are constructed with joints leaving filter or transition layers exposed or incomplete the Contractor shall ensure that the area enclosed by the cofferdams is kept entirely dewatered at all times until such filter and/or transition layers have been completed over their full length (and thickness if so required by the Engineer) to prevent contamination and/or clogging of the same. Subsequent partial inundation of the area within the cofferdams shall then also only be permitted as described in the relevant Specification.

At the edges of the embankments the Contractor shall take measures to the approval of the Engineer to prevent concentrations of surface runoff from damaging the transition layers underneath the outermost slope protection layers, which damage shall all be repaired by the Contractor to the Engineer's satisfaction. Silt or soil fines that may be deposited on these layers as a result of surface runoff from the partially completed embankments shall be removed to the satisfaction of the Engineer prior to proceeding with the construction of the layer.

The filter and drain material for the toe drain shall be placed in separate layers to ensure that the material below the drain pipe is compacted prior to installation of the drain pipe and that the drain pipe is firmly embedded in the surrounding material. The toe drain pipework shall be installed in accordance with the requirements shown on the Drawings.

After laying the drain pipes the remainder of the trench shall be backfilled and compacted by hand compactors in 150 mm to 200 mm thick layers. The materials shall be zoned and of the classes and grading shown on the Drawings. The Contractor shall at all times ensure that the drain pipes are not damaged or disturbed and are kept free of dirt or foreign material. The upstream end of any

particular leg of drain pipe shall be sealed by means of a suitable end cap as shown on the Drawings or instructed by the Engineer.

After completion of any particular embankment incorporating a toe drain the Contractor shall test the toe drain in sections to the approval and in the presence of the Engineer to ensure that the pipes and joints are clear of all obstructions.

(g) Zone 5: Riprap

Riprap shall be placed on a transition layer / bedding. Unless otherwise approved by the Engineer, the riprap shall be placed concurrently with the construction of the embankments but kept at a level of approximately 1.0 m below the level of the transition layers but no more than 3.0 m below the level of the embankment fill. The material shall be dumped as a single layer directly into its final position with a minimum amount of voids and subsequent handling except as may be necessary to finish the slopes to within the specified tolerances. The material shall be placed from the bottom of the slope by dumping from above but without permitting it to roll down the slope. The vehicles containing the riprap may be lowered down the slopes provided that this operation does not cause the underlying material to rut or to be disturbed. The methods adopted by the Contractor shall however at all times be subject to the approval of the Engineer.

The completed riprap must be a dense, uniformly thick and stable layer. The placement of riprap shall commence in a zone indicated by the Engineer (generally below the lowest drawdown level). The method of placement to achieve the end product shall be developed in this area to the satisfaction of the Engineer.

(h) Zone 6: Pervious Backfill

The material shall be handled and placed in such a manner as to prevent segregation. The method of placing pervious backfill shall be subject to the approval of the Engineer. The pervious backfill on either side of any structures shall be kept approximately at the same level as the placing of the backfill progresses. Pervious backfill shall be placed and roughly levelled off in layers not exceeding 400 mm in depth.

(i) Zone 7: Rock Backfill

The rock fragments shall be placed and spread in layers not more than (varies according to density requirements and gradation) 600 mm thick. Placing shall be performed in a manner to prevent damage to any structures. The method of placing shall be subject to the Engineer's approval. The rock backfill on each side of a structure shall be kept approximately at the same level as the placing of the backfill progresses.

(j) Zones 8 and 9: Gravel Capping and Downstream Face Protection

After the final grading has been completed, the Contractor shall place and compact the gravel crest surfacing to a total final layer thickness of at least 200 mm. The downstream face gravel protection layer shall be placed by dumping, in a single layer, without permitting any material to roll down the slope and with a minimum amount of voids and subsequent handling to achieve the specified tolerances.

(k) Zone 10: Transition layer / Riprap Bedding

Prior to the placing of a transition zone, the Contractor shall trim the face of the embankment fill material to within the tolerances specified in Clause 16.7.2.1. The transition zones shall be placed to the thicknesses shown on the Drawings and at no time shall the top level of the transition layer be more than 1.0 m below the embankment fill level. The material shall be placed from the top of the existing layer and not be allowed to roll down the slope. The Contractor shall take particular care to ensure that the zoning of the transition layers is maintained and that no contamination or segregation occurs. The fine transition layer shall be placed at a moisture content that is sufficiently low to prevent bulking and shall be tamped by means of hand equipment to a density sufficient to ensure that the material will not slump when saturated. The methods adopted by the Contractor shall at all times be subject to the approval of the Engineer.

16.6.4.8 Preparation of Material

The Contractor shall use suitable equipment for breaking down oversize clods and lumps of material ensuring that degradation of the material does not occur. Processing by means of such equipment shall continue until the material so treated has been broken down sufficiently to ensure that after compaction the resulting layer shall have a uniform moisture content throughout and be firm, well-bonded and free from nests of segregated or dry materials. During such processing the layer shall be frequently scarified and bladed to ensure that oversize clods and lumps of material are brought to the surface of the layer.

Where a layer is to join into an adjacent compacted layer the face of the compacted layer shall be cut back to a slope of 1:2 so as to give a fresh fully integrated and well-bonded contact. The surface of the underlying layer shall be scarified as specified in Clause 16.6.4.7 (c) to ensure complete bonding between two layers.

Where a narrow filter zone of processed material has to be placed, mixing of the filter material on the embankment may be dispensed with provided that it has been thoroughly mixed prior to placing and is homogeneous after placing.

The surface of an underlying layer shall always be scarified as specified in Clause 16.6.4.7 (c) to ensure complete bonding between the successive layers.

16.6.4.9 Conditioning of Material

Borrow material for the embankment core and shells shall be conditioned in an area approved by the Engineer.

Any water required before the material is loaded in the borrow pit shall be added to the material in successive applications by means of suitable irrigation equipment capable of applying the water evenly and uniformly over the area concerned. Water required to be added on the embankments shall be applied in successive applications by means of water tankers fitted with sprinkler bars or pressure distributors that will apply the water evenly and uniformly.

The water shall be thoroughly mixed with the material conditioned by means of ploughs, disc harrows, rotary mixers, motor graders or other suitable equipment as approved by the Engineer. Mixing shall continue until the required amount of water has been added and until a uniform mixture is obtained before loading or compaction of the material, as the case may be.

The various materials shall have moisture contents controlled to within the specified range, i.e. OMC +2% to OMC -1% or as determined during the construction of the trial embankment. The

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moisture contents of the materials measured at any time during and immediately after compaction shall not be allowed to vary beyond the limits specified or ordered by the Engineer from time to time for each particular zone.

Should the materials at any time be too wet, due to rain or any other cause, they shall be harrowed and allowed to dry out to within the specified range of moisture contents before being brought onto the embankment.

The Contractor shall provide the necessary staff and equipment for controlling moisture content and for ensuring the specified compaction requirements are being adhered to.

16.6.4.10 Compaction**(a) General**

Different zones or classes of fill consisting of different materials or having different compaction characteristics or requiring different compaction moisture contents shall be placed, prepared and compacted in independent operations, although these may be conducted simultaneously in order to ensure complete integration and bonding of the zones.

The longitudinal and transverse crest cambers shown on the Drawings or finally ordered by the Engineer shall be achieved over a minimum height of 15 millimetres per millimetre of camber by gradually varying the thickness of the top layers in accordance with the instructions of the Engineer.

The Contractor shall allow for settlement of the embankment and its foundation during construction to ensure that the final embankment is, within the tolerances, to the lines and levels shown on the Drawings. This settlement allowance is not included in the longitudinal camber shown on the Drawings and referred to above.

The Contractor shall not add thin veneers of fill to achieve the required finish.

Compaction shall be carried out by means of compaction equipment determined during the construction of the trial embankment, all to the approval of the Engineer, due regard being had to the type of material being compacted. The types of rollers to be used and the amount of rolling to be done shall be such as to ensure that the specified densities are obtained, over the full thickness of layer. Vibratory compaction shall be used to supplement any other compaction for layers more than 200 mm thick. Care shall be exercised when selecting the type of compaction equipment and amount of compaction at the specified moisture content to ensure that it will not promote the formation of slickensides or cause poor bonding between layers.

Special care shall be taken to ensure adequate compaction against concrete, masonry, rock, or any other hard surfaces.

In confined places, such as adjacent to instrumentation chambers, where damage by heavy compacting machinery is likely, compaction shall be carried out by power rammers and/or hand operated vibrating compactors.

All compaction and rolling shall be carried out according to a predetermined pattern in a direction parallel to the centreline of the embankment, the rollers commencing at the sides and proceeding towards the centre of the strip being compacted by half lap stages of the roller wheels or drums. The equipment is to travel at a speed that will give optimum compaction per pass.

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Compaction of each layer shall be conducted as close to the edge as is safe and practicable provided that sufficient overlap is always given when compacting adjacent layers. The outer shell zones shall be overfilled sufficiently to ensure that all the material to the outer edges of the zones is adequately compacted. During compaction the layer shall be maintained to the required shape and cross-section, and all ruts, holes and depressions corrected by means of frequent blading with self-propelled graders. Care shall be exercised that degradation and segregation of the material does not occur.

Any layer that has softened after it has been compacted due to rain or any other cause shall be re-compacted by the Contractor after being re-worked to its full depth, provided that the moisture content falls to within the specified limits.

(b) Specific Compaction Requirements**(i) Zone 1: Selected Earthfill Materials**

The material in this zone shall have a moisture content between the limits specified (or determined during the trial embankment) and shall be compacted to a dry density of nowhere less than 95% of Proctor density. Special care shall be taken to achieve the required densities in areas against concrete, masonry and rock surfaces.

(ii) Zone 2: Unselected Fill Materials

The material for Zone 2 shall have a moisture content between the limits determined during the trial embankment and shall be compacted to a dry density of nowhere less than 95% Proctor density.

(iii) Zone 3: Rockfill for Embankment

When each layer of rockfill material has been placed, the layer shall be compacted by four passes of a vibratory roller. One pass of the roller is defined as "the required number of successive roller one way trips which, by means of sufficient overlay, will ensure complete coverage of the entire surface of the layer by the roller." Second and subsequent passes of the roller shall not be made until each pass, as defined above, is completed.

The vibratory roller shall be a towed or self-propelled as approved by the Engineer and shall have a smooth steel drum with a width not less than 2.5 m, a minimum static weight of 10 tonnes, a minimum dynamic force of 16 tonnes when operating at 1 400 vibrations per minute, and an applied force not less than 13.5 tonnes per m of compaction drum length. Any towed roller shall have at least 90 percent of its weight transmitted to the ground through the compaction drum when the roller is standing in a level position and hitched to the towing vehicle. Rollers shall be operated at speeds not exceeding 2.5 km per hour and shall at all times during compaction be operated between 1 100 and 1 500 vibrations per minute. The Contractor shall furnish to the Engineer adequate data pertaining to the rollers to verify that all the above requirements shall be met and the rollers shall be subject to the approval of the Engineer.

The Engineer may direct a reduction in the number of passes required for compaction. Each pass of the roller shall be offset so that the total compaction effort shall be distributed evenly over the entire area. Special attention shall be given by the Contractor to ensure that no additional passes are permitted over the area. The roller will not be allowed to remain stationary on rockfill with the vibratory mechanism operating.

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The roller shall not be operated within 3 m of retaining walls with the vibratory mechanism operating. The 3 m strips immediately adjacent to retaining walls shall be compacted by placing rockfill materials with 300 mm maximum dimensions in layers not greater than 450 mm thick, and compacting with four passes made with the vibratory mechanism not operating.

(iv) Zone 4: Filters, Drains and Transition Zone Materials

Compaction of the filter sand for the blanket drain only shall be done with one or two passes of a roller with the vibratory compaction turned off.

Filter sand in the chimney drain shall be loosely placed and saturated without compaction.

In constricted areas such as the toe drain, filter sand in relatively thin layers need to follow the geometry of the toe drain excavation closely without being disturbed during placement of the filter stone and slotted pipes. In these instances the filter sand may be placed moist and compacted to the required line, grade and thickness.

(v) Zone 5: Riprap

Riprap shall be placed without compaction in such a manner to ensure a layer of uniform thickness and evenly distributed material.

(vi) Zone 6: Pervious Backfill

Water shall be added as necessary so that the moisture content is uniformly distributed throughout each layer and sufficient to attain the required relative density of the material in place. The pervious backfill shall be compacted by tampers or rollers, treads of crawler-type tractors, surface vibrators, or immersion vibrators so that the relative density of the compacted material is not less than 70 percent of solid density. The thickness of the horizontal layers after compaction shall not be more than 150 mm if compaction is performed by tampers or rollers; not more than 300 mm if compaction is performed by treads of crawler-type tractors, surface vibrators, or similar equipment; and not more than the penetrating depth of the vibrator if compaction is performed by immersion vibrators.

(vii) Zone 7: Rock Backfill

Rock backfill shall be compacted in accordance with Clause 16.6.4.10 (b)(iii).

(viii) Zone 8: Gravel for Downstream Slope Protection

This material shall be placed dry.

(ix) Zone 9: Capping Gravel

Crest gravel shall be compacted to at least 95% Proctor density and to a total layer thickness of at least 200 mm.

(x) Zone 10: Transition Layer / Riprap Bedding

Compaction shall be as indicated on the Drawings or specified elsewhere.

(xi) Topsoil

Topsoil shall be lightly compacted when slightly moist by means of tamping or screed bars.

(xii) Grass Downstream Slope Protection

Where the downstream slope of the embankment is to be grassed, the topsoil shall be mixed into the outer 200 mm (min) of the shell zone, moisture conditioned and compacted with the fill material in that zone.

16.6.4.11 Installation of Instrumentation

The requirements for instrumentation to be placed in the embankments will be indicated on the Drawings. The Contractor shall co-ordinate the required activities with his placing / compaction programme for the embankments.

16.6.4.12 Backfilling around Structures**(a) General**

No backfilling shall be commenced until permission to do so have been given by the Engineer. Embankments shall be constructed simultaneously on both sides of structures to minimize unequal loading.

Where shown on the Drawings or instructed, all trenches and other excavations outside structures shall be carefully refilled and compacted with approved material in layers of thickness not exceeding 250 mm un-compacted.

During the placing of each such layer, the fill material shall be well rolled and compacted, sufficient water being added uniformly to ensure that the density specified for the particular zone is achieved. Each layer shall be completed before the next is added.

In general, fill material shall not be deposited in water but it may be so deposited in exceptional circumstances (such as to facilitate dewatering) with the prior consent of the Engineer.

(b) Restricted Working

Where the use of conventional Plant for compacting adjacent to a structure is not possible, the material to be compacted shall be spread in loose layers of thickness not exceeding 250 mm and compacted by means of mechanical hand tampers to at least the density specified for that particular zone.

16.6.4.13 Finishing**(a) Final Grading**

On completion of earthworks to the finished level and after completion of backfilling of all trenches, the whole surface shall be graded, shaped, and compacted to final grades and levels.

(b) Preparation of surfaces to be lined

The embankment surfaces to be lined shall comply with the following requirements:

- Shall be free of all protrusions, stones, roots, vegetation and other materials which may be detrimental to the performance of the liner. A maximum particle size of 3 mm is required and if the excavated soil is unsuitable, a stabilised sand blinding of at least 75 mm thick should be applied. Alternatively, a non-woven geotextile may be used on the slopes, while sand only on the floors will suffice;
- To prevent the formation of gas under the liner, all vegetation must be removed and a suitable weed killer applied, if necessary. The base of the earthworks or structure must be clean and dry. Should ground-water be present, a suitable drainage system must be provided; and
- Earthworks Tolerances for the excavation and backfilling of embankments shall be in accordance with Table 16/1 with the degree of Accuracy II in Clause 16.7 of this Section.

(c) Gravel Capping

After the final grading has been completed, the Contractor shall place the gravel capping and compact it to a Proctor density of at least 95% and a compacted thickness of at least 300 mm.

(d) Topsoiling

Topsoiling shall be done according to the provisions of Section 47 - Landscaping Rehabilitation.

(e) Grass or other vegetation

Grassing shall be done according to the provisions of Section 47 - Landscaping Rehabilitation.

(f) Pitching of Surfaces

On completion of final grading in terms of Clause 16.6.4.13 (a), designated surfaces shall, where scheduled, be pitched with stone or other materials of the type and in the manner shown on the Drawings.

(g) Gabions

Where shown on the Drawings and as scheduled in the Bill of Quantities, gabions shall be constructed to the details and in the manner specified in Section 21 - Gabions and Reno Mattress Structures.

16.6.4.14 Transport for Earthworks**(a) Freehaul**

All haulage from (or to) a particular designated site to (or from) the embankment in one direction and within 1 km is regarded as freehaul.

(b) Overhaul

Haulage of material beyond the applicable freehaul distance specified in Clause 16.6.4.14 (a) will be regarded as overhaul.

Overhaul distances will be measured to the nearest 0.1 km from the end of the 1.0 km free haul, using the shortest practical route agreed with the Engineer from the point of loading to the point of dumping in one direction only as follows (Distance categories to follow the free haul):

- a) Between 1 km up to and including 3 km
- b) Between 3 km up to and including 5 km
- c) Between 5 km up to and including 7 km
- d) Between 7 km up to and including 9 km
- e) Between 9 km up to and including 11 km
- f) Between 11 km up to and including 13 km

No payment will be made against this item for overhaul of material used for reinstatement of Contractor's working and accommodation areas (including the areas designated for the Engineer's use) and temporary roads.

(c) Long haul

Should any haulage be required exceeding 13 km, such haulage will be regarded as long haul requiring specific approval by the Engineer. The following separate distance category is provided for this:

- Over 13km - measurement unit: m³km.

16.7 TOLERANCES**16.7.1 General**

The degree of accuracy of the finished work and the permissible deviations (PD) shall be within the appropriate limits given in Clause 16.7.2.

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16.7.2 Positions, Levels, Dimensions, and Moisture Content**16.7.2.1 Positions, Levels, and Dimensions**

Subject to the lines of the completed work being satisfactory to the Engineer, the following tolerances in Table 16/1 shall apply to the positions, levels, and dimensions of the finished work, due allowance being made for the expected settlement given on the Drawings.

**TABLE 16/1
DIMENSION TOLERANCES**

ITEM	PD FROM DESIGNATED DIMENSIONS, MM		
	DEGREE OF ACCURACY		
	III	II	I
1) Embankment crest level	*	+ 100, - 0	*
2) Horizontal crest width	*	± 300	*
3) Horizontal width of rockfill and earthfill zones	*	± 300	*
4) Thickness of filter and drainage layers	*	+ 100, - 0	*
5) Thickness of riprap	*	+ 25% of specified thickness, - 0	*
6) Topsoil thickness on downstream face	*	+ 50, - 0	
7) Horizontal position of earthfill zones, filter layers, riprap, and crest	*	± 500	*
8) Gravel capping	*	- 0, no top limit	*

16.7.2.2 Moisture Content

Except where otherwise required in terms of the project specification, the moisture content found in at least 90% of the tests shall be within the limits given in Table 16/2 below:

**TABLE 16/2
MOISTURE CONTENT TOLERANCES**

ITEM	PD FROM PROCTOR OPTIMUM MOISTURE CONTENT, % POINTS		
	DEGREE OF ACCURACY		
	III	II	I
1) Homogeneous fill material	*	± 2	*
2) Core zone	*	+ 3, - 1	*
3) Outer zones	*	+ 1, - 3	*
4) Random fill material	*	+ 2, - 3	*
5) Dispersive soil	*	+3, - 0	*

Should the results of the tests on any particular layer or part of a layer of a compacted fill show that the moisture content is not within the appropriate limits given above, the compacted layer or part of the layer shall be harrowed and wetted or dried, as applicable, and re-compacted, all at the Contractor's expense.

16.8 SUPERVISION, RECORDS AND TESTS

16.8.1 Supervision

All the activities / operations specified in this Section shall at all times be under the direct supervision of a suitably qualified and experienced professional Civil Engineer assisted by other suitably qualified and experienced technical personnel all approved by the Engineer.

16.8.2 Records

A complete record shall be kept of all embankment placing operations, which shall cover the location in the borrow pit or excavations, quality and quantity of material placed, the locations of all materials placed, the moisture condition of the material during placing and compaction, the number of roller passes required on each layer to reach the specified compaction, the lengths, widths and thicknesses of the layers and the results of all tests including details of location.

A daily record shall also be kept of the progress of the work and any other record that the Engineer may from time to time require.

All the above records shall be available at all times during the progress of the work for inspection by the Engineer, and a copy of the preceding day's test records shall be deposited with the Engineer daily.

16.8.3 Exploratory Holes

The Engineer may require the Contractor to drill, auger, or excavate holes in advance of the start of construction to determine founding condition or for other purposes. When so requested by the Engineer, the Contractor shall provide labour, tools, machinery, and equipment for sinking such exploratory holes and for refilling them. The operations specified in this section will be paid for as daywork.

16.8.4 Testing by the Contractor

The Contractor shall agree with the Engineer the number of tests to satisfy himself as to the consistency of materials placed in embankments, around and over pipes, and as backfill to structures. In addition he shall carry out routine compaction control tests to ensure that the specified densities are being attained. Records of the test results and the working sheets shall be kept in a systematic manner and shall be submitted to the Engineer on a regular basis.

The sampling procedures and sizes of samples for tests shall be as agreed by the Engineer for each embankment zone and the Contractor shall allow for performing grading analyses on samples of riprap up to 300 mm in dimension.

All Site testing carried out by the Contractor shall be performed in an approved suitably equipped and staffed laboratory by competent and sufficiently experienced laboratory staff in accordance with the quality control procedures. Off-site testing shall be carried out by a recognised testing institution, an approved laboratory or a firm approved by the Engineer.

All testing described in this Section shall be carried out by the Contractor in accordance with the methods referred to in this Section and to confirm compliance with the specified requirements.

16.8.5 Additional Testing by the Contractor

In addition to the tests specified in SANS 1083 and Clauses 16.8.9 and 16.8.10, the materials shall be sampled and the tests shall be conducted in accordance with the test methods specified in either TMH1 "Standard Methods of Testing Road Construction Materials", the British Standards Institution, the Procedures for Sampling, Classification, and Testing of Soils and Installation of Instruments of the United States Department of the Interior, Bureau of Reclamation as described in the "Earth Manual" as revised or the American Society of Testing Materials (ASTM) as directed by the Engineer.

16.8.6 Continual Testing by the Engineer

Routine in-situ control tests will be carried out by the Engineer at such frequency as he considers necessary for the proper evaluation of the quality of the embankment, etc. (See also Clauses 16.6.4.7(a), 16.6.4.7(g) and Clause 16.9.1.2).

16.8.7 Frequency of Testing

The lot sizes for testing for compliance of filters, drain and transition layer materials and riprap with the requirements of Clause 16.4 shall be twice the lot sizes specified in SANS 1083 for filter, drains and transition layer materials and six times the lot sizes specified in SANS 1083 for riprap except for the riprap grading, which is dealt with hereafter.

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At least one field density test for each 1 000 m² of each layer with a minimum of 3 tests in any one layer or portion thereof shall be carried out.

Moisture content tests in the borrow pits shall be carried out at a rate of at least one test for each 200 m³ of material in the borrow pit and also on the embankments at a rate of at least one check test for each 1 000 m² of each layer with a minimum of 3 tests in any one layer or portion thereof placed at one time.

Density tests on filter, drain and transition layer materials shall be carried out at a rate of not less than three tests per layer or portion thereof placed at one time or one test for every 1 000m² of material placed, whichever is the greater number of tests, as approved by the Engineer.

Field density and moisture content tests are to be carried out immediately after the compaction of the section of the layer is completed and in any event not later than 12 hours after the completion of the section of the layer. If such tests are not carried out by the Contractor within this period then the Engineer may at his discretion pass or fail the layer or section of the layer regardless of any soil test results which may then be provided.

Grading analyses and tests on the compaction and other specified physical properties of the materials obtained from the borrow pits or excavations shall be carried out for each zone and/or type of material at frequencies and in accordance with such instructions as the Engineer may order from time to time. These tests shall, however, be conducted at a frequency of not less than one for every 2 500 m³ of material placed and compacted.

For the filters and drains and the transition layers beneath the riprap at least one grading analysis shall be performed for every 500 m³ of material placed in each zone. For the collector, strip or toe drains at least one sample shall be taken for every 300 m length placed.

Grading analyses on the riprap shall be conducted at a frequency of at least one test for every 5 000 m³ placed for the first 15 000 m³ and thereafter every 20 000 m³.

16.8.8 Material or Compaction Standard not to Specification

Where tests reveal that the material used does not comply with the applicable requirements of the specification, or that the compaction specified has not been attained, the Contractor shall so rectify the work that the material complies with the said requirements and the compaction specified is attained.

Where in the opinion of the Engineer the compacted material too frequently fails to meet the specified requirements, the Contractor shall submit revised proposals for executing and supervising the embankment construction procedures for the approval of the Engineer.

16.8.9 Soundness Test for Riprap and Rockfill

The basic principles for determining the soundness of the selected riprap shall be SANS 5839, adapted as stated below:

- a) Initially the sample shall be broken into an approximately uniform grading and shall be screened. The portion passing the 19.0 mm sieve but retained on the 13.2 mm sieve shall be used in the test;
- b) The test sample shall weigh 1 000 grams +/- 2% and shall be washed as described in SANS 5839;
- c) The procedure specified in Section 3 of SANS 5839 shall be followed for 5 cycles;

- d) The sample shall then be sieved using a 11.2 mm size as defined in Table 3 of SANS 5839; and
- e) The percentage loss shall be determined from the mass of the material retained on the sieve and mass of the original sample.

16.8.10 Grading Tests for Riprap and Rockfill

The grading analyses shall be performed by the Contractor at the Contractor's Site laboratory or such other locality approved by the Engineer.

The samples shall be separated into the size fractions shown on the Drawings using suitable standard square mesh screens or individual sizing squares as appropriate.

The dry mass of the materials shall be determined using appropriate platform and other scales.

To assist with the visual control of the riprap and rockfill grading the Contractor shall make up two samples of riprap / rockfill, each up to 15 tonne in mass to the gradings of the coarse and fine limits of the specified riprap and rockfill grading envelope.

16.8.11 Trial Embankment

The Engineer may order the construction of a trial embankment to test the properties and compaction characteristics of the earthfill material. In such an event the Contractor shall construct the trial embankment in the manner specified for the main embankment. Payment for such work will be made in terms of Item 16.010.

16.8.12 Density

The density of the earthfill shall be measured in accordance with the standard Proctor test (see ASTM D 698).

Should the average Proctor density determined from 10 consecutive routine compaction control tests at random locations in the earthfill fall below the specified density, the Engineer may order that, before further material is placed, the Contractor shall submit a revised compaction procedure for approval by the Engineer.

Should the Engineer consider that any area in the earthfill is not receiving adequate compaction he may require specific tests to be carried out.

Should the Proctor density determined in any specific test be more than 5 percentage points below that required for the layer, the material in the area of work represented by that specific test shall be reworked until it complies with the said requirement or it shall be removed from the embankment, as directed, at the Contractor's expense.

16.9 MEASUREMENT AND PAYMENT

16.9.1 Basic Principles

16.9.1.1 Measurement

The basic principles of measurement of the volume of the earthworks required for the construction of a small dam are as follows:

- a) The quantity will be measured only as fill in the embankment, a separate item being scheduled for each source from which such fill is to be obtained;
- b) Excavations that are necessary for the core trench, footings, spillway, and ancillary works will be measured in the excavation, to lines and levels shown on the Drawings;
- c) Borrow areas will be designated; and
- d) Agreement must be reached on Site as to the proportion of each zone of the embankment that is to come from each source.

The measurement of depths for restricted excavations (Clause 9.2) will be based on the assumption that untrimmed general earthworks or bulk general excavation to finished level, or both, are completed before the restricted excavation is started.

16.9.1.2 Payment

The rates tendered under this Section shall not include for the general obligations, Contractor's Equipment and work deemed to be covered by the items provided in Section 1 – General.

The basic principle of payment for earthworks is that, except in the case of Clause 16.9.1.1 b), the rate shall cover the cost of excavation, haulage, and stockpiling for re-use and the disposal of surplus material within an area designated on the Drawings.

The cost of additional tests carried out by the Contractor will be paid for as daywork provided that, where the results of the tests indicate that the materials or workmanship, or both, do not comply with the applicable requirements of this Section, the cost shall be borne by the Contractor. Where the results of the tests prove compliance with this Section, the cost will be borne by the Employer.

16.9.1.3 Classification of Excavations

Separate items are scheduled for each part of the work covered by Clause 16.9.1.1 b). The material excavated will, where practicable, be regarded as bulk excavation and will be classified in terms of Clause 16.4.2.2, as applicable.

16.9.2 Computation of Quantities

16.9.2.1 General

Subject to the terms of Clause 16.9.2.2, the volume of embankments (see Clause 16.9.1.1 a)) and excavations (see Clause 16.9.1.1 b)) will be calculated from the original levels and the dimensions of the sections, and profiles as shown on the Drawings or instructed. No embankment formed and

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no excavation made outside the specified lines and levels will be included in the measurement unless such extra work has been done on the written instructions of the Engineer.

Volumes of material removed incidentally during Site clearing operations as specified in Clauses 16.6.4.1(a) and 16.6.4.1(b) will be excluded in both embankment and excavation quantities, but the volumes (calculated from the areas and depths) moved in the stripping of the Site in terms of Clause 16.6.4.1(b), after Site clearance or in excavation of stated depths of topsoil will be added to the embankment volume and deducted from the excavation volume, as applicable.

16.9.2.2 Computation of Cross-Sections

The Engineer has prepared cross-sections for the measurement and computation of quantities. Should he wish to check the Engineer's quantities, the Contractor may, at his own expense, take the levels and prepare the cross-sections necessary for the measurement and computation of quantities. The Engineer may conduct such check tests on the Contractor's cross-sections as he considers necessary to confirm their accuracy and adequacy. Failure on the part of the Contractor to submit his own cross-sections to the Engineer before commencing construction will be held to indicate his acceptance of the levels and cross-sections provided by the Engineer for the purpose of measurement and payment of quantities and, in the event of such failure, no subsequent claim in this regard will be considered.

16.9.2.3 Riprap

The volume of riprap will be computed by multiplying the specified controlled thickness (see Clause 16.3.1) by the surface area of the embankment as determined from the levels existing after stripping and excavation of the foundation, and from the slopes given on the Drawings or ordered.

16.9.2.4 Filter and Drainage Layers

The volume of sand and gravel materials imported for use in filter and drainage layers will be computed from the sections, and thickness shown on the Drawings or instructed. Unless extra work has been done on excavation for filter and drainage layers on the written instructions of the Engineer, no payment will be made for extra materials used.

16.9.3 Scheduled Items

16.9.3.1 Site Clearance

16.001 Clear and strip site

Unit: ha or m²

The area measured will be that ordered in writing or shown on the Drawings to be cleared and stripped. Except for the removal and disposal of trees and stumps of girth exceeding 1 m, the rate shall cover the cost of complying with Clause 16.6.4.1(a) and Clause 16.6.4.1(b).

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16.002 Remove and grub large trees (complete with stumps) or stumps only, as scheduled, of girth

- a) **Over 1 m and up to and including 2 m** **Unit: No.**
- b) **Over 2 m and up to and including 3 m** **Unit: No.**
- c) **Over 3 m, in increments of 1 m** **Unit No.**

The girth of a tree or stump will be measured at the narrowest point of the tree or stump in the first metre of its height above ground level. Trees and stumps of girth exceeding 1 m will be measured individually and classified according to size in increments of 1 m as indicated above. The rate shall cover the cost of clearing and grubbing trees and stumps of all sizes, cutting branches, backfilling holes, and removing, transporting, and disposing of all such trees, stumps, and branches and associated material.

16.003 Extra-over 16.001 for removal of rocks, etc. as specified in Clause 16.6.4.1(a) **Unit: m³**

16.004 Extra-over 16.001 for removal and recovering of fencing **Unit: m**

The rate shall cover the cost of complying with Clause 16.6.4.1(a).

16.005 Extra-over 16.001 for recovering other scheduled material **Unit: Sum**

The sum shall cover the cost of complying with Clause 16.6.4.1(a) for the material scheduled.

16.006 Clearing of basin **Unit: Sum or ha**

The area required to be cleaned and cleared in terms of this Section will be measured as shown on the Drawings. The sum or rate, as applicable, shall cover the cost of compliance with Clause 16.6.4.1(c).

16.007 Remove topsoil to nominal depth 150 mm (or other stated depth), stockpile and maintain **Unit: m² or m³**

The rate shall cover the cost of removal of topsoil to a nominal depth of 150 mm (or other stated depth), stockpiling, and preventing dust nuisance. Where removal to greater depths is ordered, the area measured for payment will, unless otherwise scheduled, be increased pro rata to the average increase in depth.

16.008 Excavation**a) Material unsuitable for embankment****Unit: m³**

The rate shall cover the cost of excavation in all materials for excavations in the dam basins and removal to designated spoil dumps and including spreading and trimming.

b) Material suitable for embankment from essential excavations for:**1) Core trench****Unit: m³****2) Spillway****Unit: m³****3) Pipe trenches****Unit: m³****4) Outlet works****Unit: m³****5) Other (as specified in BOQ)****Unit: m³**

The rate shall cover the cost of excavation of the hole in all materials (see Clause 16.4.2.2) and, except as covered by Item 16.009, trimming it ready for further construction activity.

For excavation to stockpile, the rate shall also cover the cost of loading, hauling, offloading, stockpiling and maintenance of the stockpile (dust prevention, shaping to provide proper drainage and to prevent the forming of water pools, etc.).

c) Extra-over items (b) (1)-(4) for excavation in:**Hard rock material****Unit: m³**

The rate shall cover the extra cost of excavating in the applicable harder material.

16.009 Preparation of exposed surfaces**a) Core trench****Unit: m²****b) Area to be covered by dam wall****Unit: m²**

The plan area of the core trench at original ground level as shown on the Drawings will be measured for payment under (a) above. The rates for (a) and (b) above shall cover the cost of complying with Clause 16.6.4.2.

c) Cleaning of seams and crevices**Unit: cubic metre (m³)**

Cleaning of seams and crevices shall be measured as the volume of the voids created below the excavation surface shown on the Drawings and shall include for the removal to spoil of all unsuitable material in the seams and crevices and cleaning with air / water jets.

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d) Cement grout **Unit: cubic metre (m³)**

The rate shall include for the supply, mixing of cement and water in the specified proportions and application.

e) Cement mortar **Unit: cubic metre (m³)**

The rate shall include for the supply, mixing of cement, sand and water in the specified proportions and rodding into position.

f) Concrete filling **Unit: cubic metre (m³)**

The rate shall include for all materials, placing and compaction into position. Distinction shall be made between different classes of concrete.

g) Slush grouting **Unit: square metre (m²)**

The rate shall include for all materials, mixing and application to the areas as ordered by the Engineer.

16.010 Forming embankment (see Annexure 16/1)**a) Selected impervious material** **Unit: m³****b) Unselected pervious material** **Unit: m³****c) Riprap material** **Unit: m³****d) Topsoil from stockpile to downstream slope** **Unit: m³****e) Coarse filter material** **Unit: m³****f) Fine filter material** **Unit: m³****g) Gravel capping** **Unit: m³****h) Other (as specified in BOQ)** **Unit: m³**

The rates for (a)-(h) above shall cover the cost of selecting and taking delivery and loading of material excavated under Item 16.008 (b), or of excavating, selecting and loading material from borrow pits in the designated borrow area(s), or of selecting and loading the material at stockpiles. In all cases the rates shall also include for haulage, spreading, adding water or drying, compacting and grading in the relevant zones or parts of the embankment, including the cost of temporary stockpiling to suit the Contractor's work methods or material processing, or both, where necessary, and final grading in terms of Clause 16.6.4.2(c) of borrow pits that are in the dam basin.

16.011 Toe drain, complete construction **Unit: m**

The rate shall cover the cost of the excavation, supply of all materials at the drain, and the complete construction of the toe drain to the details given on the Drawings.

16.012 Extra-over 16.010 for forming trial embankments (provisional) **Unit: Sum or m³**

The sum shall cover the cost of delays to and disruption of the Works, the additional cost of handling small quantities and the cost of forming a trial embankment as specified in Clause 16.8.11. The volumes of material moved will be added to those measured under Item 16.010.

16.013 Overhaul **Unit: Cubic Metre (m³)**

Overhaul distances will be measured to the nearest 0.1 km from the end of the 1.0 km free haul, using the shortest practical route agreed with the Engineer from the point of loading to the point of dumping in one direction only as follows (Distance categories to follow the free haul):

- a) Between 1 km up to and including 3 km
- b) Between 3 km up to and including 5 km
- c) Between 5 km up to and including 7 km
- d) Between 7 km up to and including 9 km
- e) Between 9 km up to and including 11 km
- f) Between 11 km up to and including 13 km
- g) Over 13 km (Long haul Unit: m³km)

The rate tendered shall include full compensation for all costs associated with loading, transporting and tipping of material applicable to the greater distance in a distance category over and above the free haul distance, including equipment, materials, fuel and personnel.

16.014 Prepare surface areas to be lined (Embankment floor) **Unit: m²**

The rate shall cover all cost associated with the compaction, grading, shaping, raking and levelling and testing of the surfaces to be lined on the floor of the embankment reservoir.

16.015 Prepare surface areas to be lined (Embankment slopes) **Unit: m²**

The rate shall cover all cost associated with the compaction, grading, shaping, raking and levelling and testing of the surfaces to be lined on the slopes of the embankment reservoir.

16.016 Topsoiling

Refer to the provisions of Section 47 – Landscaping and Rehabilitation.

16.017 Pitching / Gabions

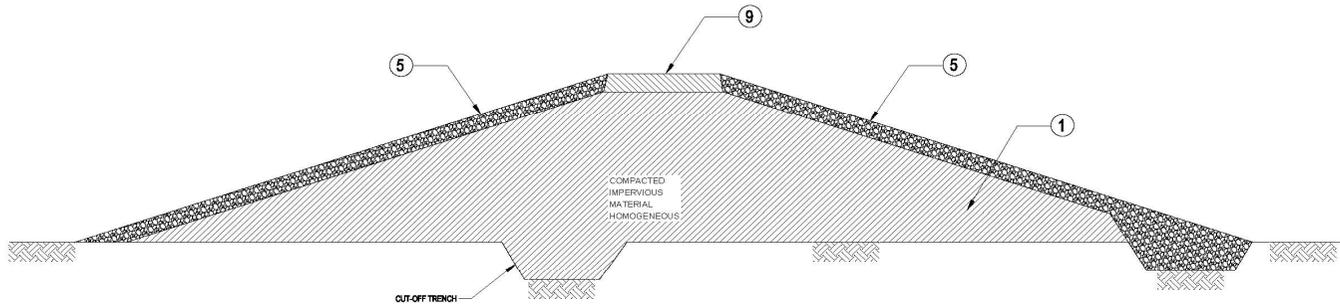
If required, see Section 21 - Gabions and Reno Mattress Structures.

16.018 Supply of materials from commercial sources**Unit: m³**

- a) 13 mm Aggregate.

ANNEXURE 16/1
TYPICAL DAM CROSS SECTIONS SHOWING EMBANKMENT ZONES

PART C3.1 - SPECIFICATION



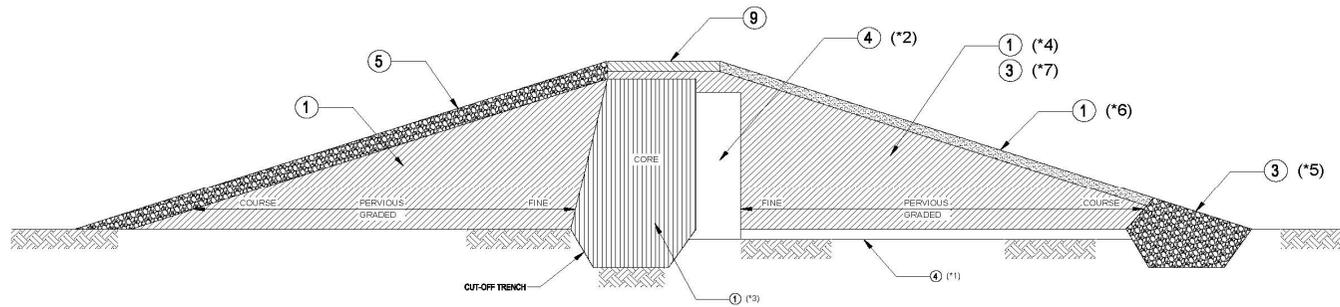
TYPE A CROSS SECTION

NOTES:

1. HORIZONTAL DRAIN.
2. VERTICAL DRAIN.
3. CORE / SELECTED EARTH FILL (IMPERVIOUS).
4. SELECTED EARTH FILL (PERVIOUS / SEMI-PERVIOUS).
5. ROCKFILL TOE.
6. TOP SOIL ON DOWNSTREAM SLOPE.
7. ROCKFILL.

DAM ZONE DESCRIPTIONS

ZONE	MATERIAL
①	SELECTED EARTH FILL.
②	UNSELECTED FILL MATERIAL.
③	ROCK FILL.
④	FILTER, DRAIN AND TRANSITION ZONE.
⑤	RIPRAP.
⑥	PERVIOUS BACKFILL.
⑦	ROCK BACKFILL.
⑧ + ⑨	GRAVEL.
⑩	TRANSITION LAYER / RIPRAP BEDDING.



TYPE B CROSS-SECTION SHOWING

TYPICAL DAM CROSS SECTIONS SHOWING EMBANKMENT ZONES