2.4 CONTRACTOR

Responsibilities

In this CQA Plan, Contractor refers to an independent party or parties, contracted by the Owner, performing the work in general accordance with this CQA Plan, the Drawings, and the Technical Specifications. The Contractor will be responsible for the installation of the soils, pipe, drainage aggregate, and geosynthetic components of the liner systems. This work will include subgrade preparation, anchor trench excavation and backfill, placement of drainage aggregate for the slurry drain system, installation of piping, placement of cast-in-place concrete, and coordination of work with the Geosynthetic Installer and other subcontractors.

The Contractor will be responsible for constructing the barrier system and appurtenant components in general accordance with the *Drawings* and complying with the quality control requirements specified in the *Technical Specifications*.

Qualifications

Qualifications of the Contractor are specific to the construction contract. The Contractor should have a demonstrated history of successful earthworks, piping, and liner system construction and shall maintain current state and federal licenses as appropriate.

2.5 RESIN SUPPLIER

Responsibilities

The Resin Supplier produces and delivers the resin to the Geosynthetics Manufacturer.

Qualifications

Qualifications of the Resin Supplier are specific to the Manufacturer's requirements. The Resin Supplier will have a demonstrated history of providing resin with consistent properties.

2.6 MANUFACTURERS

Responsibilities

The Manufacturers are responsible for the production of finished material (geomembrane, geotextile, and pipe) from appropriate raw materials.

Qualifications

The Manufacturer(s) will be able to provide sufficient production capacity and qualified personnel to meet the demands of the project. The Manufacturer(s) must be a well-established firm(s) that meets the requirements identified in the Technical Specifications.

2.7 GEOSYNTHETIC INSTALLER/LINING CONCRACTOR

Responsibilities

The Geosynthetic Installer/Lining Contractor is responsible for field handling, storage, placement, seaming, ballasting or anchoring against wind uplift, and other aspects of the geosynthetic material installation. The Geosynthetic Installer/Lining Contractor may also be responsible for specialized construction tasks (i.e., including construction of anchor trenches for the geosynthetic materials).

If required, the Geosynthetic Installer/Lining Contractor shall conduct tests to confirm that the geomembrane liner offered is resistant for the duration of the guarantee period to the effects of the liquids intended for storage. The Engineer may, at his discretion, request that immersion tests be undertaken for a period of 28 days minimum for the proposed lining in a liquid sample provided by the client. These samples will be tested for changes in physical and mechanical properties and compared with those immersed in water over the same period of time.

Qualifications

The Geosynthetic Installer/Lining Contractor will be trained and qualified to install the geosynthetic materials of the type specified for this project. The Geosynthetic Installer/Lining Contractor shall meet the qualification requirements identified in the Technical Specifications.

2.8 CQA CONSULTANT

Responsibilities

The CQA Consultant is a party, independent from the Owner, Contractor, Manufacturer, and Geosynthetic Installer, who is responsible for observing, testing, and documenting activities related to the CQC and CQA of the earthwork, piping, and geosynthetic components used in the construction of the Project as required by this CQA Plan and the Technical Specifications. The CQA Consultant will also be responsible for issuing a CQA report at the completion of the Project construction, which documents construction and associated CQA activities. The CQA report will be signed and sealed by the CQA Officer who will be a Professional Engineer.

Qualifications

The CQA Consultant shall be a well-established firm specializing in geotechnical and geosynthetic engineering that possess the equipment, personnel, and licenses necessary to conduct the geotechnical and geosynthetic tests required by the project plans and Technical Specifications. The CQA Consultant will provide qualified staff for the project, as necessary, which will include, at a minimum, a CQA Officer and a CQA Site Manager. The CQA Officer will be a professionally registered engineer.

The CQA Consultant will be experienced with earthwork and installation of geosynthetic materials similar to those materials used in construction of the Project. The CQA Consultant will be experienced in the preparation of CQA documentation including CQA Plans, field documentation, field testing procedures, laboratory testing procedures, construction specifications, construction Drawings, and CQA reports.

The CQA Site Manager will be specifically familiar with the construction of earthworks, piping, and geosynthetic lining systems. The CQA Manager will be trained by the CQA Consultant in the duties as CQA Site Manager.

2.9 CQA LABORATORY

Responsibilities

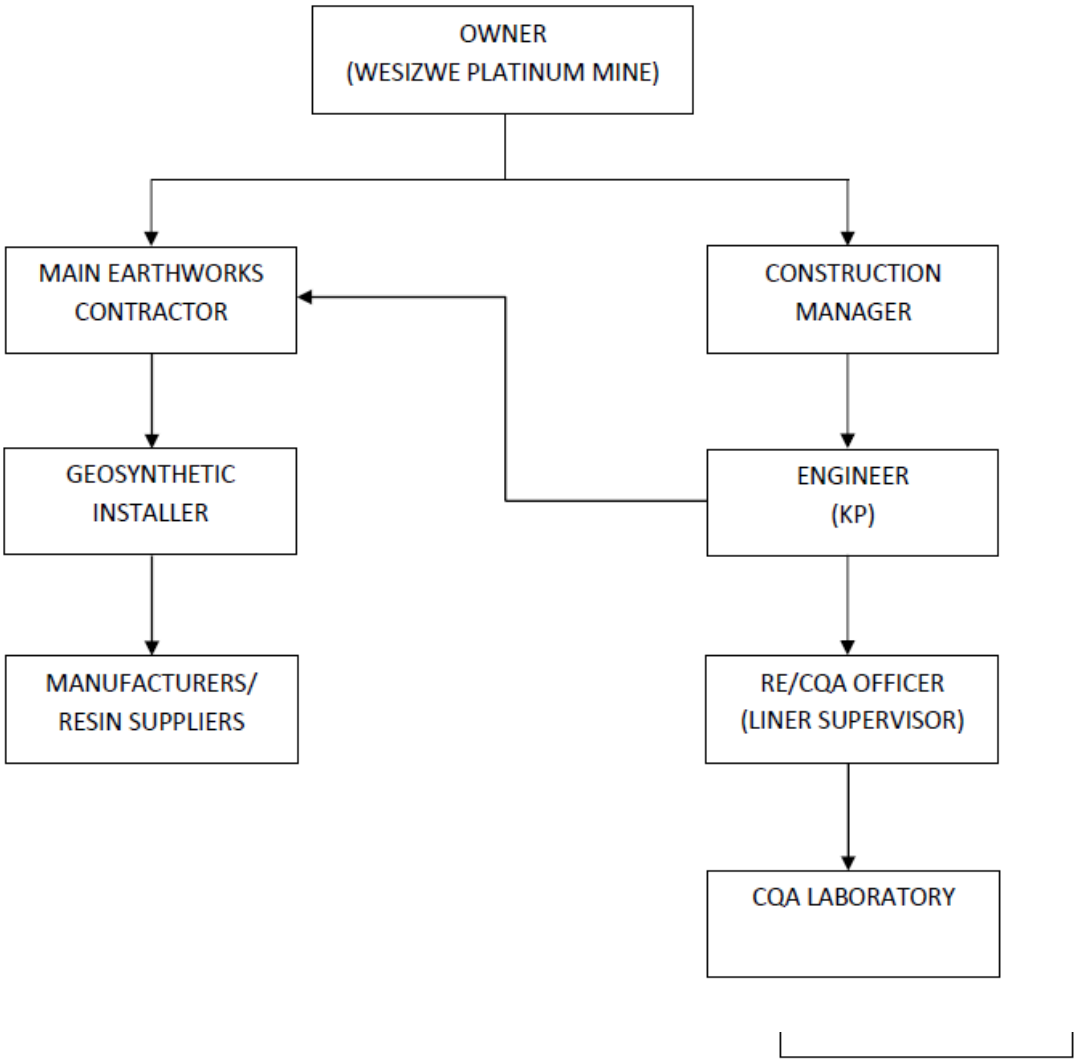
The CQA Laboratory is a party, independent from the Contractor, Manufacturer, Geosynthetic Installer, that is responsible for conducting tests in general accordance with ASTM and other applicable test standards on samples of geosynthetic materials, soil, and in the field and in either an on-site or off-site laboratory.

Qualifications

The CQA Laboratory will have experience in testing soils and geosynthetic materials and will be familiar with ASTM and other applicable test standards. The CQA Laboratory will be capable of providing test results within a maximum of seven days of receipt of samples and will maintain that capability throughout the duration of earthworks construction and geosynthetic materials installation. The CQA Laboratory will also be capable of transmitting geosynthetic destructive test results within 24 hours of receipt of samples and will maintain that capability throughout the duration of geosynthetic material installation.

2.10 LINES OF COMMUNICATION

The following organization chart indicates the lines of communication and authority related to this project.



2.11 DEFECT IDENTIFICATION AND RECTIFICATION

If a defect is discovered in the work, the CQA Engineer will evaluate the extent and nature of the defect. If the defect is indicated by an unsatisfactory test result, the CQA Engineer will determine the extent of the defect area by additional tests, observations, a review of records, or other means that the CQA Engineer deems appropriate.

After evaluating the extent and nature of a defect, the CQA Engineer will notify the Construction Manager and schedule appropriate re-tests when the work defect is corrected by the Contractor.

The Contractor will correct the defect to the satisfaction of the CQA Engineer. If a project specification criterion cannot be met, or unusual weather conditions hinder work, then the CQA Engineer will develop and present to the Design Engineer suggested solutions for approval.

Defect corrections will be monitored and documented by CQA personnel prior to subsequent work by the Contractor within the area of the defect.

3. CQA CONSULTANTS PERSONNEL ORGANIZATION AND DUTIES

The CQA Officer will provide supervision within the scope of work of the CQA Consultant. The scope of work for the CQA Consultant includes monitoring of construction activities including the following:

- subgrade preparation;
- construction of compacted clay liner;
- installation of geomembrane;
- installation of drainage aggregate;
- installation of piping; and
- installation of geotextile.

Duties of CQA personnel are discussed in the remainder of this section.

3.1 CQA PERSONNEL

The CQA Consultant's personnel will include:

- the CQA Officer, who works from the office of the CQA Consultant and who conducts periodic visits to the site as required; and
- the CQA Site Manager, who is located at the site.

3.2 CQA OFFICER

The CQA Officer shall supervise and be responsible for monitoring CQA activities relating to the construction of the earthworks, piping, and installation of the geosynthetic materials of the Project.

Specifically, the CQA Officer:

- reviews the project design, this CQA Plan, Drawings, and Technical Specifications;
- reviews other site-specific documentation; unless otherwise agreed, such reviews are for familiarization and for evaluation of constructability only, and hence the CQA Officer and the CQA Consultant assume no responsibility for the liner system design;
- reviews and approves the Geosynthetic Installer's Quality Control (QC) Plan;
- attends Pre-Construction Meetings as needed;
- administers the CQA program (i.e., provides supervision of and manages on-site CQA personnel, reviews field reports, and provides engineering review of CQA related activities);
- provides quality control of CQA documentation and conducts site visits;
- reviews the Record Drawings; and
- with the CQA Site Manager, prepares the CQA report documenting that the project was constructed in general accordance with the Construction Documents.

3.3 CQA SITE MANAGER

The CQA Site Manager:

- acts as the on-site representative of the CQA Consultant;
- attends CQA-related meetings (e.g., pre-construction, daily, weekly (or designates a representative to attend the meeting);
- oversees the ongoing preparation of the *Record Drawings*;
- reviews test results provided by Contractor;
- assigns locations for testing and sampling;
- oversees the collection and shipping of laboratory test samples;
- reviews results of laboratory testing and makes appropriate recommendations;

- reviews the calibration and condition of on-site CQA equipment;
- prepares a daily summary report for the project;
- reviews the MQC documentation;
- reviews the Geosynthetic Installer's personnel Qualifications for conformance with those pre-approved for work on site;
- notes on-site activities in daily field reports and reports to the CQA Officer and Construction Manager;
- reports unresolved deviations from the CQA Plan, *Drawings*, and *Technical Specifications* to the Construction Manager; and
- assists with the preparation of the CQA report.

4. SITE AND PROJECT CONTROL

4.1 PROJECT COORDINATION MEETINGS

Meetings of key project personnel are necessary to assure a high degree of quality during construction and to promote clear, open channels of communication. Therefore, Project Coordination Meetings are an essential element in the success of the project. Several types of Project Coordination Meetings are described below, including:

(i) pre-construction meetings;
(ii) progress meetings; and
(iii) problem or work defect meetings.

4.1.1 Pre-Construction Meeting

Pre-Construction Meeting will be held at the site prior to construction of the Project. At a minimum, the Pre-Construction Meeting will be attended by the Contractor, the Geosynthetic Installer's Superintendent, the CQA Consultant, and the Construction Manager.

Specific items for discussion at the Pre-Construction Meeting include the following:

- appropriate modifications or clarifications to the CQA Plan;
- the *Drawings* and *Technical Specifications*;

- the responsibilities of each party;
- lines of authority and communication;
- methods for documenting and reporting, and for distributing documents and reports;
- acceptance and rejection criteria;
- protocols for testing;
- protocols for handling defects, repairs, and re-testing;
- the time schedule for all operations;
- procedures for packaging and storing archive samples;
- panel layout and numbering systems for panels and seams;
- seaming procedures;
- repair procedures; and
- soil stockpiling locations.

The Construction Manager will conduct a site tour to observe the current site conditions and to review construction material and equipment storage locations. A person in attendance at the meeting will be appointed by the Construction Manager to record the discussions and decisions of the meeting in the form of meeting minutes. Copies of the meeting minutes will be distributed to all attendees.

4.1.2 Progress Meetings

Progress meetings will be held between the CQA Site Manager, the Contractor, Construction Manager, and other concerned parties participating in the construction of the project. This meeting will include discussions on the current progress of the project, planned activities for the next week, and revisions to the work plan and/or schedule. The meeting will be documented in meeting minutes prepared by a person designated by the CQA Site Manager at the beginning of the meeting. Within 2 working days of the meeting, draft minutes will be transmitted to representatives of parties in attendance for review and comment. Corrections and/or comments to the draft minutes shall be made within 2 working days of receipt of the draft minutes to be incorporated in the final meeting minutes.

4.1.3 Problem or Work Defect Meeting

A special meeting will be held when and if a problem or defect is present or likely to occur. The meeting will be attended by the Contractor, the Construction Manager, the CQA Site Manager, and other parties as appropriate. If the problem requires a design modification, the Engineer should either be present at, consulted prior to, or notified immediately upon conclusion of this meeting. The purpose of the work defect meeting is to define and resolve the problem or work defect as follows:

- define and discuss the problem or defect;
- review alternative solutions;
- select a suitable solution agreeable to all parties; and
- implement an action plan to resolve the problem or defect.

The Construction Manager will appoint one attendee to record the discussions and decisions of the meeting. The meeting record will be documented in the form of meeting minutes and copies will be distributed to all affected parties. A copy of the minutes will be retained in facility records.

5. DOCUMENTATION

5.1 OVERVIEW

An effective CQA Plan depends largely on recognition of all construction activities that should be monitored and on assigning responsibilities for the monitoring of each activity. This is most effectively accomplished and verified by the documentation of quality assurance activities. The CQA Consultant will document those quality assurance requirements which have been addressed and satisfied.

The CQA Site Manager will provide the Construction Manager with signed descriptive remarks, data sheets, and logs to verify that monitoring activities have been carried out. The CQA Site Manager will also maintain, at the job site, a complete file of *Drawings* and *Technical Specifications*, a CQA Plan, checklists, test procedures, daily logs, and other pertinent documents.

5.2 DAILY RECORDKEEPING

Preparation of daily CQA documentation will consist of daily field reports prepared by the CQA Site Manager which may include CQA monitoring logs and testing data sheets. This information may be regularly submitted to and reviewed by the Construction Manager. Daily field reports will include documentation of the observed activities during each day of activity. The daily field reports may include monitoring logs and testing data sheets. At a minimum, these logs and data sheets will include the following information:

- the date, project name, location, and other identification;
- a summary of the weather conditions;
- a summary of locations where construction is occurring;
- equipment and personnel on the project;
- a summary of meetings held and attendees;
- a description of materials used and references of results of testing and documentation;
- identification of defective work and materials;
- results of re-testing corrected “defective work;”
- an identifying sheet number for cross referencing and document control;
- descriptions and locations of construction monitored;
- type of construction and monitoring performed;
- description of construction procedures and procedures used to evaluate construction;
- a summary of test data and results;
- calibrations or re-calibrations of test equipment and actions taken as a result of re-calibration;
- decisions made regarding acceptance of units of work and/or corrective actions to be taken in instances of substandard testing results;
- a discussion of agreements made between the interested parties which may affect the work; and
- signature of the respective CQA Site Manager.

5.3 CONSTRUCTION PROBLEMS AND RESOLUTION DATA SHEETS

Construction Problems and Resolution Data Sheets, to be submitted with the daily field reports prepared by the CQA Site Manager, describing special construction situations, will be cross-referenced with daily field reports, specific observation logs, and testing data sheets and will include the following information, where available:

- an identifying sheet number for cross-referencing and document control;
- a detailed description of the situation or defect;
- the location and probable cause of the situation or defect; how and when the situation or defect was found or located;
- documentation of the response to the situation or defect;
- final results of responses;
- measures taken to prevent a similar situation from occurring in the future; and
- signature of the CQA Site Manager and a signature indicating concurrence by the Construction Manager.

The Construction Manager will be made aware of significant recurring nonconformance with the Drawings, Technical Specifications, or CQA Plan. The cause of the nonconformance will be determined and appropriate changes in procedures or specifications will be recommended. These changes will be submitted to the Construction Manager for approval. When this type of evaluation is made, the results will be documented and any revision to procedures or specifications will be approved by the Contractor and Engineer.

A summary of supporting data sheets, along with final testing results and the CQA Site Manager's approval of the work, will be required upon completion of construction.

5.4 PHOTOGRAPHIC DOCUMENTATION

Photographs will be taken and documented in order to serve as a pictorial record of work progress, problems, and mitigation activities. These records will be presented to the Construction Manager upon completion of the project. Photographic reporting data sheets, where used, will be cross-referenced with observation and testing data sheet(s), and/or construction problem and solution data sheet(s).

5.5 DESIGN AND/OR SPECIFICATIONS CHANGES

Design and/or specifications changes may be required during construction. In such cases, the CQA Site Manager will notify the Engineer. Design and/or specification changes will be made with the written agreement of the Engineer and will take the form of an addendum to the *Drawings* and *Technical Specifications*.

5.6 CQA REPORT

At the completion of the Project, the CQA Consultant will submit to the Owner a CQA report signed and sealed by the Professional Engineer. The CQA report will acknowledge: (i) that the work has been performed in compliance with the *Drawings* and *Technical Specifications*; (ii) physical sampling and testing has been conducted at the appropriate frequencies; and (iii) that the summary document provides the necessary supporting information. At a minimum, this report will include:

- MQC documentation;
- a summary report describing the CQA activities and indicating compliance with the *Drawings* and *Technical Specifications* which is signed and sealed by the CQA Officer;
- a summary of CQA/CQC testing, including failures, corrective measures, and retest results;
- Contractor and Installer personnel resumes and qualifications as necessary;
- documentation that the geomembrane trial seams were performed in general accordance with the CQA Plan and *Technical Specifications*;
- documentation that non-destructive tests were carried out on field seams using a method in general accordance with the applicable test standards;
- documentation that non-destructive testing was monitored by the CQA Consultant, that the CQA Consultant informed the Geosynthetic Installer of any required repairs, and that the CQA Consultant monitored the seaming and patching operations for uniformity and completeness;
- records of sample locations, the name of the individual conducting the tests, and the results of tests;
- *Record Drawings* as provided by the Surveyor;

- daily field reports.

The *Record Drawings* will include scale drawings depicting the location of the construction and details pertaining to the extent of construction (e.g., plan dimensions and appropriate elevations). *Record Drawings* and required base maps will be prepared by a qualified Professional Land Surveyor. These documents will be reviewed by the CQA Consultant and included as part of the CQA Report.

6. EARTHWORK

6.1 INTRODUCTION

This section prescribes the CQA activities to be performed to monitor that prepared subgrade is constructed in general accordance with *Drawings* and *Technical Specifications*. The prepared subgrade construction procedures to be monitored by the CQA Consultant, if required, shall include:

- vegetation removal;
- subgrade preparation;
- fine-grading; and
- anchor trench excavation and backfill.

6.2 GENERAL SETTING OUT

The Contractor shall be responsible for maintaining accurately ascertained site datum levels at his own expense. He shall further ensure that all level control and setting out of the works is executed in accordance with the survey data given on the construction drawings.

Immediately following the issue of the order to commence, the Contractor shall, at his own expense, carry out and record a check level grid of the site of works, in order to accept the contour levels shown on these drawings. Any discrepancies causing non-acceptance by the Contractor of the levels shown on the drawings are to be pointed out to the Engineer within two weeks of the above order being given, and the alterations checked and agreed with the Engineer. Failing this, the original levels as shown on the construction drawings will be deemed

correct and acceptable. In addition to the above, the following survey tasks shall be undertaken by the Contractor for agreement with the Engineer.

- ground levels shall be recorded at 10 m intervals on the centre line, upstream and downstream toe positions of all embankments and fills after site clearance and again after removal of unsuitable material where present. In the case of large embankments or fills the Engineer may specify that the intensity of recorded levels be increased to that of a 5 m grid.
- ground levels shall be recorded at 2.5 m and 5.0 m intervals on the entire line left and right bank positions of all trenches, canals and drains prior to excavation and again on completion of the excavation to the required depths and grades.
- ground levels shall be recorded on a 10 m grid over discard borrow areas. After removal of unsuitable material and/or topsoil and/or fill material as required, the Contractor shall re- survey the ground and record levels as described above. The grids and lines before and after soil removal shall be coincident in plan.

The Contractor shall allow for these levelling operations in the Preliminary and General section of the Bill of Quantities. No separate payment will be made for these surveying operations. The agreed survey data shall be the basis of all earthworks measurement.

All survey submitted by the Contractor is to be approved in writing by the Engineer before being considered valid as a basis of measurement.

The Contractor is to inform the Engineer in writing upon the completion of impoundment walls and trenches to design elevations and cross-sections. Thereafter, a check may be carried out by the Engineer's Representative to verify these elevations and cross-sections.

The cost of this check survey will be paid for by the Employer under the Preliminary and General only if the results of the survey show that the design levels and cross-sections have been achieved. The Contractor shall pay for the costs of the check survey where the results show that the design levels and cross-sections have not been achieved.

Any further costs involved to check if the required design levels and cross-sections have been obtained after the corrective measures have been applied shall be borne by the Contractor.

6.3 CQA MONITORING ACTIVITIES

6.3.1 Vegetation Removal

The CQA Site Manager will monitor and document that vegetation is sufficiently cleared and grubbed in areas where geosynthetics are to be placed. Vegetation removal shall be performed as described in the *Technical* Specification and the *Drawings*.

6.3.2 Grading

Construction of the barrier system will require minor re-grading in certain areas. The CQA Site Manager shall monitor and document that site re-grading performed meets the requirements of the *Technical Specifications* and the *Drawings*. At a minimum, the CQA Site Manager shall monitor that:

- the subgrade surface is free of sharp rocks, debris, and other undesirable materials;
- the subgrade surface is smooth and uniform by visually monitoring proof rolling activities; and
- the subgrade surface meets the lines and grades shown on the *Drawings*.

6.3.3 Classes of excavation

SANS 1200, Sub Clause 3.1.2 to be replaced with the following:

All excavation quantities throughout in all classes of material will be the measured nett. Excavations shall be measured per cubic metre and divided into the following classes: (Note: Excavations shall only be paid in one of the classes of material, i.e. no extra over).

Material Class "A"

This classification shall include all kinds of ground encountered except those defined in Class "B" hereinafter and shall include made-up ground pavings, rubbish, gravel, sand, silt, hard ouklip and calcareous material, clay, soft rock, ground interspersed with small boulders of rock not exceeding 0,5 m^3 (one half of a cubic metre), dumped waste rock material in compacted embankments and all other materials which can, in the opinion of the Engineer, be excavated by hand or by machine without drilling and blasting.

Material Class "B"

In the case of canal, trench and small excavation, this classification shall mean granite, quartz, dolomite etc, or rock of similar hardness which in the opinion of the Engineer or his representative, can only be removed by drilling and blasting. Solid boulders in excess of 0.5 m^3 (one half of a cubic metre) will be classified in this category. This classification shall apply whether or not blasting is authorised.

In the case of bulk excavation this classification shall mean granite, quartz, dolomite etc or rock of similar hardness found in its original position which cannot be loosened by a bulldozer having a minimum fly wheel power of 130 kW and operating weight of 23,000 kg (e.g. a Caterpillar D7, Komatsu D85 or equivalent in good condition, fitted with an approved single tine ripper and driven by a competent operator). This classification shall apply whether or not blasting is authorised.

One rate has been allowed in the Schedule of Rates for Class "B" material to cover all types and depths of excavation work. Spoiling of Class "B" material shall be as for Class "A" material. The excavation rate for Class "B" shall therefore include any extra required for spoiling the rock.

Note: If the Contractor considers that any material to be excavated is classified as Class "B" above, he shall submit a written request to the Engineer or his representative for his ruling. Failing such a request, the excavations shall be deemed to be in Class "A". The decision of the Engineer as to the classification of the material shall be final and binding.

6.3.4 Materials suitable for replacing over-break in excavation for foundations (SANS 12OOD, sub-clause 3.2.2)

Backfilling to over-excavation below the required levels or depths necessary to obtain a suitable bottom is to be carried out to the instructions and satisfaction of the Engineer and entirely at the Contractor's expense as follows:

- Where the material excavated is not required for structural support, the over-excavation will be filled with selected material, free from stones in 200 mm layers and compacted to a density not less than that of the surrounding undisturbed material.

- Where the material excavated is required for structural support, the over-excavation shall be backfilled with 20 Mega Pascal (MPa) concrete, (or concrete of other strength to be specified by the Engineer) including all necessary work etc, to prevent its inclusion with the structural concrete.

6.3.5 Anchor Trench Construction

During construction, the CQA Site Manager will monitor that the anchor trench excavation and backfill methods are consistent with the requirements specified in the *Technical Specifications* and the *Drawings*. The CQA Site Manager will monitor, at a minimum, that:

- the anchor trench is free of sharp rocks, debris and other undesirable materials and that particles are no larger than 150 mm in longest dimension;
- the anchor trench is constructed to the lines and grades shown on the *Drawings*; and
- compaction requirements are met, through visual observations, as specified in the *Technical Specifications.*

6.4 DEFECTS

If a defect is discovered in the earthwork product, the CQA Site Manager will immediately determine the extent and nature of the defect. If the defect is indicated by an unsatisfactory test result, the CQA Site Manager will determine the extent of the defective area by additional tests, observations, a review of records, or other means that the CQA Site Manager deems appropriate. If the defect is related to adverse site conditions, such as overly wet soils or non-conforming particle sizes, the CQA Site Manager will define the limits and nature of the defect.

Should any ground or any of the excavations collapse, other than that required to be excavated owing to the omission or inefficiency of planking and strutting or any other cause, it must be dug out, and made good.

These remedial measures will be carried out to the satisfaction of the Engineer at the Contractor's expense.

6.4.1 Notification

After evaluating the extent and nature of a defect, the CQA Site Manager will notify the Construction Manager and Contractor and schedule appropriate re-evaluation when the work defect is to be corrected.

6.4.2 Repairs and Re-Testing

The Contractor will correct defects to the satisfaction of the CQA Site Manager. If a project specification criterion cannot be met, or unusual weather conditions hinder work, then the CQA Site Manager will develop and present to the Construction Manager suggested solutions for his approval.

Re-evaluations by the CQA Site Manager shall continue until it is verified that defects have been corrected before any additional work is performed by the Contractor in the area of the defects.

7. DRAINAGE AGGREGATE

7.1 INTRODUCTION

This section prescribes the CQA activities to be performed to monitor that drainage aggregates are constructed in general accordance with *Drawings* and *Technical Specifications*. The drainage aggregates construction procedures to be monitored by the CQA Consultant include drainage aggregate placement.

7.2 TESTING ACTIVITIES

Aggregate testing will be performed for material qualification and material conformance. These two stages of testing are defined as follows:

- Material qualification tests are used to evaluate the conformance of a proposed aggregate source with the *Technical Specifications* for qualification of the source prior to construction.
- Aggregate conformance testing is used to evaluate the conformance of a particular batch of aggregate from a qualified source to the *Technical Specifications* prior to installation of the aggregate.

The Contractor will be responsible for submitting material qualification test results to the Construction Manager and to the CQA Site Manager for review. The CQA Laboratory will perform the conformance testing and CQC testing. Aggregate testing will be conducted in general accordance with the current versions of the corresponding American Society for Testing and Materials (ASTM) test procedures. The test methods indicated in Table 1 are those that will be used for this testing unless the test methods are updated or revised prior to construction. Revisions to the test methods will be reviewed and approved by the Engineer and the CQA Site Manager prior to their usage.

7.2.1 Compaction Control

The Contractor shall provide an adequate site laboratory, equipment, facilities and personnel for carrying out the required compaction tests. Should the Engineer at any time consider any of the above to be inadequate for this purpose, he shall instruct the Contractor to cease further work on compaction until such time as the Contractor has remedied the deficiency.

The onus shall be on the Contractor to ensure the following:

- that the state of the material when placed is such that the compaction as specified in the *Technical Specifications*;
- that material selected for use in compacted embankments shall be approved by the Engineer on the basis of the maximum dry density (Proctor or Mod AASHTO, whichever is applicable) being equal to or greater than a minimum density to be specified by the Engineer.

Hence with the objective of controlling the selection and compaction of all materials used in the various layers of fill the Contractor shall perform grading analyses, Proctor or Mod AASHTO density tests whichever is applicable on each type of material which he proposes to use including mixed or blended materials.

In addition to the tests required for his own control the Contractor shall allow for at least two density checks per 400 square metre block of material compacted per layer. The recognised method of determining the density is the sand replacement test. However, the Radio Isotope or other approved method may be used (if approved by the Engineer) for density and moisture checks, provided suitable agreement is obtained between this method and the sand

replacement method and provided the necessary calibration and specified tests to these instruments are undertaken at intervals to be specified by the Engineer. If nuclear density measuring devices are used, they shall be calibrated against sand replacement tests.

If an alternative method of density determination is accepted, the sand replacement method shall be used to check every fourth density determination, and the moisture content of the sample shall be determined by oven drying as specified for the Modified AASHTO and Standard Proctor compaction methods.

To account for material variability, approved density tests will be accepted based on the following:

a) Walls/Fill compacted to 98% Standard Proctor Density

- If any one of the two density tests per 400 m^2 block is below 98% Standard Proctor Density then the entire block will be re-ripped, re-watered and re-compacted.
- Density test will be deemed to have passed if an average Standard Proctor Density of 98% or above is achieved, provided any individual test results in the group is greater than -2% of the Standard Proctor Density of 98%.

b) Walls/Fill compacted to 95% Standard Proctor Density

- If any one of the two density tests per 400 m^2 block is below 95% Standard Proctor Density then the entire block will be re-ripped, re-watered and re-compacted.
- Density test will be deemed to have passed if an average Standard Proctor Density of 95% or above is achieved, provided any individual test results in the group is greater than -2% of the Standard Proctor Density of 95%.

The compaction control tests shall be carried out as laid down in "Standard Methods of Testing Materials" published by the Department of Transport, Pretoria.

Field density and moisture content tests are to be carried out within twelve hours after the completion of each section of the layer. If such tests are not carried out by the Contractor within this period then the Engineer may fail a layer or section of the layer regardless of any test results which may then or subsequently be provided, and this decision shall be final.

When the compaction of any section of any layer, for which a density and moisture content is specified, is completed, the Contractor shall supply to the Engineer copies of test results whether successful or otherwise within 6 hours of determination.

The Contractor is to note that no subsequent layer is to be placed until such time as the previous layer has been approved by the Engineer in writing.

The Contractor shall maintain updated, accurate records of all compaction control tests, i.e. test data, chainage/location and layer elevation.

These records shall be available on site for inspection by the Engineer at all times.

Where tests reveal that the density or moisture content of any layer, at any depth, is not to specification, the Contractor shall re-rip, re-compact and re-water if necessary such material, or if the specified density cannot be obtained by further compaction of the material such material shall be removed and replaced by material capable of yielding the specified density.

All such testing and corrective work shall be undertaken at the Contractor's cost.

Tests to check the density, moisture content and particle size distribution of the compacted material and/or to check the testing procedures of the Contractor as described above, may be carried out by the Engineer. The costs of these tests will be paid for by the Employer only if the results of the tests show that the specified density has been obtained.

The Contractor shall pay for all such tests where the results show that the specified density has not been obtained; also he shall pay for any further tests to check if the required density, moisture content and particle size distribution has been obtained after the specified corrective measures have been carried out.

7.2.2 Sample Frequency

The test procedures for the evaluation of aggregate for material qualification and material conformance will conform to the minimum frequencies presented in Table 1A. The frequency of aggregate testing shall conform to the minimum frequencies presented in Table 1B. The actual frequency of testing required will be increased by the CQA Site Manager, as necessary, if

variability of materials is noted at the site, during adverse conditions, or to isolate failing areas of the construction.

7.2.3 Sample Selection

With the exception of qualification samples, sampling locations will be selected by the CQA Site Manager. Conformance samples will be obtained from borrow pits and/or stockpiles of material. The Contractor must plan the work and make aggregate available for sampling in a timely and organized manner so that the test results can be obtained before the material is installed. The CQA Site Manager must document sample locations so that failing areas can be immediately isolated. The CQA Site Manager will follow standard sampling procedures to obtain representative samples of the proposed aggregate materials.

7.3 CQA MONITORING ACTIVITIES

7.3.1 Drainage Aggregate

The CQA Site Manager will monitor and document the installation of the drainage aggregates. In general, monitoring of the installation of drainage aggregate includes the following activities:

- reviewing documentation of the material qualification test results provided by the Contractor;
- sampling and testing for conformance of the materials to the *Technical Specifications*;
- documenting that the drainage aggregates are installed using the specified equipment and procedures;
- documenting that the drainage aggregates are constructed to the lines and grades shown on the *Drawings*; and
- monitoring that the construction activities do not cause damage to underlying geosynthetic materials.

7.4 DEFECTS

If a defect is discovered in the drainage aggregates, the CQA Site Manager will evaluate the extent and nature of the defect. If the defect is indicated by an unsatisfactory test result, the CQA Site Manager will determine the extent of the defect area by additional tests, observations, a review of records, or other means that the CQA Site Manager deems appropriate.

7.4.1 Notification

After evaluating the extent and nature of a defect, the CQA Site Manager will notify the Construction Manager and Contractor and schedule appropriate re-tests when the work defect is to be corrected.

7.4.2 Repairs and Re-testing

The Contractor will correct the defect to the satisfaction of the CQA Site Manager. If a project specification criterion cannot be met, or unusual weather conditions hinder work, then the CQA Site Manager will develop and present to the Construction Manager suggested solutions for approval.

Re-tests recommended by the CQA Site Manager shall continue until it is verified that the defect has been corrected before any additional work is performed by the Contractor in the area of the defect. The CQA Site Manager will also verify that installation requirements are met and that submittals are provided.

8. HDPE PIPE AND FITTINGS

8.1 MATERIAL REQUIREMENTS

HDPE pipe and fittings must conform to the requirements of the *Technical Specifications*. The CQA Consultant will document that the HDPE pipe and fittings meet those requirements.

8.2 MANUFACTURER

8.2.1 Submittals

Prior to the installation of HDPE pipe, the Manufacturer will provide to the CQA Consultant:

- a properties sheet including, at a minimum, all specified properties, measured using test methods indicated in the *Technical Specifications*, or equivalent; and

The CQA Consultant will document that:

- the property values certified by the Manufacturer meet the *Technical Specifications*; and
- the measurements of properties by the Manufacturer are properly documented and that the test methods used are acceptable.

8.3 HANDLING AND LAYING

Care will be taken during transportation of the pipe such that it will not be cut, kinked, or otherwise damaged. Ropes, fabric, or rubber-protected slings and straps will be used when handling pipes. Chains, cables, or hooks inserted into the pipe ends will not be accepted. Two slings spread apart will be used for lifting each length of pipe. Pipe or fittings will not be dropped onto rocky or unprepared ground.

Pipes will be handled and stored in general accordance with the Manufacturer's recommendation. The handling of joined pipe will be in such a manner that the pipe is not damaged by dragging it over sharp and cutting objects. Slings for handling the pipe will not be positioned at joints. Sections of the pipes with deep cuts and gouges will be removed and the ends of the pipe rejoined.

8.4 PERFORATIONS

The CQA Site Manager shall monitor and document that the perforations of the HDPE pipe conform to the requirements of the *Drawings* and the *Technical Specifications*.

8.5 JOINTS

The CQA Monitor shall monitor and document that pipe and fittings are joined by the methods indicated in the *Technical Specifications*.

9. GEOMEMBRANE

9.1 GENERAL

This section discusses and outlines the CQA activities to be performed for high density polyethylene (HDPE) geomembrane installation. The CQA Site Manager will review the *Drawings*, *Technical Specifications,* and any approved Addenda regarding this material.

9.1.1 Installation of geomembrane system

General

The Lining Contractor is to undergo and abide to all the environmental requirements as set out by the mine.

Before the commencement of a contract, during the planning stage, a sheet layout will be prepared by the Lining Contractor on a plan of the RWD and TSF for approval by the Engineer and the main Contractor.

The Lining Contractor will submit a method statement for the placing of the plastic lining, given the effect of weather (rain, wind) and the shape and fall of the RWD and TSF (effect of run off on plastic laying). The final accepted method will be determined after award of the contract and will be a combined Contractor/ Lining Contractor responsibility.

The membrane sheets shall be laid and welded down the slope and adequate arrangements must be made for anchoring at the top and bottom of the embankment as well as cognisance taken for prevailing wind directions. Temporary ballast will be applied to liner to prevent damage from wind uplift and to prevent surface run-off during rainfall to enter under the liner.

Supervision and Manning

The Lining Contractor must supply an Organogram and CV's for all site personnel to be employed in the works. As indicated in the Tender Document the Lining Contractor must also

supply a schedule of personnel that it proposes to utilize on site during the carrying out of the works.

The Engineer must approve any proposed changes to the schedule of personnel in writing. The Lining Contractor shall allow in its manning levels for adequate coverage of leave requirements, to allow continuous operation at maximum production levels, i.e. working seven days a week with full crews.

The Lining Contractor will be required to have a competent, experienced Lining Installation Supervisor on site on full time basis during the lining installation. Both the Contractor and the Engineer must approve in writing, the proposed Lining Installation Supervisor.

Preparation before Laying

The Lining Contractor will be required to thoroughly check the finished earthworks surface ahead of installing the liner and to remove particles remain that could damage the liner. No protruding sharp objects will be allowed. Checking and picking of the final clay layer will be the responsibility of the Contractor.

The surface may require rolling just prior to laying of the geomembrane due typically to erosion tunnels caused by rain storms and damage due to picking. This rolling is to be done by the Contractor.

The surface must be inspected in the presence of the Engineer before the sheets are installed. If the Engineer is satisfied with the finished earthworks, he will sign the Substrate Clearance certificate to allow the Lining Contractor to commence with the installation of the plastic liner. Any subsequent repairs required to finished earthworks shall be the responsibility of the Contractor.

The Lining Contractor shall perform the works as expeditiously as possible to minimize the possibility of damage to the completed earthworks due to rain. The Contractor shall make all reasonable efforts to prevent any occurrences that may cause damage to the finished earthworks.

Procedure

The liner must be installed in accordance with the sheet layout as agreed with the Engineer.

The pattern of sheets laid must be such that no more than three sheets shall lap at any place. This can be achieved by staggering adjacent strips of sheet forming T-joints instead of "+" joints. A full record of work done with respect to date and position must be kept and forwarded on a weekly basis to the Engineer.

Individual sheets must be rolled out to ensure that the possibility of damage is kept to a minimum and the membrane is exposed to subsequent construction activities for the shortest possible time.

The programme of construction shall be such as to minimise exposure of the sheets before the filling of the lined facility is commenced.

All joints must be prepared for welding by grinding - (Extrusion Fusion welding only) - the surface of the membrane over the full width and length of the joint and must be clean.

9.1.2 Issues for consideration during tendering

This section of the specification outlines areas/items, which will require careful attention during construction.

Rain

The Lining Contractor must be aware that there will be delays due to rain and that he must allow for these both in the rates and when determining manning and equipment levels required to meet construction deadlines.

The plastic lining should be placed from the highest point on the dam down to the lowest point in order to prevent storm-water flowing under the Liner. However, if the Contractor can show means for protecting the Liner and sub-strate, he may obtain written permission from the Engineer to change this philosophy.

Wind

Very strong winds can occur just prior to and during storm events. It is essential that the Lining Contractor utilizes sand bags during the laying operation to ensure that lifting followed by tearing, creasing and other damage is not allowed to occur. This type of occurrence will lead to time delays associated with relaying and rechecking etc, which could have a severe impact on the project schedule.

Measurement

The unit of measurement for the installation of a suitable type of impermeable lining by an approved lining sub-contractor in accordance with the specifications, shall be the square metre of lining placed according to the dimensions indicated on the drawings or as specified by the Engineer. No extras will be paid for overlaps at joints, waste, etc. The lining that is placed in the anchor trenches, to the dimensions shown on the drawings will be included in the measured quantity.

Payment will be as detailed in the attached Bill of Quantities and where required separate items will be scheduled for attachments to concrete structures, pipes, sumps etc.

The rates in the schedule must include for:

- Supply of liner to the specifications (including compatible welding rods)
- all relevant insurances
- transport costs (including delivery to site and offloading
- storage,
- laying,
- welding
- QA/QC requirements,
- experienced supervision,
- labour, and
- preparing the surface just prior to laying (picking and rolling), etc.

No additional payments or claims of any nature will be considered.

9.2 GEOMEMBRANE MATERIAL CONFORMANCE

9.2.1 Introduction

The CQA Site Manager will document that the geomembrane delivered to the site meets the requirements of the *Technical Specifications* prior to installation. The CQA Site Manager will:

- review the manufacturer's submittals for compliance with the *Technical Specifications*;
- document the delivery and proper storage of geomembrane rolls; and
- conduct conformance testing of the rolls before the geomembrane is installed.

The following sections describe the CQA activities required to verify the conformance of geomembrane.

9.2.2 Review of Quality Control

Material Properties Certification

The Manufacturer will provide the Construction Manager and the CQA Site Manager with the following:

- property data sheets, including, at a minimum, all specified properties, measured using test methods indicated in the *Technical Specifications*, or equivalent;
- sampling procedures and results of testing.

The CQA Site Manager will document that:

- the property values certified by the Manufacturer meet all of the requirements of the *Technical Specifications*; and
- the measurements of properties by the Manufacturer are properly documented and that the test methods used are acceptable.

Geomembrane Roll MQC Certification

Prior to shipment, the Manufacturer will provide the Construction Manager and the CQA Site Manager with MQC certificates for every roll of geomembrane provided. The MQC certificates will be signed by a responsible party employed by the Geomembrane Manufacturer, such as the production manager. The MQC certificates shall include:

- roll numbers and identification; and
- results of MQC tests - as a minimum, results will be given for thickness, specific gravity, carbon black content, carbon black dispersion, tensile properties, and puncture resistance evaluated in general accordance with the methods indicated in the *Technical Specifications* or equivalent methods approved by the Construction Manager.

The CQA Site Manager will document that:

- MQC certificates have been provided at the specified frequency, and that the certificates identify the rolls related to the roll represented by the test results; and

- review the MQC certificates and monitor that the certified roll properties meet the specifications.

9.2.3 Conformance Testing

The CQA Site Manager shall obtain conformance samples (at the manufacturing facility or site) at the specified frequency and forward them to the Geosynthetics CQA Laboratory for testing to monitor conformance to both the *Technical Specifications* and the list of properties certified by the Manufacturer. The test procedures will be as indicated in Table 2A. Where optional procedures are noted in the test method, the requirements of the *Technical Specifications* will prevail.

Samples will be taken across the width of the roll and will not include the first linear 1 meter of material. Unless otherwise specified, samples will be 1 metres long by the roll width. The CQA Site Manager will mark the machine direction on the samples with an arrow along with the date and roll number. The required minimum sampling frequencies are provided in Table 3A.

The CQA Site Manager will examine results from laboratory conformance testing and will report any non-conformance to the Construction Manager and the Geosynthetic Installer. The procedures prescribed in the *Technical Specifications* will be followed in the event of a failing conformance test.

9.3 DELIVERY

9.3.1 Transportation and Handling

The CQA Site Manager will document that the transportation and handling does not pose a risk of damage to the geomembrane.

Upon delivery of the rolls of geomembrane, the CQA Site Manager will document that the rolls are unloaded and stored on site as required by the *Technical Specifications*. Damage caused by unloading will be documented by the CQA Site Manager and the damaged material shall not be installed.

9.3.2 Storage

The Geosynthetic Installer will be responsible for the storage of the geomembrane on site. The Contractor will provide storage space in a location (or several locations) such that on-site transportation and handling are optimized, if possible, to limit potential damage.

The CQA Site Manager will document that storage of the geomembrane provides adequate protection against sources of damage.

9.4 GEOMEMBRANE INSTALLATION

9.4.1 Introduction

The CQA Consultant will document that the geomembrane installation is carried out in general accordance with the *Drawings, Technical Specifications,* and Manufacturer's recommendations.

9.4.2 Earthwork

Surface Preparation

The CQA Site Manager will document that:

- the prepared subgrade meets the requirements of the *Technical Specifications* and has been approved; and
- placement of the overlying materials does not damage, create large wrinkles, or induce excessive tensile stress in any underlying geosynthetic materials.
- The Geosynthetic Installer will certify in writing that the surface on which the geomembrane will be installed is acceptable. The Certificate of Acceptance, as presented in the *Technical Specifications*, will be signed by the Geosynthetic Installer and given to the CQA Site Manager prior to commencement of geomembrane installation in the area under consideration.

After the subgrade has been accepted by the Geosynthetic Installer, it will be the Geosynthetic Installer's responsibility to indicate to the Construction Manager any change in the subgrade soil condition that may require repair work. If the CQA Site Manager concurs with the Geosynthetic

Installer, then the CQA Site Manager shall monitor and document that the subgrade soil is repaired before geosynthetic installation begins.

At any time before and during the geomembrane installation, the CQA Site Manager will indicate to the Construction Manager locations that may not provide adequate support to the geomembrane.

Geosynthetic Termination

The CQA Site Manager will document that the geosynthetic terminations (Anchor Trench) have been constructed in general accordance with the *Drawings*. Backfilling above the terminations will be conducted in general accordance with the *Technical Specifications*.

9.4.3 Geomembrane Placement

Panel Identification

A field panel is the unit area of geomembrane which is to be seamed in the field, i.e., a field panel is a roll or a portion of roll cut in the field. It will be the responsibility of the CQA Site Manager to document that each field panel is given an "identification code" (number or letter-number) consistent with the Panel Layout Drawing. This identification code will be agreed upon by the Construction Manager, Geosynthetic Installer and CQA Site Manager. This field panel identification code will be as simple and logical as possible. Roll numbers established in the manufacturing plant must be traceable to the field panel identification code.

The CQA Site Manager will establish documentation showing correspondence between roll numbers, and field panel identification codes. The field panel identification code will be used for all CQA records.

Field Panel Placement

Location

The CQA Site Manager will document that field panels are installed at the location indicated in the Geosynthetic Installer's Panel Layout Drawing, as approved or modified by the Construction Manager.

Installation Schedule

Field panels may be installed using one of the following schedules:

- all field panels are placed prior to field seaming in order to protect the subgrade from erosion by rain;
- field panels are placed one at a time and each field panel is seamed after its placement (in order to minimize the number of unseamed field panels exposed to wind); and
- any combination of the above.

If a decision is reached to place all field panels prior to field seaming, it is usually beneficial to begin at the high point area and proceed toward the low point with “shingle” overlaps to facilitate drainage in the event of precipitation. It is also usually beneficial to proceed in the direction of prevailing winds. Accordingly, an early decision regarding installation scheduling should be made if and only if weather conditions can be predicted with reasonable certainty. Otherwise, scheduling decisions must be made during installation, in general accordance with varying conditions. In any event, the Geosynthetic Installer is fully responsible for the decision made regarding placement procedures.

The CQA Site Manager will evaluate every change in the schedule proposed by the Geosynthetic Installer and advise the Construction Manager on the acceptability of that change. The CQA Site Manager will document that the condition of the subgrade soil has not changed detrimentally during installation.

The CQA Site Manager will record the identification code, location, and date of installation of each field panel.

Weather Conditions

Geomembrane placement will not proceed unless otherwise authorized when the ambient temperature is below 4.4°C or above 50°C. In addition, wind speeds and direction will be monitored for potential impact to geosynthetic installation. Geomembrane placement will not be performed during any precipitation, in the presence of excessive moisture (e.g., fog, dew), and/or in an area of ponded water.

The CQA Site Manager will document that the above conditions are fulfilled. Additionally, the CQA Site Manager will document that the subgrade soil has not been damaged by weather

conditions. The Geosynthetics Installer will inform the Construction Manager if the above conditions are not fulfilled.

Method of Placement

The CQA Site Manager will document the following:

- equipment used does not damage the geomembrane by handling, trafficking, excessive heat, leakage of hydrocarbons or other means;
- the surface underlying the geomembrane has not deteriorated since previous acceptance, and is still acceptable immediately prior to geomembrane placement;
- geosynthetic elements immediately underlying the geomembrane are clean and free of debris;
- personnel working on the geomembrane do not smoke, wear damaging shoes, or engage in other activities which could damage the geomembrane;
- the method used to unroll the panels does not cause scratches or crimps in the geomembrane and does not damage the supporting soil;
- the method used to place the panels minimizes wrinkles (especially differential wrinkles between adjacent panels); and
- adequate temporary loading and/or anchoring (e.g., sand bags, tires), not likely to damage the geomembrane, has been placed to prevent the uplift by wind (in case of high winds, continuous loading, e.g., by adjacent sand bags, is recommended along edges of panels to minimize risk of wind flow under the panels).

The CQA Site Manager will inform the Construction Manager if the above conditions are not fulfilled.

Damaged panels or portions of damaged panels that have been rejected will be marked and their removal from the work area recorded by the CQA Site Manager. Repairs will be made in general accordance with procedures described in Section 9.4.5.

9.4.4 Field Seaming

This section details CQA procedures to document that seams are properly constructed and tested in general accordance with the Manufacturer's specifications and industry standards.

Requirements of Personnel

All personnel performing seaming operations will be qualified by experience or by successfully passing seaming tests, as outlined in the *Technical Specifications*. The most experienced seamer, the "master seamer", will provide direct supervision over less experienced seamers.

The Geosynthetic Installer will provide the Construction Manager and the CQA Site Manager with a list of proposed seaming personnel and their experience records. These documents will be reviewed by the Construction Manager and the Geosynthetics CQA Manager.

Seaming Equipment and Products

Approved processes for field seaming are fillet extrusion welding and double-track fusion welding.

Fillet Extrusion Process

The fillet extrusion-welding apparatus will be equipped with gauges giving the temperature in the apparatus.

The Geosynthetic Installer will provide documentation regarding the extrusion welding rod to the CQA Site Manager, and will certify that the extrusion welding rod is compatible with the *Technical Specification*, and in any event, is comprised of the same resin as the geomembrane.

The CQA Site Manager will log apparatus temperatures, ambient temperatures, and geomembrane surface temperatures at appropriate intervals.

The CQA Site Manager will document that:

- the Geosynthetic Installer maintains, on site, the number of spare operable seaming apparatus decided at the Pre-construction Meeting;
- equipment used for seaming is not likely to damage the geomembrane;
- the extruder is purged prior to beginning a seam until all heat-degraded extrudate has been removed from the barrel;
- the electric generator is placed on a smooth base such that no damage occurs to the geomembrane;
- a smooth insulating plate or fabric is placed beneath the hot welding apparatus after usage; and

- the geomembrane is protected from damage in heavily trafficked areas.

Fusion Process

The fusion-welding apparatus must be automated vehicular-mounted devices. The fusion-welding apparatus will be equipped with gauges giving the applicable temperatures and pressures.

The CQA Site Manager will log ambient, seaming apparatus, and geomembrane surface temperatures as well as seaming apparatus speeds.

The CQA Site Manager will also document that:

- the Geosynthetic Installer maintains on-site the number of spare operable seaming apparatus decided at the Pre-construction Meeting;
- equipment used for seaming is not likely to damage the geomembrane;
- for cross seams, the edge of the cross seam is ground to a smooth incline (top and bottom) prior to welding;
- the electric generator is placed on a smooth cushioning base such that no damage occurs to the geomembrane from ground pressure or fuel leaks;
- a smooth insulating plate or fabric is placed beneath the hot welding apparatus after usage; and
- the geomembrane is protected from damage in heavily trafficked areas.

Seam Preparation

The CQA Site Manager will document that:

- prior to seaming, the seam area is clean and free of moisture, dust, dirt, debris, and foreign material; and
- seams are aligned with the fewest possible number of wrinkles and “fishmouths.”

Weather Conditions for Seaming

The normally required weather conditions for seaming are as follows unless authorized in writing by the Engineer:

- seaming will only be approved between ambient temperatures of 4.4°C and 50°C.

If the Geosynthetic Installer wishes to use methods that may allow seaming at ambient temperatures below 4.4°C or above 50°C, the Geosynthetic Installer will demonstrate and certify that such methods produce seams which are entirely equivalent to seams produced within acceptable temperature, and that the overall quality of the geomembrane is not adversely affected.

The CQA Site Manager will document that these seaming conditions are fulfilled and will advise the Geosynthetics Installer if they are not.

Overlapping and Temporary Bonding

The CQA Site Manager will document that:

- the panels of geomembrane have a finished overlap of a minimum of 75mm for both extrusion and fusion welding;
- no solvent or adhesive bonding materials are used; and
- the procedures utilized to temporarily bond adjacent panels together does not damage the geomembrane.

The CQA Site Manager will log appropriate temperatures and conditions, and will log and report non-compliances to the Construction Manager.

Trial Seams

Trial seams shall be prepared with the procedures and dimensions as indicated in the *Technical Specifications*. The CQA Site Manager will observe trial seam procedures and will document the results of trial seams on trial seam logs. Each trial seam samples will be assigned a number. The CQA Site Manager, will log the date, time, machine temperature(s), seaming unit identification, name of the seamer, and pass or fail description for each trial seam sample tested.

Separate trial seaming logs shall be maintained for fusion welded and extrusion welded trial seams.

General Seaming Procedure

Unless otherwise specified, the general production seaming procedure used by the Geosynthetic Installer will be as follows:

- fusion-welded seams are continuous, commencing at one end to the seam and ending at the opposite end.
- cleaning, overlap, and shingling requirements shall be maintained.
- if seaming operations are carried out at night, adequate illumination will be provided at the Geosynthetic Installer's expense.
- seaming will extend to the outside edge of panels to be placed in the anchor trench.

The CQA Site Manager shall document geomembrane seaming operations on seaming logs. Seaming logs shall include, at a minimum:

- seam identifications (typically associated with panels being joined);
- seam starting time and date;
- seam ending time and date;
- seam length;
- identification of person performing seam; and
- identification of seaming equipment.

Separate logs shall be maintained for fusion and extrusion welded seams. In addition, the CQA Site Manager shall monitor during seaming that:

- fusion-welded seams are continuous, commencing at one end of the seam and ending at the opposite end.
- cleaning, overlap, and shingling requirements are maintained.

Non-destructive Seam Continuity Testing

Concept

The Geosynthetic Installer will non-destructively test field seams over their length using a vacuum test unit, air pressure test (for double fusion seams only), or other method approved by the Construction Manager. The purpose of nondestructive tests is to check the continuity of seams. It does not provide information on seam strength. Continuity testing will be carried out as the seaming work progresses, not at the completion of field seaming.

The CQA Site Manager will:

- observe continuity testing;
- record location, date, name of person conducting the test, and the results of tests; and

- inform the Geosynthetic Installer of required repairs. The Geosynthetic Installer will complete any required repairs in general accordance with Section 9.4.5.

The CQA Site Manager will:

- observe the repair and re-testing of the repair;
- mark on the geomembrane that the repair has been made; and
- document the results.

The following procedures will apply to locations where seams cannot be non-destructively tested:

All such seams will be cap-stripped with the same geomembrane:

- If the seam is accessible to testing equipment prior to final installation, the seam will be non-destructively tested prior to final installation.
- If the seam cannot be tested prior to final installation, the seaming and cap-stripping operations will be observed by the CQA Site Manager and Geosynthetic Installer for uniformity and completeness.

The seam number, date of observation, name of tester, and outcome of the test or observation will be recorded by the CQA Site Manager.

Vacuum Testing

Vacuum testing shall be performed utilizing the equipment and procedures specified in the *Technical Specifications*. The CQA Site Manager shall observe the vacuum testing procedures and document that they are performed in accordance with the *Technical Specifications*. The result of vacuum testing shall be recorded on the CQA seaming logs. Results shall include, at a minimum, the personnel performing the vacuum test and the result of the test (pass or fail), and the test date. Seams failing the vacuum test shall be repaired in accordance with the procedures listed in the *Technical Specifications*. The CQA Site Manager shall document seam repairs in the seaming logs.

Air Pressure Testing

Air channel pressure testing shall be performed on double-track seams created with a fusion welding device, utilizing the equipment and procedures specified in the *Technical Specifications*. The CQA Site Manager shall observe the air channel pressure testing procedures and

document that they are performed in accordance with the *Technical Specifications*. The result of air channel pressure testing shall be recorded on the CQA seaming logs. Results shall include, at a minimum, personnel performing the air pressure test, the starting air pressure and time, the final air pressure and time, the drop in psi during the test, and the result of the test (pass or fail). Seams failing the air pressure test shall be repaired in accordance with the procedures listed in the *Technical Specifications*. The CQA Site Manager shall document seam repairs in the seaming logs.

Destructive Testing

Concept

Destructive seam testing will be performed on site and at the independent CQA laboratory in general accordance with the *Drawings* and the *Technical Specifications*. Destructive seam tests will be performed at selected locations. The purpose of these tests is to evaluate seam strength. Seam strength testing will be done as the seaming work progresses, not at the completion of all field seaming.

Location and Frequency

The CQA Site Manager will select locations where seam samples will be cut out for laboratory testing. Those locations will be established as follows:

- The frequency of geomembrane seam testing is a minimum of one destructive sample per 150 m of weld. The minimum frequency is to be evaluated as an average taken throughout the entire facility.
- A minimum of one test per seaming machine over the duration of the project.
- Additional test locations may be selected during seaming at the CQA Site Manager's discretion. Selection of such locations may be prompted by suspicion of excess crystallinity, contamination, offset welds, or any other potential cause of imperfect welding.

The Geosynthetic Installer will not be informed in advance of the locations where the seam samples will be taken.

Sampling Procedure

Samples will be marked by the CQA Site Manager following the procedures listed in the *Technical Specifications*. Preliminary samples will be taken from either side of the marked sample and tested before obtaining the full sample per the requirements of the *Technical Specifications*. Samples shall be obtained by the Geosynthetic Installer. Samples shall be obtained as the seaming progresses in order to have laboratory test results before the geomembrane is covered by another material. The CQA Site Manager will:

- observe sample cutting and monitor that corners are rounded;
- assign a number to each sample, and mark it accordingly;
- record sample location on the Panel Layout Drawing; and
- record reason for taking the sample at this location (e.g., statistical routine, suspicious feature of the geomembrane).

Holes in the geomembrane resulting from destructive seam sampling will be immediately repaired in general accordance with repair procedures described in Section 9.4.5. The continuity of the new seams in the repaired area will be tested in general accordance with Section 9.4.4.8.

Size and Distribution of Samples

The destructive sample will be 0.3 m wide by 1.1 m long with the seam centered lengthwise. The sample will be cut into three parts and distributed as follows:

- one portion, measuring 300 mm × 300 mm, to the Geosynthetic Installer for field testing;
- one portion, measuring 300 mm × 450 mm, for CQA Laboratory testing; and
- one portion, measuring 300 mm × 300 mm, to the Construction Manager for archive storage.

Final evaluation of the destructive sample sizes and distribution will be made at the Pre-Construction Meeting.

Field Testing

Field testing will be performed by the Geosynthetic Installer using a gauged tensiometer. Prior to field testing the Geosynthetic Installer shall submit a calibration certificate for gauge tensiometer to the CQA Consultant for review. Calibration must have been performed within

one year of use on the current project. The destructive sample shall be tested according to the requirements of the *Technical Specifications*. The specimens shall not fail in the seam and shall meet the strength requirements outlined in the *Technical Specifications*. If any field test specimen fails, then the procedures outlined in *Procedures for Destructive Test Failures* of this section will be followed.

The CQA Site Manager will witness field tests and mark samples and portions with their number. The CQA Site Manager will also document the date and time, ambient temperature, number of seaming unit, name of seamer, welding apparatus temperatures and pressures, and pass or fail description.

CQA Laboratory Testing

Destructive test samples will be packaged and shipped, if necessary, under the responsibility of the CQA Site Manager in a manner that will not damage the test sample. The Construction Manager will be responsible for storing the archive samples. This procedure will be outlined at the Pre-construction Meeting. Samples will be tested by the CQA Laboratory. The CQA Laboratory will be selected by the CQA Site Manager with the concurrence of the Engineer.

Testing will include “Bonded Seam Strength” and “Peel Adhesion.” The minimum acceptable values to be obtained in these tests are given in the *Technical Specifications*. At least five specimens will be tested for each test method. Specimens will be selected alternately, by test, from the samples (i.e., peel and shear). A passing test will meet the minimum required values in at least four out of five specimens.

The CQA Laboratory will provide test results no more than 24 hours after they receive the samples. The CQA Site Manager will review laboratory test results as soon as they become available, and make appropriate recommendations to the Construction Manager.

Geosynthetic Installer’s Laboratory Testing

The Geosynthetic Installer’s laboratory test results will be presented to the Construction Manager and the CQA Site Manager for comments.

Procedures for Destructive Test Failure

The following procedures will apply whenever a sample fails a destructive test, whether that test conducted by the CQA Laboratory, the Geosynthetic Installer's laboratory, or by gauged tensiometer in the field. The Geosynthetic Installer has two options:

- The Geosynthetic Installer can reconstruct the seam between two passed test locations.
- The Geosynthetic Installer can trace the welding path to an intermediate location at 3 m minimum from the point of the failed test in each direction and take a small sample for an additional field test at each location. If these additional samples pass the test, then full laboratory samples are taken. If these laboratory samples pass the tests, then the seam is reconstructed between these locations. If either sample fails, then the process is repeated to establish the zone in which the seam should be reconstructed.

Acceptable seams must be bounded by two locations from which samples passing laboratory destructive tests have been taken. Repairs will be made in general accordance with Section 9.4.5.

The CQA Site Manager will document actions taken in conjunction with destructive test failures.

9.4.5 Defects and Repairs

This section prescribes CQA activities to document that defects, tears, rips, punctures, damage, or failing seams shall be repaired.

Identification

Seams and non-seam areas of the geomembrane shall be examined by the CQA Site Manager for identification of defects, holes, blisters, undispersed raw materials and signs of contamination by foreign matter. Because light reflected by the geomembrane helps to detect defects, the surface of the geomembrane shall be clean at the time of examination.

Evaluation

Potentially flawed locations, both in seam and non-seam areas, shall be non-destructively tested using the methods described in Sub-section 9.4.4 under "Non-destructive Seam Continuity Testing" part, as appropriate. Each location that fails the nondestructive testing will be marked by the CQA Site Manager and repaired by the Geosynthetic Installer. Work will not proceed

with any materials that will cover locations which have been repaired until laboratory test results with passing values are available.

Repair Procedures

Portions of the geomembrane exhibiting a flaw, or failing a destructive or nondestructive test, will be repaired. Several procedures exist for the repair of these areas. The final decision as to the appropriate repair procedure will be at the discretion of the CQA Consultant with input from the Construction Manager and Geosynthetic Installer. The procedures available include:

- patching, used to repair large holes, tears, undispersed raw materials, and contamination by foreign matter;
- grinding and re-welding, used to repair small sections of extruded seams;
- spot welding or seaming, used to repair small tears, pinholes, or other minor, localized flaws;
- capping, used to repair large lengths of failed seams;
- removing bad seam and replacing with a strip of new material welded into place (used with large lengths of fusion seams).

In addition, the following provisions will be satisfied:

- surfaces of the geomembrane which are to be repaired will be abraded no more than 20 minutes prior to the repair;
- surfaces must be clean and dry at the time of the repair;
- all seaming equipment used in repairing procedures must be approved;
- the repair procedures, materials, and techniques will be approved in advance by the CQA Consultant with input from the Engineer and Geosynthetic Installer;
- patches or caps will extend at least 150 mm beyond the edge of the defect, and all corners of patches will be rounded with a radius of at least 75 mm;
- cuts and holes to be patched shall have rounded corners; and
- the geomembrane below large caps should be appropriately cut to avoid water or gas collection between the two sheets.

Verification of Repairs

The CQA Monitor shall monitor and document repairs. Records of repairs shall be maintained on repair logs. Repair logs shall include, at a minimum:

- panel containing repair and approximate location on panel;
- approximate dimensions of repair;
- repair type, i.e. fusion weld or extrusion weld
- date of repair;
- seamer making the repair; and
- results of repair non-destructive testing (pass or fail).

Each repair will be non-destructively tested using the methods described herein, as appropriate. Repairs that pass the non-destructive test will be taken as an indication of an adequate repair. Large caps may be of sufficient extent to require destructive test sampling, per the requirements of the *Technical Specifications*. Failed tests shall be redone and re-tested until passing test results are observed.

Large Wrinkles

When seaming of the geomembrane is completed (or when seaming of a large area of the geomembrane liner is completed) and prior to placing overlying materials, the CQA Site Manager will observe the geomembrane wrinkles. The CQA Site Manager will indicate to the Geosynthetic Installer which wrinkles should be cut and re-seamed. The seam thus produced will be tested like any other seam.

9.4.6 Lining System Acceptance

The Geosynthetic Installer and the Manufacturer(s) will retain all responsibility for the geosynthetic materials in the liner system until acceptance by the Construction Manager.

The geosynthetic liner system will be accepted by the Construction Manager when:

- the installation is finished;
- verification of the adequacy of all seams and repairs, including associated testing, is complete;

- all documentation of installation is completed including the CQA Site Manager's acceptance report and appropriate warranties; and
- CQA report, including "as built" drawing(s), sealed by a registered professional engineer has been received by the Construction Manager.

The CQA Site Manager will document that installation was carried out in general accordance with the *Technical Specifications* for the project.

Acceptance of sheets or rolls

The Contractor shall carry out a visual inspection of the sheets or rolls on arrival at site for possible transport damage. Sheets or rolls showing damage shall be singled out and clearly labelled as such.

A further inspection by the Lining Contractor is required prior to fabrication or installation. Any damaged sheets are to be rejected for installation.

Suitability of Lining Sub-contractor

In his assessment of the suitability of the Lining Contractor, the Engineer must be satisfied that such a contractor can perform according to the functional and organisational requirement of the works to be undertaken and preference will be given to those contractors which are listed in accordance with the ISO 9000 standards.

The Lining Contractor shall further be required to submit the following supportive documentation with his tender:

- Specifications of all materials tendered;
- Liner Production Quality Assurance /Quality Control Schedule;
- On-Site Quality Assurance /Quality Control Schedule;
- Experience list of all similar lining works completed over the last 10 years;
- Organogram and CV's of site personnel to be employed in the works.

Testing requirements for liner welding

The sections below outline the minimum requirements for testing of the liner welds. The methods proposed by the Lining Contractor are to be outlined in greater detail in the method statements and QA/QC procedures submitted with the tender. The methods and procedures used in the works will be subject to the approval of the Engineer.

Welding tests

The Engineer may, at his discretion, call for welding tests to be conducted prior to contract award and must include the following on the membrane liner:

(i) A single weld at least 10 m long performed in the open;

(ii) Patching of a 400 mm x 300 mm hole by hand welding;

(iii) The welding of three sheets to form a T-joint.

The Engineer reserves the right to take as many samples as and where it is considered necessary after the demonstration.

Completed seam test

Whether the double-track fusion welding or the extrusion welding systems are employed on site, the seams should all be confirmed as continuous and fully integrated by undertaking non-destructive and destructive tests.

Vacuum Tests

This test creates a vacuum on one side of the joint. If a vacuum of –75 kPa can be maintained for 3 minutes, the joint shall be considered to be effective. This test must be done where the sheets are lapped or where patching is done and on straight runs at a rate of one test per 50 linear metres of weld.

Electric spark tests

This method shall be used over 100% of all the extrusion-fusion welds on site and which method shall be subject to the approval of the Engineer.

Air Pressure Testing (double-track fusion welding)

Preparation:

Ensure that all testing equipment is clean and dust-free. Make a straight cut 90° across the weld, as close as possible after the beginning of the weld but not further than 100mm from the edge of the sheet.

Testing:

Force open the void between the welds at the cut end, using a screw driver or similar blunt object. Insert the pressure gauge/needle assembly into the void, clamp, secure and tighten the

gasket hard up against the cut face over the void, allowing it to flow freely out of the opposite end.

Immediately after completing a seam, commence the testing procedure. Seal the one end of the seam by applying heat with a hot air gun until a seal is achieved. While hot, clamp off the seam end, using the vice grip.

Pump air into the void to a pressure of 3 Bar. Maintain this pressure for a minimum of 2 minutes.

Repairs:

If the pressure of 3 Bar cannot be attained or the pressure drop is greater than specified, check both ends of the seam to ensure a proper seal and retest.

Should the test still be unsuccessful and no visible leak could be detected, repair the failed seam by extrusion welding the outside edge of the wedge- welded seam.

Identification of Tested Areas

The Tester shall mark each seam tested individually, by signing his name and date tested with an indelible pen on the plastic sheet. This position should also be transferred on to the sheet layout drawing. Once non-destructive tests have been carried out to the satisfaction of the Engineer, further destructive tests shall be carried out to confirm the integrity of the weld.

Destructive peel testing

The destructive peel tests will be carried out on all seams at 150m intervals or one per hour per machine minimum. The Lining Contractor must be capable of performing the peel test on site.

This test determines the effectiveness of the weld by peeling the weld apart at a rate of 50 mm/min on a strip 25 mm wide cut perpendicular to the joint direction at both ends of all samples. An increasing force is applied to the two strips of membrane forming the joint. If one of the strips breaks prior to full separation across the weld, it is considered acceptable. If the weld separates, the weld is considered unacceptable.

9.4.7 Corrective Measures

All defects, tears, sample holes or other physical damage to the membrane, must be patched with a piece of membrane of the same type and thickness as the parent membrane. This patch

shall be welded over the defect using a weld of at least 10mm width, using the extrusion fusion welding method.

9.4.8 Handover/Completion

Acceptance of the laid sheets by the Engineer will happen on a weekly basis. This sign off will be based on approval of plastic, the welds, the foundation material and the ballast left in place after moving off the cell. However as plastic lifting is the Lining Contractors responsibility, the daily signing off will not exempt the Contractor/Lining Contractor from liability for damage caused to the liner and subgrade due to their negligence on adjacent cells. Taking over in sections as per sub clause 48.2 of the GCC will only occur if the Owner requests to start placing geofabric, pipes and gravel on a pad before the final taking over certificate for the completed Works.

10. GEOTEXTILE

10.1 INTRODUCTION

This section of the CQA Plan outlines the CQA activities to be performed for the geotextile installation. The CQA Consultant will review the *Drawings*, and the *Technical Specifications*, and any approved addenda or changes.

10.2 MANUFACTURING

The Manufacturer will provide the Construction Manager with a list of guaranteed “minimum average roll value” properties (defined as the mean less two standard deviations), for each type of geotextile to be delivered. The Manufacturer will also provide the Construction Manager with a written quality control certification signed by a responsible party employed by the Manufacturer that the materials actually delivered have property “minimum average roll values” which meet or exceed all property values guaranteed for that type of geotextile.

The quality control certificates will include:

- roll identification numbers; and
- results of MQC testing.

The Manufacturer will provide, as a minimum, test results for the following:

- mass per unit area;
- grab strength;
- tear strength;
- puncture strength;
- permittivity; and
- apparent opening size.

MQC tests shall be performed at the frequency listed in the *Technical Specifications*. CQA tests on geotextile produced for the project shall be performed according to the test methods specified and frequencies presented in Table 3A.

The CQA Site Manager will examine Manufacturer certifications to evaluate that the property values listed on the certifications meet or exceed those specified for the particular type of geotextile and the measurements of properties by the Manufacturer are properly documented, test methods acceptable and the certificates have been provided at the specified frequency properly identifying the rolls related to testing. Deviations will be reported to the Construction Manager.

10.3 LABELING

The Manufacturer will identify all rolls of geotextile with the following:

- manufacturer's name;
- product identification;
- lot number;
- roll number; and
- roll dimensions.

The CQA Site Manager will examine rolls upon delivery and deviation from the above requirements will be reported to the Construction Manager.

10.4 SHIPMENT AND STORAGE

During shipment and storage, the geotextile will be protected from ultraviolet light exposure, precipitation or other inundation, mud, dirt, dust, puncture, cutting or any other damaging or deleterious conditions. To that effect, geotextile rolls will be shipped and stored in relatively opaque and watertight wrappings.

Protective wrappings will be removed less than one hour prior to unrolling the geotextile. After the wrapping has been removed, a geotextile will not be exposed to sunlight for more than 15 days, except for UV protection geotextile, unless otherwise specified and guaranteed by the Manufacturer.

The CQA Site Manager will observe rolls upon delivery at the site and deviation from the above requirements will be reported to the Geosynthetic Installer.

10.5 CONFORMANCE TESTING

10.5.1 Tests

Upon delivery of the rolls of geotextiles, the CQA Site Manager will obtain conformance samples and forward to the Geosynthetics CQA Laboratory for testing to evaluate conformance to *Technical Specifications*. Required test and testing frequency for the geotextiles are presented in Table 3. These conformance tests will be performed in general accordance with the test methods specified in the *Technical Specifications* and will be documented by the CQA Site Manager.

10.5.2 Sampling Procedures

Samples will be taken across the width of the roll and will not include the first 1.0 m. Unless otherwise specified, samples will be 1 metre long by the roll width. The CQA Site Manager will mark the machine direction on the samples with an arrow.

Unless otherwise specified, samples will be taken at a rate as indicated in Table 3 for geotextiles.

10.5.3 Test Results

The CQA Site Manager will examine results from laboratory conformance testing and will report non-conformance with the *Technical Specifications* and this CQA Plan to the Construction Manager.

10.5.4 Conformance Sample Failure

The following procedure will apply whenever a sample fails a conformance test that is conducted by the CQA Laboratory:

- The Manufacturer will replace every roll of geotextile that is in nonconformance with the *Technical Specifications* with a roll(s) that meets *Technical Specifications*; or
- The Geosynthetic Installer will remove conformance samples for testing by the CQA Laboratory from the closest numerical rolls on both sides of the failed roll. These two samples must conform to the *Technical Specifications*. If either of these samples fail, the numerically closest rolls on the side of the failed sample will be tested by the CQA Laboratory. These samples must conform to the *Technical Specifications*. If any of these samples fail, every roll of geotextile on site from this lot and every subsequently delivered roll that is from the same lot must be tested by the CQA Laboratory for conformance to the *Technical Specifications*. This additional conformance testing will be at the expense of the Manufacturer.

The CQA Site Manager will document actions taken in conjunction with conformance test failures.

10.6 HANDLING AND PLACEMENT

The Geosynthetic Installer will handle all geotextiles in such a manner as to document they are not damaged in any way, and the following will be complied with:

- In the presence of wind, all geotextiles will be weighted with sandbags or the equivalent. Such sandbags will be installed during placement and will remain until replaced with earth cover material.

- Geotextiles will be cut using an approved geotextile cutter only. If in place, special care must be taken to protect other materials from damage, which could be caused by the cutting of the geotextiles.
- The Geosynthetic Installer will take all necessary precautions to prevent damage to underlying layers during placement of the geotextile.
- During placement of geotextiles, care will be taken not to entrap in the geotextile stones, excessive dust, or moisture that could damage the geotextile, generate clogging of drains or filters, or hamper subsequent seaming.
- A visual examination of the geotextile will be carried out over the entire surface, after installation, to document that no potentially harmful foreign objects, such as needles, are present.

The CQA Site Manager will note non-compliance and report it to the Construction Manager.

10.7 SEAMS AND OVERLAPS

All geotextiles will be continuously sewn in accordance with *Technical Specifications*. Geotextiles will be overlapped 300 mm prior to seaming. No horizontal seams will be allowed on side slopes (i.e. seams will be along, not across, the slope), except as part of a patch.

Sewing will be done using polymeric thread with chemical and ultraviolet resistance properties equal to or exceeding those of the geotextile.

10.8 REPAIR

Holes or tears in the geotextile will be repaired as follows:

- On slopes: A patch made from the same geotextile will be double seamed into place. Should a tear exceed 10 percent of the width of the roll, that roll will be removed from the slope and replaced.
- Non-slopes: A patch made from the same geotextile will be spot-seamed in place with a minimum of 150 mm overlap in all directions.

Care will be taken to remove any soil or other material that may have penetrated the torn geotextile.

The CQA Site Manager will observe any repair, note any non-compliance with the above requirements and report them to the Construction Manager.

10.9 PLACEMENT OF SOIL OR AGGREGATE MATERIALS

The Contractor will place all soil or aggregate materials located on top of a geotextile, in such a manner as to document:

- no damage of the geotextile;
- minimal slippage of the geotextile on underlying layers; and
- no excess tensile stresses in the geotextile.

Non-compliance will be noted by the CQA Site Manager and reported to the Construction Manager.

Earthworks, substrate requirements

The flexible membrane lining that is offered must be considered an integral part of the total system. To ensure the integrity of the system, earthworks should be carried out in accordance with the attached Earthworks Specification. The following requirements are, however, highlighted:

a) The area to be lined must 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 5-10mm will be allowed, but no sharp edge stones/debris can be tolerated. The material on which the liner will be placed at the RWD and TSF will be a compacted fine grained soil with possible contamination with stones.

   "Picking" of the debris/stones etc. will still need to be undertaken to remove unsuitable objects that may exist; this work is to be done by the Contractor and is to be included in the tendered price. The "picking" is considered an essential activity in maintaining the integrity of the geomembrane and the Contractor will be required to submit a method statement to the Engineer for approval for this operation. Following the picking operation the surface must be rolled again with a smooth drum compactor. This is to be done by the Earthworks Contractor.

b) The base and embankment slopes must be compacted in accordance with the attached Earthworks Specification and the embankment slopes must be stable.

c) All vegetation must be removed and a suitable weed killer applied, if necessary.

d) The base of the earthworks or structure must be clean and dry. Should ground water be present, a suitable drainage system must be provided for provision for the continuous removal of water from the operation area if necessary. This work will be considered a variation to the contract unless otherwise stated.

e) Excavation and subsequent backfilling of perimeter lining anchor trenches measuring, is to be done by the Lining Contractor and is to be included in the tendered price.

f) The backfilling must only be carried out once the structure has been filled, and the liner has settled. Suitable backfill material, which must be free of rocks, stones and other sharp objects and have maximum particle size of 10mm must be used. Tolerances for the excavation and backfilling of the lining anchor trenches are:

- the work shall be finished to a permissible deviation from designated levels with reference to the nearest transferred bench mark of ±50mm).
- the flatness of the finished surface (i.e. the maximum deviation of the surface from any straight line of length 3,0m) shall be ±50mm.
- abrupt changes in a continuous surface are to be limited to a maximum of 3mm.
- trench to be backfilled and compacted flush with liner surface to 98% Standard Proctor Density at OMC –1% to +2%.

TABLE 1 A: TEST PROCEDURES FOR THE EVALUATION OF AGGREGATE

TEST METHOD	DESCRIPTION	TEST STANDARD
Sieve Analysis	Particle Size Distribution of Fine and Coarse Aggregates	ASTM C 136
Hydraulic Conductivity (Rigid Wall Permeameter)	Permeability of Aggregates	ASTM D 2434

TABLE 1 B: MINIMUM AGGREGATE TESTING FREQUENCIES FOR CONFORMANCE TESTING

TEST	TEST METHOD	DRAINAGE AGGREGATE
Sieve Analysis	ASTM C 136	1 per 3,900 m^3
Hydraulic Conductivity	ASTM D 2434	1 per 7,650 m^3

TABLE 2 A: GEOMEMBRANE CONFORMANCE TESTING REQUIREMENTS

TEST NAME	TEST METHOD	FREQUENCY
Specific Gravity	ASTM D 792 Method A or ASTM D 1505	18,600 m^2
Thickness	ASTM D 5199	18,600 m^2
Tensile Strength at Yield	ASTM D 6693	18,600 m^2
Tensile Strength at Break	ASTM D6693	18,600 m^2
Elongation at Yield	ASTM D 6693	18,600 m^2
Elongation at Break	ASTM D 6693	18,600 m^2
Carbon Black Content	ASTM D 1603	18,600 m^2
Carbon Black Dispersion	ASTM D 5596	18,600 m^2
Interface Shear Strength[1,2]	ASTM D 5321	1 per project

Notes:

1. To be performed at normal stresses of 10, 20, and 40 psi between geomembrane and geonet.

TABLE 3 A: GEOTEXTILE CONFORMANCE TESTING REQUIREMENTS

TEST NAME	TEST METHOD	MINIMUM FREQUENCY
Mass per Unit Area	ASTM D 5261	1 test per 24,000m^2
Grab Strength	ASTM D 4632	1 test per 24,000m^2
Puncture Resistance	ASTM D 4833	1 test per 24,000m^2
Permittivity	ASTM D 4491	1 test per 24,000m^2
Apparent Opening Size	ASTM D 4751	1 test per 24,000m^2

APPENDIX E
OPERATION AND MAINTENANCE MANUAL FOR HDPE LINER

WESIZWE PLATINUM LIMITED



OPERATION AND MAINTENANCE MANUAL FOR LINERS

PREPARED FOR:

Wesizwe Platinum Limited

PREPARED BY:

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Report Number: 301-00509/02

Date: January 2016

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WESIZWE PLATINUM LIMITED

OPERATIONS & MAINTENANCE MANUAL

FOR LINERS

REPORT NO. 301-00509/02

JANUARY 2016

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WESIZWE PLATINUM LIMITED

OPERATIONS & MAINTENANCE MANUAL

FOR LINERS

REPORT NO. 301-00509/02

JANUARY 2016

1 OPERATIONAL PROCEDURES

1.1 INTRODUCTION

The tensioned membrane High Density Polyethylene Geo-membrane has been designed to operate with minimal supervision and maintenance.

The system has been designed to operate at any normal basin water levels with an emphasis on safety for operators, and on safe storage of the liquid it contains.

The liner system will give many years of trouble-free operation with minimal servicing, if a number of simple operations are followed.

This manual covers the following:

Maintenance of the liner system,

1. Operation of the liner,
2. Repairs,
3. Cleaning,
4. Monitoring and
5. Inspection

1.2 MATERIALS

The Liner is fabricated from High Density Polyethylene Flexible Geo-membrane Lining Material.

1.3 PERIMETER FIXING

The liner is anchored in a perimeter anchor trench.

1.4 APPEARANCE DURING NORMAL OPERATION

The liner should sit flat on the surface of the earthworks in a slightly tensioned state, with no obvious excess tension or slack in any areas. It is normal for folds to form when the dam is empty due to heat expansion.

2 OPERATING AND MONITORING REQUIREMENTS

2.1 INSPECTIONS

- Visually inspect surface of liner for any damage
- Note any surface ponding of water on the liner and check these areas for sedimentation or damage.
- Look for differential tensions in liner, should these become obvious, please notify the supplier immediately.

Prompt attention to all abnormal occurrences is a must for continues long term performance of the liner.

2.2 DEBRIS REMOVAL

All debris that collects on the liners should be removed by a suitable method, such as:

- Manual sweeping and pick up
- Air blower
- Water wash down

2.3 PROTECTION DURING NORMAL OPERATIONS

Care should be taken not to damage the liners during these operations. Sharp edges on tools shall be removed and or padded. Petrol, oils or other petroleum products should never be allowed to come in contact with the HDPE liners.

2.4 MONTHLY INSPECTIONS

Further to the above, the following inspections should be carried out:

- Inspections of visual areas for any mechanical damage.
- Check all nuts and bolts on make-offs when exposed and tighten if necessary.

2.5 YEARLY INSPECTIONS

- Inspect outside surface for cracks, chaffing or damage.
- Inspect non-interference points (sump junctions) for build-up of sedimentation.

2.6 REPAIRS

2.6.1 General

- Repairs of membrane; fixings; seals, should only be carried out by personnel who are capable and experienced in this class of work.
- All work performed on the liner is to be accomplished with care to protect the liner from damage.
- Only rubber soled shoes should be used when walking on the liners. The shoe soles shall be inspected prior to entrance onto the liner for embedded sharp objects such as rocks, glass, thorns, etc.
- All electrical cords and connections used for maintenance and repairs on the liner shall be of an approved type to meet project safety requirements, including earth-leakage protection.

2.7 CLEANING LINERS

The removal of dry materials such as leaves, weeds, paper etc. can be accomplished by the use of hand held air blowers, an air compressor with an airline and/or brooms. Areas such as folds and drainage troughs may require a vacuum attachment.

The removal of dirt, pollen and general airborne contaminants can be accomplished by washing debris into the drainage troughs with a water hose and then pumping out.

Solid objects (rocks, bottles, etc.) thrown onto the liners by vandals should be removed as soon as possible to prevent the build-up of debris and possible membrane damage.

Dirt and algae should periodically be removed from the surface of the liner by hosing and brooming, into the sump. No chemical or solvent cleaners should be used in this process. Attention should be given to areas around walkways to remove any sedimentation, which can cause ponding of surface water in these areas.

The reservoir should be drained periodically (annually, or as required after inspection) to allow a complete cleaning of the entire surface area and removal of any sedimentation.

APPENDIX F
CLAY MATERIAL DISPERSIVITY ASSESSMENT

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Contact: J van Tonder

14 January 2016

KHH2275

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Attention: Mr. A Strauss

Dear Sir

WESIZWE PLATINUM PROJECT TAILINGS STORAGE FACILITY – DISPERSIVITY TESTS AND ANALYSIS ON FOUNDATION MATERIALS

1. INTRODUCTION

Knight Piésold was appointed by Bakubung Minerals (Pty) Ltd. to conduct further geotechnical analysis on the materials at the proposed tailings storage facility at Wesizwe Platinum Project. Knight Piésold conducted the geotechnical investigation for the proposed tailings storage facility in 2013. The report was referred to as “Styldrift Tailings Storage Facility on Mimosa Farm”. Refer to report KHH2076.

The National Standards for Disposal of Waste to Landfill (R636) specify that the construction of the containment barrier should be included in an application for waste management license approval to support the design of the tailings storage facility.

The purpose of this additional geotechnical investigation was to conduct additional laboratory tests on the proposed floor materials of the tailings storage facility (TSF) to determine dispersivity nature of the material with different agents, including leachate from the pilot plant. This report describes the results of the investigation and includes a geotechnical analysis of the findings.

2. METHOD OF INVESTIGATION

Two bulk samples were collected from the proposed foundations by excavating two test pits with a TLB machine to the proposed foundation level. The two samples, collected at positions TP25 and TP32 according to the positions of the initial geotechnical investigation, are described as follows:

- Sample TP25: 0,4m – 1,4m: reddish brown sandy clay. Colluvium
- Sample TP32: 0,4m – 1,5m: black, sandy clay with scattered calcrete gravel. Colluvium.

The compaction characteristics of both samples were determined to correlate with the previous tests conducted during the initial geotechnical investigation.

Two samples of tailings leachate were obtained from Wesizwe. The one representing the Merensky leachate and the second representing the UG2 leachate. The Merensky sample represents leachate produced by processing ore of the lower Merensky platinum reef, whereas the UG2 sample represent leachate produced by processing ore of the upper UG2 chromite reef. These leachates have been sampled from the pilot plant after the flotation process and have not yet been processed by the thickening plant. The thickening plant will only be commissioned later during 2016.

The samples were submitted to Geostrada laboratory in Pretoria. The following tests were conducted on both types of soils using the leachate.

- Chemical dispersivity
- Crump test
- Double hydrometer
- Falling Head permeability tests

The detailed results of the laboratory tests are provided in Appendix A.

3. LABORATORY TEST RESULTS AND EVALUATION

The compaction test on the brown colluvial soil yielded a standard Proctor maximum dry density (MDD) of 1510kg/m^3 with an optimum moisture content (OMC) of 27%. The same test on the black colluvial soil (TPM35) yielded a slightly lower but similar MDD of 1470 kg/m^3 with an OMC of 26%.

The chemical dispersivity test results include the Cation Exchange Capacity (CEC) and Exchangeable Sodium Percentage (ESP), which are used to determine the dispersivity of the soils from the dispersivity chart. The results are displayed in Table 1 and indicate that both soils falls within the non-dispersive category.

Crump Tests were conducted using distilled water, a 1 mol sodium hydroxide solution and the Merensky / UG2 leachate samples. These four solutions were used to conduct crump tests on both soil samples. The results indicated that under all scenarios, on both samples, the leachate solutions are non-dispersive.

The double hydrometer test compares the measured percentage of fines in a sample that has been artificially dispersed to that of distilled water and the leachate samples. The interpretation of the hydrometer tests indicates that non-dispersive soils are generally less than 30%. The double hydrometer tests indicated that both the leachate samples measured 0% dispersivity on both types of soils, similar to the 0% measured on distilled water.

Three falling head permeability tests were conducted on both soil samples. These include a permeability test utilizing distilled water, Merensky leachate water and UG2 leachate water. Table 2 provides a summary of the results.

The results of the permeability test with the distilled water yielded low coefficients of permeability of between 4 x 10^{-8} cm/s and 2 x 10^{-7} cm/s. These values correlate with the permeability tests conducted during the initial geotechnical investigation. The Merensky and UG2 leachates yielded similar coefficients of permeability of between 1 x 10^{-8} cm/s and 3 x 10^{-7} cm/s. It may be concluded that the permeability of the foundation soils are not influenced by the leachate water.

4. CONCLUSIONS

The dispersivity tests conducted on both soil samples, representing the recommended foundations for the tailings storage facility, indicates that the materials are not sensitive with respect to dispersivity once the leachate samples are introduced.

It should be noted that the sampled leachates are products from the pilot plant from the flotation process and not from the final process, which involves the thickening process. It is anticipated that the thickening process will reduce the water content within the leachate samples, however, it is unknown what type of chemicals are added to the leachate during this process.

It is, however, believed that the leachate produced from the thickening process should not have significant effects on the permeability of the soils. There it is recommended that further crumb tests should be conducted once the leachate from the thickening plant is available.

Please contact us should you have any further queries.

JVAN TONDER Pr.Sci.Nat.
for *Knight Piésold*

Table 1: Chemical Dispersivity Chart

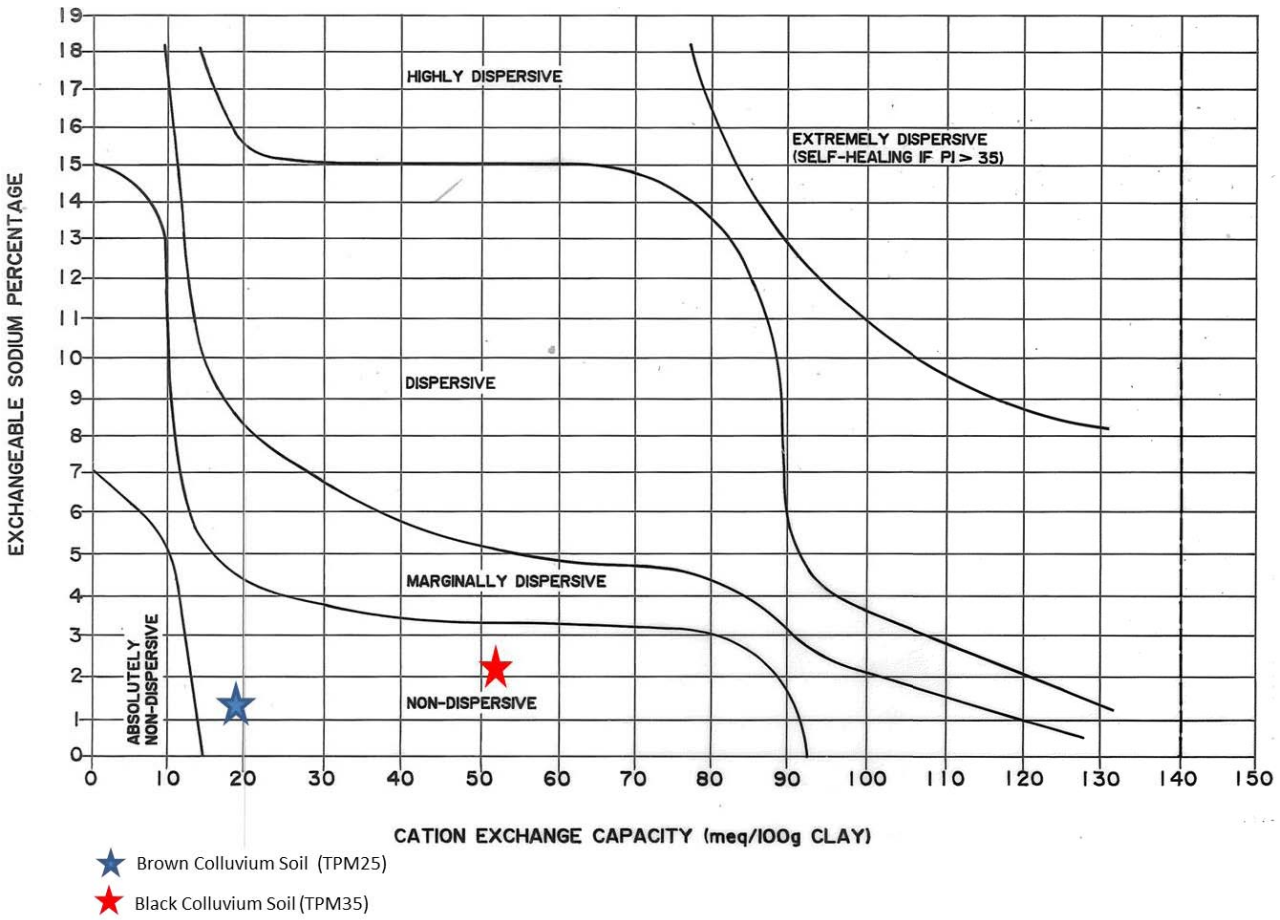

Table 2: Summary of Permeability Test Results

Sample Number	Soil Sample Type	Testing Medium	Coefficient of Permeability (k-value) cm/s
TPM25	Brown Colluvium	Distilled Water	4×10^{-8}
		Merensky Leachate	1×10^{-8}
		UG2 Leachate	3×10^{-7}
TPM35	Black Colluvium	Distilled Water	2×10^{-7}
		Merensky Leachate	6×10^{-8}
		UG2 Leachate	3×10^{-7}

APPENDIX A

LABORATORY TEST RESULTS

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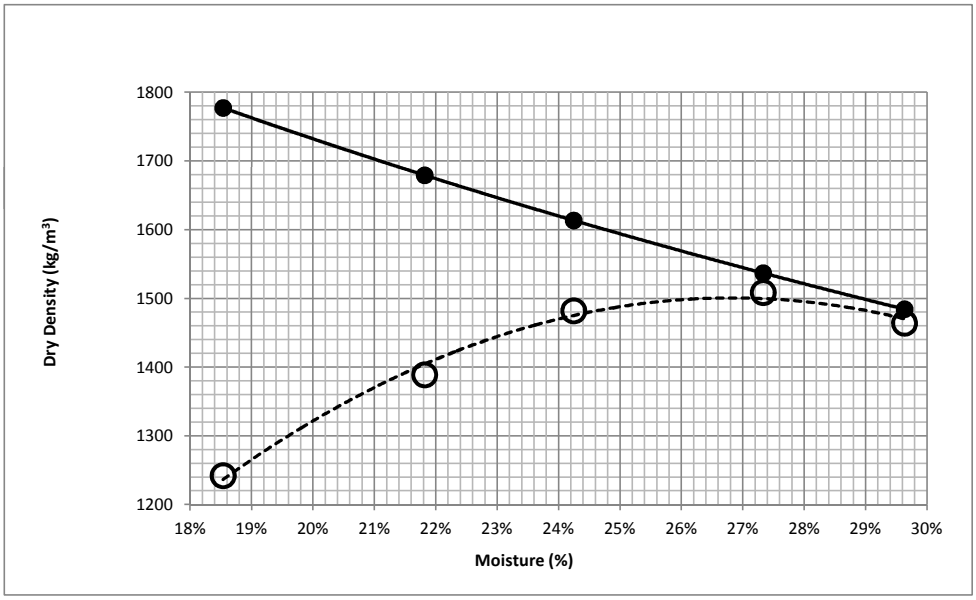
Project:	Wesizwe
Sample Number:	TPM25
Test:	Std PROCTOR Moisture Density Relation
Test Date:	14-Sep-15
Lab no:	15/486

Max Optimum Dry Density (kg/m^3)	1510
Optimum Moisture (%)	26.8%
Specific Gravity (kg/m^3)	*2.65*

Moisture (%)	18.5%	21.8%	24.2%	27.3%	29.6%
Moist Density (kg/m^3)	1472.5	1692.0	1841.3	1921.0	1898.0
Dry Density (kg/m^3)	1242.3	1389.0	1482.0	1508.6	1464.1
Zero Voids Density (kg/m^3)	1777.1	1679.2	1613.4	1536.9	1484.4



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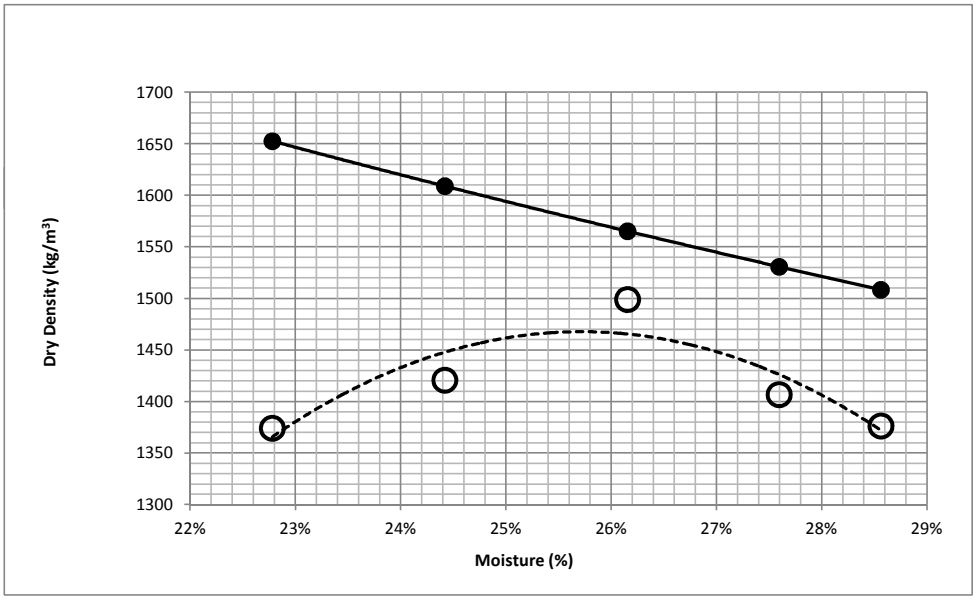
Project:	Wesizwe
Sample Number:	TP35
Test:	Std PROCTOR Moisture Density Relation
Test Date:	14-Sep-15
Lab no:	15/487

Max Optimum Dry Density (kg/m^3)	1470
Optimum Moisture (%)	26.2%
Specific Gravity (kg/m^3)	*2.65*

Moisture (%)	22.8%	24.4%	26.2%	27.6%	28.6%
Moist Density (kg/m^3)	1687.2	1767.7	1891.1	1795.0	1769.5
Dry Density (kg/m^3)	1374.2	1420.8	1499.0	1406.8	1376.4
Zero Voids Density (kg/m^3)	1652.5	1608.9	1565.2	1530.7	1508.4



Client:	GEOSTRADA
Project:	WESIZWE (2015-C-1505)
Project No.:	2015-S-1652
Date:	2015-11-26

TEST RESULTS: CHEMICAL DISPERSION

Soillab No.:	2015-S-1652-01	2015-S-1652-02
Sample No.:	5/11494 TPM 25 0.4-1.4m	5/11495 TP 35 0.4-1.5m
pH (TMH1) A20	6.36	7.46
EC (mS/m) (TMH1) A21	74.5	138.0
*** Na (me/100g) #**	0.26	1.12
*** K (me/100g) #**	0.40	0.41
*** Ca (me/100g) #**	6.45	19.13
*** Mg (me/100g) #**	8.10	21.79
*** CEC (me/100g) #**	18.86	52.57
*** ESP** = $\frac{\text{Na}}{\text{CEC}}$ **x 100**	1.38	2.13
*** EmgP** = $\frac{\text{Mg}}{\text{CEC}}$ **x 100**	42.95	41.45
*** ESP + EMgP**	44.33	43.58

Note:
* Not Accredited
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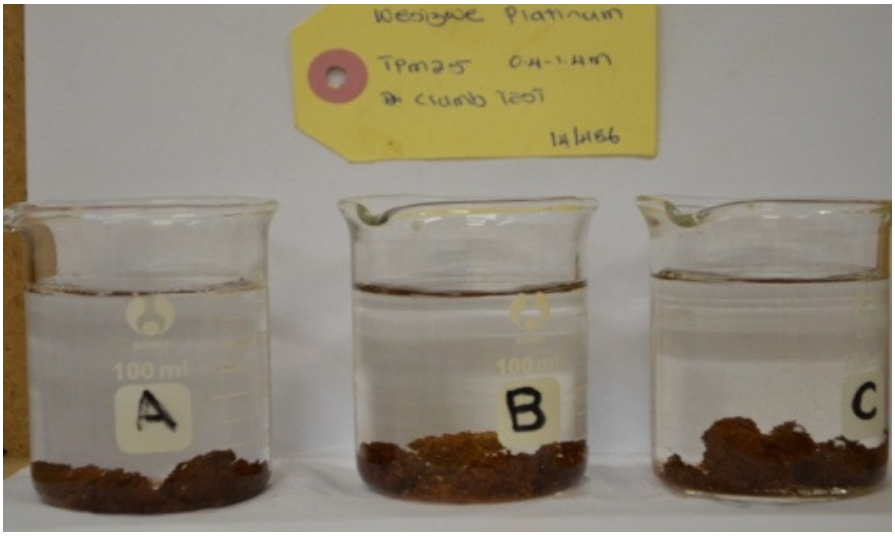
Project:	Wesizwe Platinum
Test:	Crumb Dispersive Test
Sample Number:	TPM 25
Sample Position:	0.4m - 1.4m
Sample Receive Date:	02-Sep-15
Lab Reference:	15/486
Test Date:	18-Sep-15

Merensky Leachate

Elapsed Time: Zero Minutes

Distilled Water (Left)	0.001 mol/litre Sodium Hydroxide (Center)	Process Water Supllied by Client (Right)



Result after Elapsed Time: 5 Minutes

Distilled Water (Left)	0.001 mol/litre Sodium Hydroxide (Center)	Process Water Supllied by Client (Right)
Non-dispersive	**Non-dispersive**	**Non-dispersive**

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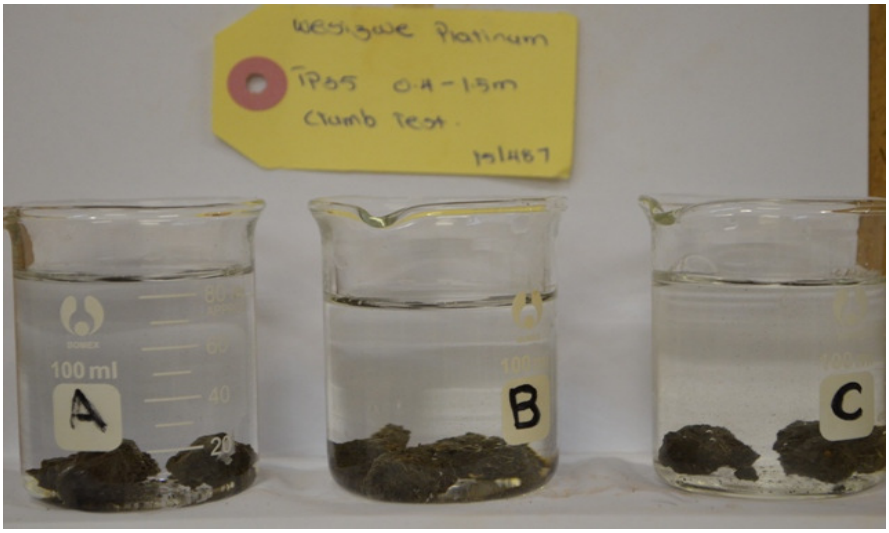
Project:	Wesizwe Platinum
Test:	Crumb Dispersive Test
Sample Number:	TPM 35
Sample Position:	0.4m - 1.5m
Sample Receive Date:	02-Sep-15
Lab Reference:	15/487
Test Date:	18-Sep-15

Merensky Leachate

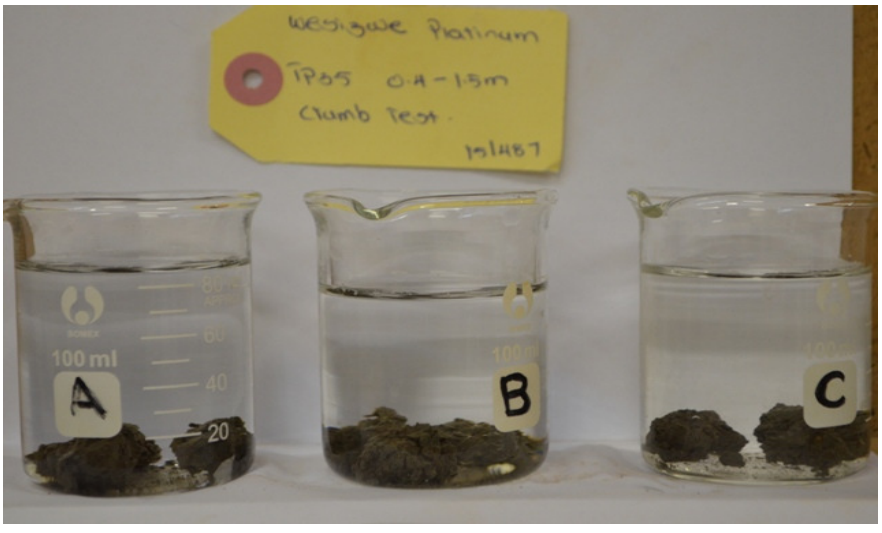
Elapsed Time: Zero Minutes

Distilled Water (Left)	0.001 mol/litre Sodium Hydroxide (Center)	Process Water Supllied by Client (Right)



Result after Elapsed Time: 5 Minutes

Distilled Water (Left)	0.001 mol/litre Sodium Hydroxide (Center)	Process Water Supllied by Client (Right)
Non-dispersive	**Non-dispersive**	**Non-dispersive**



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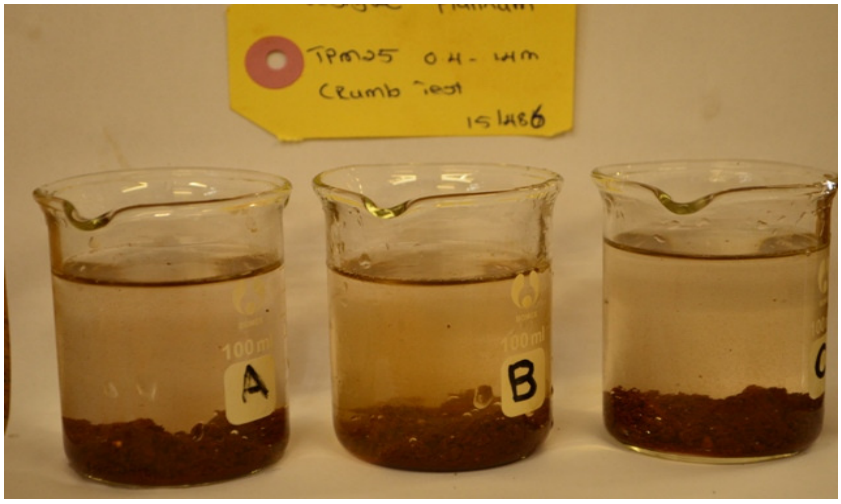
Project:	Wesizwe Platinum
Test:	Crumb Dispersive Test
Sample Number:	TPM 25
Sample Position:	0.4m - 1.4m
Sample Receive Date:	05-Nov-15
Lab Reference:	15/486 (2)
Test Date:	26-Nov-15

UG2 Leachate

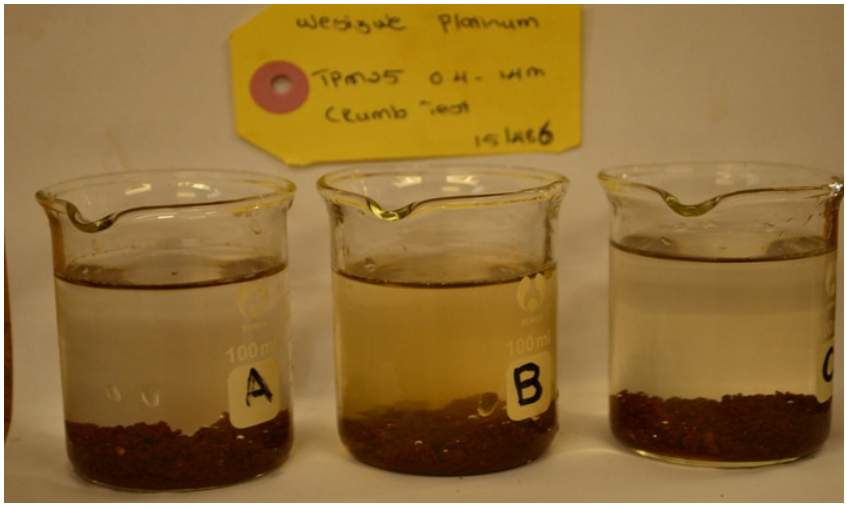
Elapsed Time: Zero Minutes

Distilled Water (Left)	0.001 mol/litre Sodium Hydroxide (Center)	Process Water Supllied by Client (Right)



Result after Elapsed Time: 5 Minutes

Distilled Water (Left)	0.001 mol/litre Sodium Hydroxide (Center)	Process Water Supllied by Client (Right)
Non-dispersive	**Non-dispersive**	**Non-dispersive**



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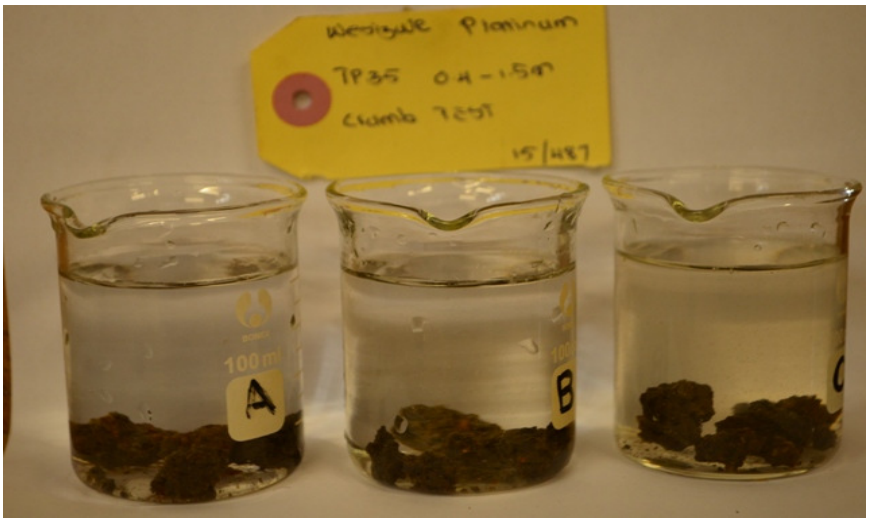
Project:	Wesizwe Platinum
Test:	Crumb Dispersive Test
Sample Number:	TPM 35
Sample Position:	0.4m - 1.5m
Sample Receive Date:	05-Nov-15
Lab Reference:	15/487 (2)
Test Date:	26-Nov-15

UG2 Leachate

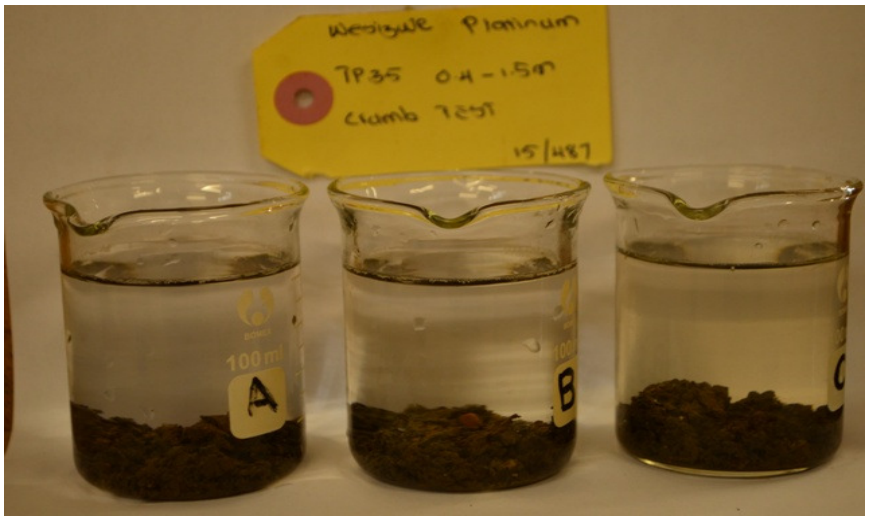
Elapsed Time: Zero Minutes

Distilled Water (Left)	0.001 mol/litre Sodium Hydroxide (Center)	Process Water Supllied by Client (Right)



Result after Elapsed Time: 5 Minutes

Distilled Water (Left)	0.001 mol/litre Sodium Hydroxide (Center)	Process Water Supllied by Client (Right)
Non-dispersive	**Non-dispersive**	**Non-dispersive**



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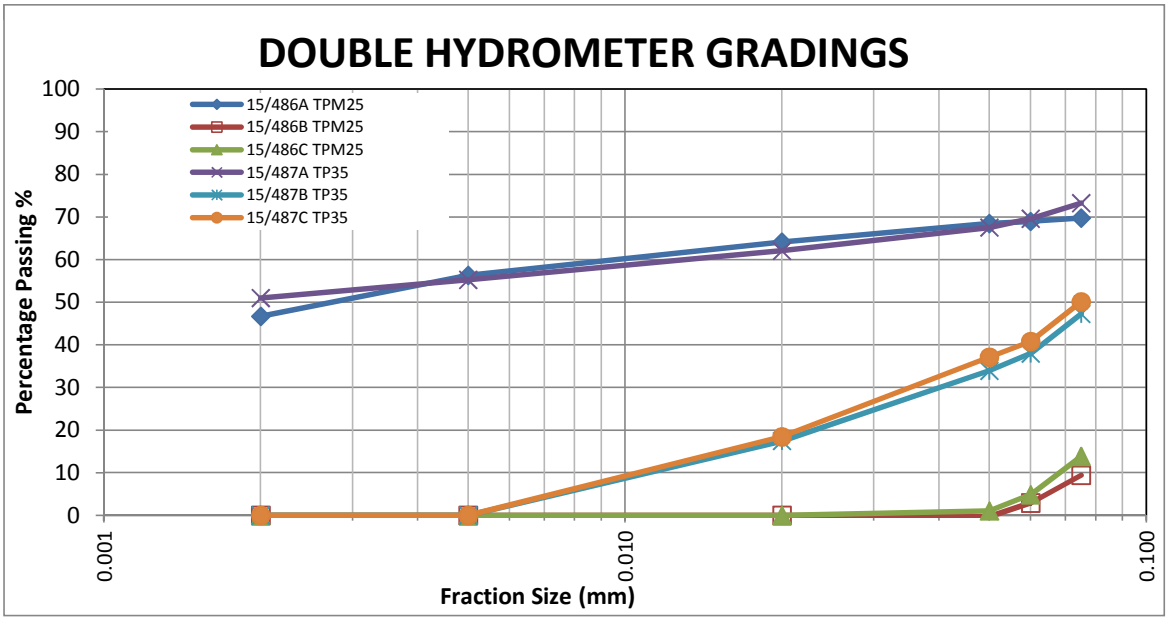
Project: Wesizwe Platinum
Test: DOUBLE HYDROMETER (KH HEAD) **Final**
Date: 26-Oct-15

Lab Sample No.		15/486A	15/486B	15/486C	15/487A	15/487B	15/487C
Client Sample No.		TPM25	TPM25	TPM25	TP35	TP35	TP35
Agent:		Normal Disp.	Dist. Water	Process Water	Normal Disp.	Dist. Water	Process Water
Description / Notes		0	0	0	0	0	0
Percentage Passing Size (mm)	0.075	70	9	14	73	47	50
	0.060	69	3	5	70	38	41
	0.050	68	0	1	68	34	37
	0.020	64	0	0	62	17	18
	0.005	56	0	0	55	0	0
	0.002	47	0	0	51	0	0
Particle Density		2.65	2.65	2.65	2.65	2.65	2.65
Percentage Dispersion on 2 Micron (BS1377:Part 5:1990:6.4 & ASTM D4221)		100%	0%	0%	100%	0.0%	0.0%

Note: Sample A: Dispersed; Sample B: Dist. Water; Sample C:Process Water



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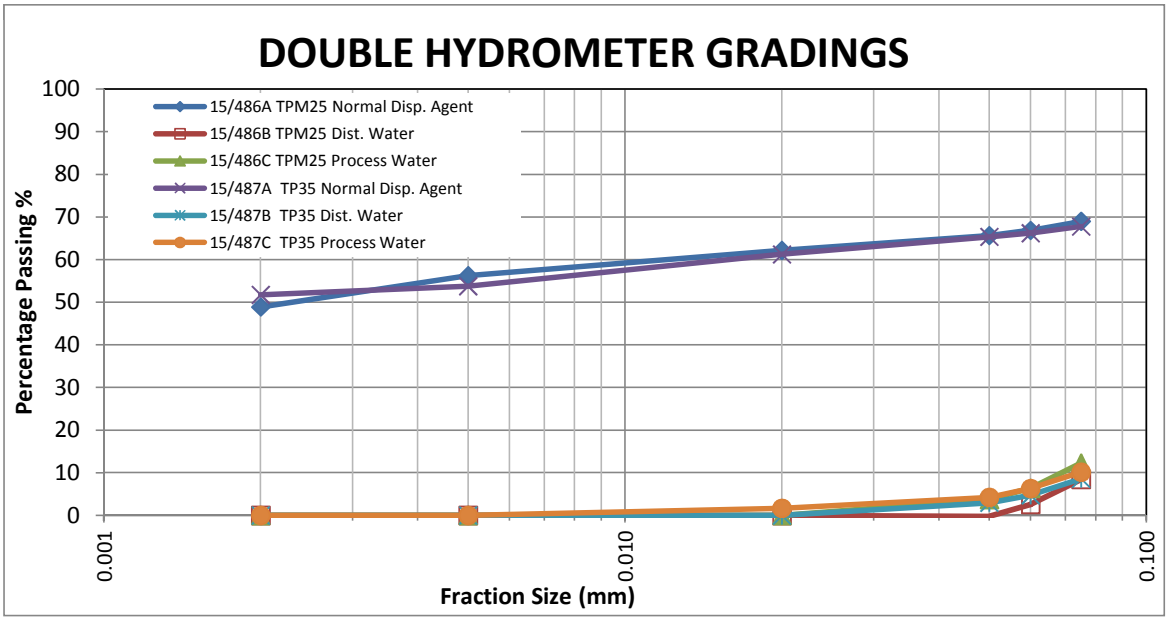
Project: Wesizwe Platinum
Test: DOUBLE HYDROMETER (KH HEAD) **Final**
Date: 28-Nov-15

Lab Sample No.		15/486A	15/486B	15/486C	15/487A	15/487B	15/487C
Client Sample No.		TPM25	TPM25	TPM25	TP35	TP35	TP35
Agent:		Normal Disp.	Dist. Water	Process Water	Normal Disp.	Dist. Water	Process Water
Description / Notes		-	-	-	-	-	-
Percentage Passing Size (mm)	0.075	69	8	12	68	9	10
	0.060	67	3	6	66	5	6
	0.050	66	0	4	65	3	4
	0.020	62	0	0	61	0	2
	0.005	56	0	0	54	0	0
	0.002	49	0	0	52	0	0
Particle Density		2.65	2.65	2.65	2.65	2.65	2.65
Percentage Dispersion on 2 Micron (BS1377:Part 5:1990:6.4 & ASTM D4221)		100%	0%	0%	100%	0.0%	0.0%

Note: Sample A: Dispersed; Sample B: Dist. Water; Sample C:Process Water



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Project:	Wesizwe
Sample Number:	TMP25
Sample Position:	0.4-1.4m
Test:	Falling Head Permeability (Page 1/2)
Sample Date:	-
Lab Number:	15/486
Test Date:	12-Oct-15

Preparation:

Method: Material moisture adjusted then compacted in 3 layers in mould to client target specified dry density target moisture.

Specified Dry Density (kg/m^3) & Opt. Moisture (%): 1510.0 @ 26.8%

Target of Dry Density (%): 95%

Target Dry Density (kg/m^3) & Moisture (%): 1434.5 @ 26.8%

Sample Diam. D (mm) :	63.19	Sample Moisture :	
Sample Length L (mm) :	63.18	Tin No:	MT33
Moist soil mass (g) :	364.60	Tin Weight (g):	38.322
Particle Density ρ_s :	*2.65*	Tin & Wet Soil (g):	100.252
Bulk Density (kg/m^3) :	1840.14	Tin & Dry Soil (g):	86.449
Dry Density (kg/m^3) :	1430.01	Moisture Content:	28.7%

Actual Dry Density (kg/m^3) & Moisture (%) Achieved: 1430.0 28.7%

Actual Density Achieved(%): 94.7%

Calculations:

		Volumetric Tube:	
Sample Area A:	3136.1 mm^2	$h_{1:\ Top}$ (cm):	354.0
Sample Volume V:	198.1 cm^3	$h_{2:\ Bottom}$ (cm):	294.5
Voids Ratio (ρ_S/ρ_D-1):	0.853	$V_{1\ Top}$ (cm^3):	0
		V_2 Bottom (cm^3):	100
Temperature (°C):	22	Tube Area a (mm^2):	168.1

Permeability: $k_T = 3.84(aL/At)\log10(h_1/h_2)x10^{-5}$ m/s (K.H. Head)

Permeability k = 4.2E-10 m/s

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Project:	Wesizwe
Sample Number:	TMP25
Sample Position:	0.4-1.4m
Test:	Falling Head Permeability (Page 2/2)
Sample Date:	-
Lab Number:	15/486
Test Date:	12-Oct-15

Measurement Data:

Date & Time	Elapsed Time (minutes)	Top Reading - In (ml)	Height above outlet h (mm)	Height h_1 h_2, h_3 per Run (mm)	Height Ratio (h1/h2)	Falling Head Permeability (m/s)
Run 1						
10/12/15 14:45	0	0.0	3540.0	3540.0	1.021	4.93E-10
10/12/15 16:00	75	0.0	3540.0			
10/13/15 7:40	1015	6.2	3503.1			
10/13/15 12:30	1305	7.8	3493.6			
10/13/15 15:50	1505	8.8	3487.6			
10/14/15 6:55	2410	12.4	3466.2	3466.2		**4.20E-10**
10/14/15 12:38	2753	13.8	3457.9			
10/14/15 15:50	2945	14.6	3453.1			
10/15/15 7:10	3865	17.8	3434.1			
10/15/15 12:35	4190	18.8	3428.1			
10/15/15 15:30	4365	19.4	3424.6			
10/16/15 10:37	5512	23.4	3400.8	3400.8	1.019	3.47E-10
						Final Moist 31.3%

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Project:	Wesizwe
Sample Number:	TMP25
Sample Position:	0.4-1.4m
Test:	Falling Head Permeability with TSF Water (Page 1/2)
Sample Date:	-
Lab Number:	15/486
Test Date:	16-Oct-15

Preparation:

Method: Material moisture adjusted then compacted in 3 layers in mould to client target specified dry density target moisture.

Specified Dry Density (kg/m^3) & Opt. Moisture (%): 1510.0 @ 26.8%

Target of Dry Density (%): 95%

Target Dry Density (kg/m^3) & Moisture (%): 1434.5 @ 26.8%

Sample Diam. D (mm) :	63.19	Sample Moisture :	
Sample Length L (mm) :	63.18	Tin No:	MT16
Moist soil mass (g) :	364.60	Tin Weight (g):	37.831
Particle Density ρ_s :	*2.65*	Tin & Wet Soil (g):	93.756
Bulk Density (kg/m^3) :	1840.14	Tin & Dry Soil (g):	81.833
Dry Density (kg/m^3) :	1447.83	Moisture Content:	27.1%

Actual Dry Density (kg/m^3) & Moisture (%) Achieved: 1447.8 27.1%

Actual Density Achieved(%): 95.9%

Calculations:

		Volumetric Tube:	
Sample Area A:	3136.1 mm^2	$h_{1:\ Top}$ (cm):	354.0
Sample Volume V:	198.1 cm^3	$h_{2:\ Bottom}$ (cm):	294.5
Voids Ratio (ρ_S/ρ_D-1):	0.830	$V_{1\ Top}$ (cm^3):	0
		V_2 Bottom (cm^3):	100
Temperature (°C):	22	Tube Area a (mm^2):	168.1

Permeability: $k_T = 3.84(aL/At)\log10(h_1/h_2)x10^{-5}$ m/s (K.H. Head)

Permeability k = 1.3E-10 m/s

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Project:	Wesizwe
Sample Number:	TMP25
Sample Position:	0.4-1.4m
Test:	Falling Head Permeability (Page 2/2)
Sample Date:	-
Lab Number:	15/486
Test Date:	16-Oct-15

Measurement Data:

Date & Time	Elapsed Time (minutes)	Top Reading - In (ml)	Height above outlet h (mm)	Height h_1 h_2, h_3 per Run (mm)	Height Ratio (h1/h2)	Falling Head Permeability (m/s)
Run 1						
10/16/15 13:45	0	0.0	3540.0	3540.0	1.008	1.53E-10
10/16/15 22:07	502	1.0	3534.1			
10/17/15 7:00	1035	2.4	3525.7			
10/17/15 13:00	1395	3.2	3521.0			
10/17/15 20:45	1860	3.8	3517.4			
10/18/15 8:35	2570	4.6	3512.6			
10/18/15 17:35	3110	5.0	3510.3	3510.3		**1.33E-10**
10/19/15 7:20	3935	6.0	3504.3			
10/19/15 12:00	4215	6.2	3503.1			
10/19/15 16:00	4455	6.2	3503.1			
10/19/15 23:14	4889	6.8	3499.5			
10/20/15 7:00	5355	7.4	3496.0			
10/20/15 13:00	5715	8.0	3492.4			
10/20/15 16:00	5895	8.2	3491.2			
10/21/15 8:10	6865	9.4	3484.1	3484.1	1.008	1.13E-10
						Final Moist 30.6%

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bennie@geotesting.co.za

Project:		Wesizwe
Sample Number:		TMP25
Sample Position:		0.4-1.4m
Test:	Falling Head Permeability with	TSF Water 2(Page 1/2)
Sample Date:		-
Lab Number:		15/486 (2)
Test Date:		18-Nov-15

Preparation:

Method: Material moisture adjusted then compacted in 3 layers in mould to client target specified dry density target moisture.

Specified Dry Density (kg/m^3) & Opt. Moisture (%): 1510.0 @ 26.8%

Target of Dry Density (%): 95%

Target Dry Density (kg/m^3) & Moisture (%): 1434.5 @ 26.8%

Sample Diam. D (mm) :	63.18	Sample Moisture :	
Sample Length L (mm) :	63.04	Tin No:	MT03
Moist soil mass (g) :	364.60	Tin Weight (g):	38.262
Particle Density ρ_s :	*2.65*	Tin & Wet Soil (g):	102.440
Bulk Density (kg/m^3) :	1844.81	Tin & Dry Soil (g):	88.091
Dry Density (kg/m^3) :	1432.34	Moisture Content:	28.8%

Actual Dry Density (kg/m^3) & Moisture (%) Achieved: 1432.3 28.8%

Actual Density Achieved(%): 94.9%

Calculations:

		Volumetric Tube:	
Sample Area A:	3135.1 mm^2	$h_{1:\ Top}$ (cm):	354.0
Sample Volume V:	197.6 cm^3	$h_{2:\ Bottom}$ (cm):	294.5
Voids Ratio (ρ_S/ρ_D-1):	0.850	$V_{1\ Top}$ (cm^3):	0
		V_2 Bottom (cm^3):	100
Temperature (°C):	22	Tube Area a (mm^2):	168.1

Permeability: $k_T = 3.84(aL/At)\log10(h_1/h_2)x10^{-5}$ m/s (K.H. Head)

Permeability k = 2.6E-09 m/s

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Project: Wesizwe
Sample Number: TMP25
Sample Position: 0.4-1.4m
Test: Falling Head Permeability (Page 2/2)
Sample Date: -
Lab Number: 15/486 (2)
Test Date: 18-Nov-15

Measurement Data:

Date & Time	Elapsed Time (minutes)	Top Reading - In (ml)	Height above outlet h (mm)	Height h_1 h_2, h_3 per Run (mm)	Height Ratio (h1/h2)	Falling Head Permeability (m/s)
Run 1						
11/18/15 13:00	0	0.0	3540.0	3540.0	1.061	2.97E-09
11/18/15 16:00	180	8.4	3490.0			
11/18/15 21:15	495	17.9	3433.5			
11/19/15 7:40	1120	34.1	3337.1	3337.1		**2.64E-09**
11/19/15 12:40	1420	41.2	3294.9			
11/19/15 15:40	1600	45.2	3271.1			
11/19/15 20:21	1881	52.0	3230.6			
11/20/15 6:20	2600	64.3	3157.4			
11/20/15 12:05	2825	72.0	3111.6	3111.6	1.072	2.31E-09
11/22/15 15:40	5920	138.0	2718.9			
						Final Moist 31.9%

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Project:	Wesizwe
Sample Number:	TP35
Sample Position:	0.4-1.5m
Test:	Falling Head Permeability (Page 1/2)
Sample Date:	-
Lab Number:	15/487
Test Date:	12-Oct-15

Preparation:

Method: Material moisture adjusted then compacted in 3 layers in mould to client target specified dry density target moisture.

Specified Dry Density (kg/m^3) & Opt. Moisture (%): 1470.0 @ 26.2%

Target of Dry Density (%): 95%

Target Dry Density (kg/m^3) & Moisture (%): 1396.5 @ 26.2%

Sample Diam. D (mm) :	63.58	Sample Moisture :	
Sample Length L (mm) :	63.37	Tin No:	MT14
Moist soil mass (g) :	338.90	Tin Weight (g):	38.239
Particle Density ρ_s :	*2.65*	Tin & Wet Soil (g):	104.311
Bulk Density (kg/m^3) :	1684.45	Tin & Dry Soil (g):	89.623
Dry Density (kg/m^3) :	1309.99	Moisture Content:	28.6%

Actual Dry Density (kg/m^3) & Moisture (%) Achieved: 1310.0 28.6%

Actual Density Achieved(%): 89.1%

Calculations:

		Volumetric Tube:	
Sample Area A:	3174.9 mm^2	$h_{1:\ Top}$ (cm):	345.8
Sample Volume V:	201.2 cm^3	$h_{2:\ Bottom}$ (cm):	286.3
Voids Ratio (ρ_S/ρ_D-1):	1.023	$V_{1\ Top}$ (cm^3):	0
		V_2 Bottom (cm^3):	100
Temperature (°C):	22	Tube Area a (mm^2):	168.1

Permeability: $k_T = 3.84(aL/At)\log10(h_1/h_2)x10^{-5}$ m/s (K.H. Head)

Permeability k = 1.9E-09 m/s

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Project:	Wesizwe
Sample Number:	TP35
Sample Position:	0.4-1.5m
Test:	Falling Head Permeability (Page 2/2)
Sample Date:	-
Lab Number:	15/487
Test Date:	12-Oct-15

Measurement Data:

Date & Time	Elapsed Time (minutes)	Top Reading - In (ml)	Height above outlet h (mm)	Height h_1 h_2, h_3 per Run (mm)	Height Ratio (h1/h2)	Falling Head Permeability (m/s)
Run 1						
10/12/15 14:45	0	0.0	3458.0	3458.0	1.124	2.71E-09
10/12/15 16:00	75	10.2	3397.3			
10/13/15 7:40	1015	44.0	3196.2			
10/13/15 12:30	1305	47.8	3173.6			
10/13/15 15:50	1505	50.4	3158.1			
10/14/15 6:50	2405	64.0	3077.2	3077.2		**1.95E-09**
10/14/15 12:38	2753	68.0	3053.4			
10/14/15 15:50	2945	70.2	3040.3			
10/15/15 7:10	3865	80.0	2982.0			
10/15/15 10:50	4085	82.0	2970.1	2970.1	1.036	1.18E-09
						Final Moist 39.5%

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Project:	Wesizwe
Sample Number:	TP35
Sample Position:	0.4-1.5m
Test:	Falling Head Permeability with TSF Water (Page 1/2)
Sample Date:	-
Lab Number:	15/487
Test Date:	16-Oct-15

Preparation:

Method: Material moisture adjusted then compacted in 3 layers in mould to client target specified dry density target moisture.

Specified Dry Density (kg/m^3) & Opt. Moisture (%): 1470.0 @ 26.2%

Target of Dry Density (%): 95%

Target Dry Density (kg/m^3) & Moisture (%): 1396.5 @ 26.2%

Sample Diam. D (mm) :	63.58	Sample Moisture :	
Sample Length L (mm) :	64.37	Tin No:	MT44
Moist soil mass (g) :	338.90	Tin Weight (g):	38.067
Particle Density ρ_s :	*2.65*	Tin & Wet Soil (g):	98.409
Bulk Density (kg/m^3) :	1658.28	Tin & Dry Soil (g):	85.477
Dry Density (kg/m^3) :	1302.89	Moisture Content:	27.3%

Actual Dry Density (kg/m^3) & Moisture (%) Achieved: 1302.9 27.3%

Actual Density Achieved(%): 88.6%

Calculations:

		Volumetric Tube:	
Sample Area A:	3174.9 mm^2	$h_{1:\ Top}$ (cm):	345.8
Sample Volume V:	204.4 cm^3	$h_{2:\ Bottom}$ (cm):	286.3
Voids Ratio (ρ_S/ρ_D-1):	1.034	$V_{1\ Top}$ (cm^3):	0
		V_2 Bottom (cm^3):	100
Temperature (°C):	22	Tube Area a (mm^2):	168.1

Permeability: $k_T = 3.84(aL/At)\log10(h_1/h_2)x10^{-5}$ m/s (K.H. Head)

Permeability k = 5.8E-10 m/s

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Project: Wesizwe
Sample Number: TP35
Sample Position: 0.4-1.5m
Test: Falling Head Permeability (Page 2/2)
Sample Date: -
Lab Number: 15/487
Test Date: 16-Oct-15

Measurement Data:

Date & Time	Elapsed Time (minutes)	Top Reading - In (ml)	Height above outlet h (mm)	Height h_1 h_2, h_3 per Run (mm)	Height Ratio (h1/h2)	Falling Head Permeability (m/s)
Run 1						
10/16/15 13:45	0	0.0	3458.0	3458.0	1.155	4.42E-09
10/16/15 22:07	502	54.2	3135.5			
10/17/15 7:00	1035	68.2	3052.2			
10/17/15 13:00	1395	73.6	3020.1			
10/17/15 20:45	1860	78.2	2992.7	2992.7		**2.58E-09**
10/18/15 8:35	2570	83.5	2961.2			
10/18/15 17:45	3120	87.0	2940.4			
10/19/15 7:20	3935	91.6	2913.0	2913.0	1.027	7.40E-10
Run 2						
10/19/15 8:00	0	0.0	3458.0	3458.0	1.019	6.01E-10
10/19/15 12:00	240	1.2	3450.9			
10/19/15 16:00	480	2.8	3441.3			
10/19/15 23:14	914	6.0	3422.3			
10/20/15 7:00	1380	8.6	3406.8			
10/20/15 13:00	1740	10.6	3394.9	3394.9		**5.79E-10**
10/20/15 16:00	1920	11.4	3390.2			
10/21/15 8:10	2890	17.0	3356.9	3356.9	1.011	5.57E-10
						Final Moist 36.1%

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Project:	Wesizwe
Sample Number:	TP35
Sample Position:	0.4-1.5m
Test:	Falling Head Permeability with TSF Water 2(Page 1/2)
Sample Date:	-
Lab Number:	15/487 (2) Rev 1
Test Date:	12-Oct-15

Preparation:

Method: Material moisture adjusted then compacted in 3 layers in mould to client target specified dry density target moisture.

Specified Dry Density (kg/m^3) & Opt. Moisture (%): 1470.0 @ 26.2%

Target of Dry Density (%): 95%

Target Dry Density (kg/m^3) & Moisture (%): 1396.5 @ 26.2%

Sample Diam. D (mm) :	63.58	Sample Moisture :	
Sample Length L (mm) :	63.37	Tin No:	MT51
Moist soil mass (g) :	338.90	Tin Weight (g):	37.418
Particle Density ρ_s :	*2.65*	Tin & Wet Soil (g):	100.205
Bulk Density (kg/m^3) :	1684.45	Tin & Dry Soil (g):	84.967
Dry Density (kg/m^3) :	1275.64	Moisture Content:	32.0%

Actual Dry Density (kg/m^3) & Moisture (%) Achieved: 1275.6 32.0%

Actual Density Achieved(%): 86.8%

Calculations:

		Volumetric Tube:	
Sample Area A:	3174.9 mm^2	$h_{1:\ Top}$ (cm):	345.8
Sample Volume V:	201.2 cm^3	$h_{2:\ Bottom}$ (cm):	286.3
Voids Ratio (ρ_S/ρ_D-1):	1.077	$V_{1\ Top}$ (cm^3):	0
		V_2 Bottom (cm^3):	100
Temperature (°C):	22	Tube Area a (mm^2):	168.1

Permeability: $k_T = 3.84(aL/At)\log10(h_1/h_2)x10^{-5}$ m/s (K.H. Head)

Permeability k = 2.8E-09 m/s

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Project: Wesizwe
Sample Number: TP35
Sample Position: 0.4-1.5m
Test: Falling Head Permeability (Page 2/2)
Sample Date: -
Lab Number: 15/487 (2) Rev 1
Test Date: 12-Oct-15

Measurement Data:

Date & Time	Elapsed Time (minutes)	Top Reading - In (ml)	Height above outlet h (mm)	Height h_1 h_2, h_3 per Run (mm)	Height Ratio (h1/h2)	Falling Head Permeability (m/s)
Run 1						
11/18/15 13:00	0	0.0	3458.0	3458.0	1.089	9.66E-09
11/18/15 16:00	180	25.2	3308.1			
11/18/15 21:15	495	47.6	3174.8	3174.8		**6.92E-09**
11/19/15 9:40	1240	76.2	3004.6			
11/19/15 12:40	1420	85.0	2952.3			
11/19/15 15:40	1600	90.0	2922.5	2922.5	1.086	4.19E-09
11/19/15 15:45	0	0.0	3458.0	3458.0	1.080	3.52E-09
11/19/15 20:21	276	11.0	3392.6			
11/20/15 6:20	875	31.6	3270.0			
11/20/15 12:05	1220	43.0	3202.2	3202.2		**2.77E-09**
11/22/15 15:40	4315	100.0	2863.0	2863.0	1.118	2.02E-09
						Final Moist 42.2%

APPENDIX G
HYDROGEOLOGICALSTUDIES REVIEW

Knight Piésold CONSULTING

Knight Piésold (Pty) Ltd
Pretoria, Republic of South Africa

Memorandum

To:	Andries Strauss	Date:	26 October 2015
From:	Dawid Mouton	File #:	3010050902

Subject: **REVIEW OF WESIZWE PLATINUM GEOHYDROLOGICAL EVALUATION**

Dear Andries

Herewith a brief review of the above-mentioned report:

1. INTRODUCTION

TWP Environmental Services (TWP-ES) appointed African Environmental International (AEI) to perform a geohydrological survey of the Wesizwe Platinum Mine as part of mining application and bankable feasibility study. The affected project area entails about 507ha and was subdivided into mine/plant area and tailings facility.

The project methodology followed is considered adequate for this level of investigation, which included a desk study/reconnaissance portion, followed by hydro census, geophysical surveys, borehole drilling, pump testing and sampling for geochemistry. Near-surface soils investigations were also performed to determine the coefficients of permeability of the surface/floor horizons (buffer capacity of receiving soils). AEI also set up a geohydrological model of the findings as part of the development of a numerical model. This was used to develop a groundwater flow and transport model to predict impacts on the receiving groundwater environment.

2. RELEVANT SITE INFORMATION

The site is underlain by the Rustenburg Layered Suite of the Bushveld Complex, which essentially comprises norite, gabbro and anorthosite. The study area is faulted and together with dyke intrusions, caused that groundwater is mainly manifested as secondary aquifer within deeply weathered and fractured rocks. The area classifies as a “Minor Aquifer System”, which implies relatively low-yielding boreholes, as well as significant variation. This aquifer is, however, important for local water supply and to supplying base flow for rivers. The aquifer vulnerability, as well as aquifer susceptibility, was determined and both classified as “medium”.

3. SITE INVESTIGATIONS

The scope of the site investigations is summarised as follows:

- Electrical Resistivity Surveys: Two profiles on Mimosa
  Four profiles on Frischgewaad

- 15 boreholes were drilled in total in the mining site area. Some of these include pairs of shallow and deeper holes to study potential multilayer aquifer system.
- 12 rock samples were tested for Acid-Base accounting. All rocks classified as non-acid forming, except for a single pyroxenite sample, which is intermediate acid forming.
- Results of the Cation Exchange Capacity (CEC) indicated high values, which is typical for clayey soils. It was postulated that the potential leachate from the tailings facility would probably exceed the retardation capacity of the soil zone.
- Both hydro census and NGDB data were used to determine groundwater use (domestic and irrigation). The average yield of a successful borehole in the area is 1ℓ/s to 1,5ℓ/s.
- It was found that a reasonable correlation exists between topography and static groundwater depth for the boreholes where depth <30m. This result was used to prepare a static water level contour map (Figure 4). This should be viewed as an oversimplification, since there are many local factors that would affect groundwater gradients and flow direction.
- The report provides detailed accounts of the groundwater chemistry. It is suffice to conclude that the groundwater falls in the Ca-Mg-HCO_3 field, indicating recently recharged conditions. Some of the tests indicate some influence of pollutants, possibly due to agricultural or rural influences. The extent of the chemical testing is probably sufficient for base line information, but the chemical testing should be continued on, say, 6 months intervals to expand the knowledge base and to determine normal fluctuation over time before mining activities have been commenced.
- Hydraulic conductivity in the various rock/soil types varies considerable, but is generally low (coefficient of permeability 4 x 10^{-8}m/s) to moderate (1 x 10^{-5}m/s). It follows that groundwater flow will generally be extremely slow to moderately slow.
- Results of double ring infiltration testing conducted at shallow depth, indicate coefficient of permeability (k) values of about 1 x 10^{-6}m/s. This value is somewhat higher than what is expected for predominantly clayey soil.

4. GROUNDWATER MODELLING

Based on the results of available information and groundwater site investigations, a simplified conceptual geohydrological model was developed. It was essentially based on the following assumptions:

- Boundary conditions were assumed as the Elands River (south), drainage channels (west and east) and the Pilansberg water divide (north).
- Heterogenic aquifer with no apparent correlation with known geological features.

- The representative elementary volume principle was used, which allows for average aquifer parameters over large volumes of aquifer material.
- The model is therefore not sensitive to deal with local variations and cannot model head distributions.
- It was concluded that the groundwater is mostly encountered in weathered base aquifer, combined with localised deeper weathered zones associated with vertical rock fracturing.

5. NUMERICAL MODEL

A 2-dimensional numerical model was developed to predict groundwater flow direction and plume migration. The model calibration was performed using the measured groundwater levels. A range of sensitivity analyses was also conducted for 5 different zones in the study area. Different negative impacts were identified and modelled as follows:

- Excessive Lowering (>6m) of groundwater table: area of influence confined to 700m around shaft area.
- Contamination during operation: A wide range of between 2m to 200m per year was determined for the tailings area due to uncertainties in the distribution of fractured aquifer system in the surrounding hard rock aquifer. The modelled results showed plume migration of 300m over 15 years.
- Plume migration in shaft area was considered to be somewhat less (220m over 15 years) than tailings area, due to relatively low rock mass permeabilities encountered in the shaft area.

6. COMMENTS ON REPORT

The Geohydrological Report by African Engineering International is considered a comprehensive account of the work performed on feasibility level. The investigation approach and methodology followed were in accordance with standard practise and their results based on sound assumptions. The work forms a sound basis for detailed design phase studies. The following aspects should particularly be attended to:

- The generalised model whereby topography mimics the groundwater level is oversimplified and this should be improved to allow for localised influences of structural geology and lithology.
- The numerical flow model must be refined by conducting further investigations in the affected areas of plume migration to determine hydraulic properties more accurately. Particularly, the affect of the Rustenburg Fault system should be investigated in more detail.

- The groundwater monitoring must continue as outlined in the report. Seasonal fluctuations must be determined of groundwater levels, but also possible affects on groundwater quality. It is important to establish reliable groundwater based line data.
- It is foreseen that detailed design level geohydrological investigations should include the following:
  - Electrical resistivity and/or electromagnetic surveys, particularly to identify structural features that could affect the groundwater model.
  - Percussion drilling within the assumed affected areas.
  - Pump testing to determine hydraulic conductivity and transmissivity properties.
  - Water quality testing.
  - Updating groundwater and numerical models.

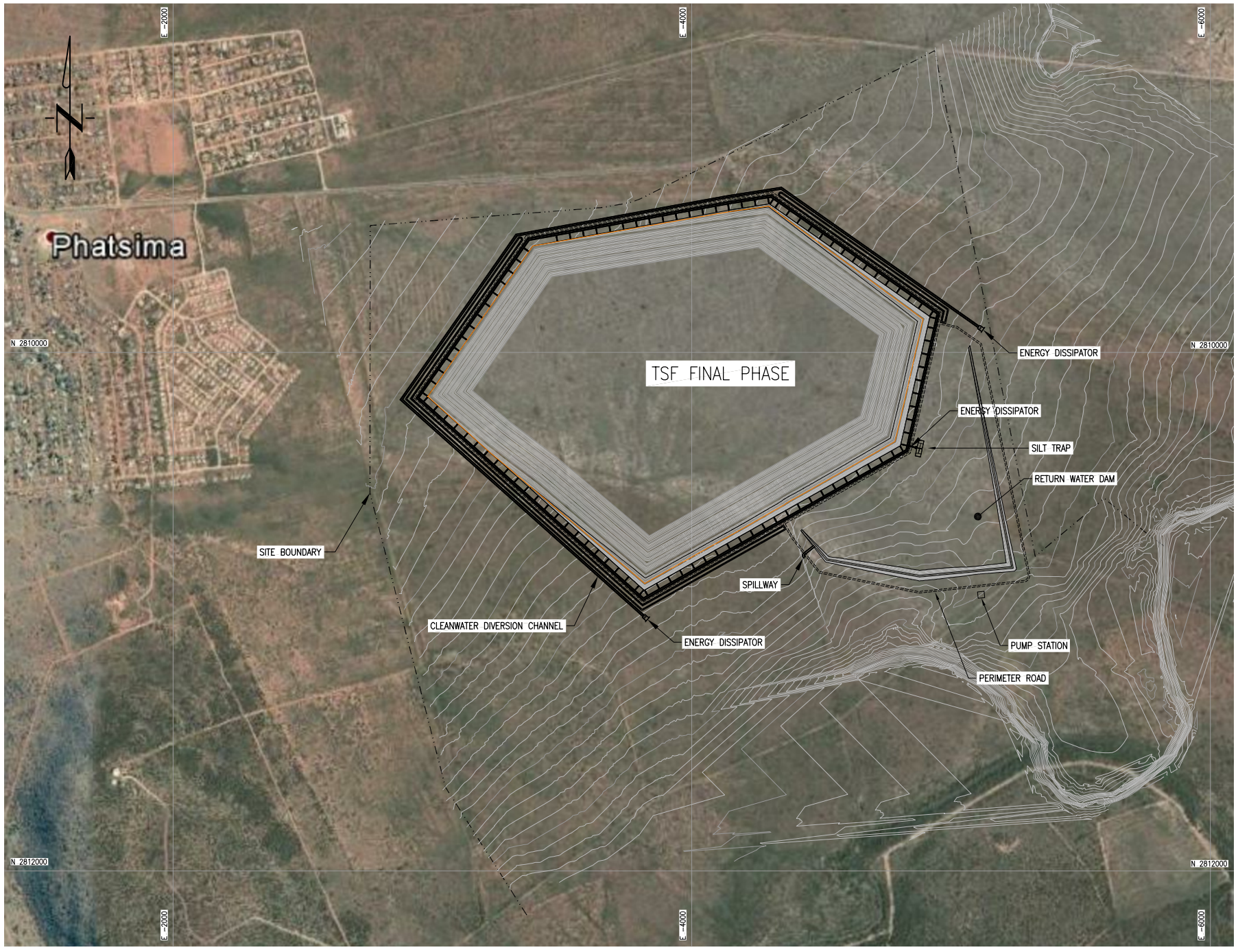
Kind regards

DAWID MOUTON Pr.Sci.Nat.

WESIZWE PLATINUM

MIMOSA TSF DESIGN

PRO. NO. 301-00509/02



LIST OF DRAWINGS		
DRAWING NO.	DRAWING DESCRIPTION	REVISION
301-00509/02-000	LOCALITY PLAN AND LIST OF DRAWINGS	A
301-00509/02-001	GENERAL ARRANGEMENT	A
301-00509/02-002	PHASE 1 – PROJECTED CONSTRUCTION	A
301-00509/02-003	PHASE 1 – EARTHWORKS AND FILTER DRAIN DETAILS AND SECTIONS	A
301-00509/02-004	PHASE 1 – LONGITUDINAL SECTIONS	A
301-00509/02-005	TRAINING WALL LAYOUT AND SECTIONS	A
301-00509/02-006	PHASE 1 – SLURRY DISTRIBUTION PIPELINE AND DETAILS	A
301-00509/02-007	PERMANENT DECANT DETAILS AND SECTIONS	A
301-00509/02-008	SILT TRAP DETAILS AND SECTIONS	A
301-00509/02-009	PHASE 2 – PROJECTED CONSTRUCTION LAYOUT AND SECTIONS	A
301-00509/02-010	PHASE 3 – PROJECTED CONSTRUCTION LAYOUT AND SECTIONS	A
301-00509/02-011	PHASE 3 – SLURRY DISTRIBUTION PIPELINE AND DETAILS	A
301-00509/02-012	INTERMEDIATE DECANT – CATWALK PLATFORM AND WALKWAY DETAILS	A
301-00509/02-013	PERMANENT DECANT – CATWALK PLATFORM AND WALKWAY DETAILS	A
301-00509/02-014	INSTRUMENTATION LAYOUT AND DETAILS	A
301-00509/02-015	LONGITUDINAL SECTIONS	A

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PRIMARY DISCIPLINE	CIVIL	
DRAWN	ME	28/09/2015
DRAWING CHECK	TM & JZ	28/09/2015
DESIGN	RG	28/09/2015
DESIGN CHECK	AS	28/09/2015
PROJECT ENGINEER	AS	–

REVISION					
REV.No.	DATE	DESCRIPTION	DRAWN	CHKD.	APPD.
A	22.01.16	ISSUED FOR INFORMATION	ME	MM	AS
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REFERENCE DRAWINGS		
DRAWING No.	MAKERS No.	TITLE
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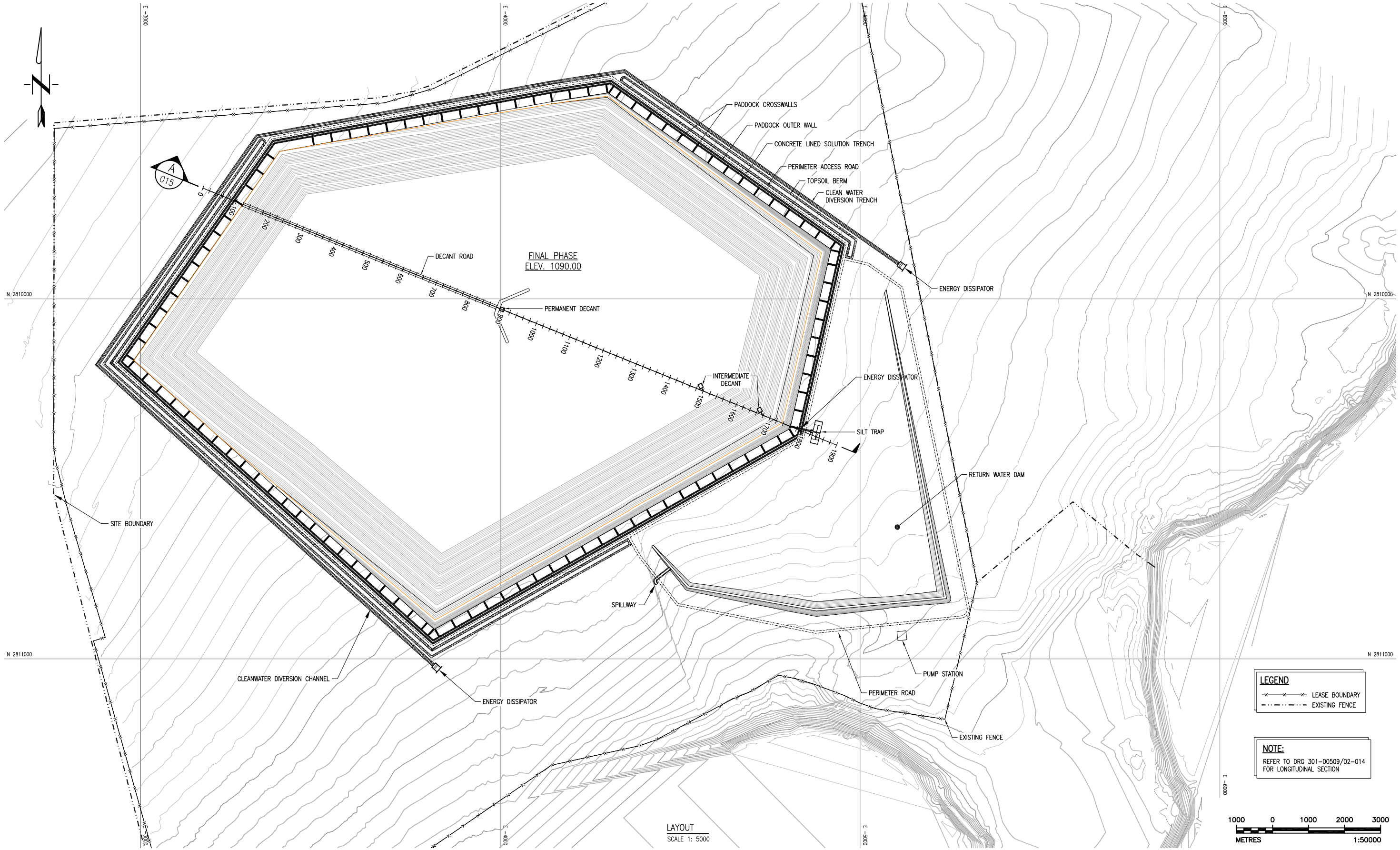
WESIZWE PLATINUM LTD.

MIMOSA TSF DESIGN

LOCALITY MAP AND LIST OF DRAWINGS

DRAWING NUMBER	SCALE	REV.
301-00509/02-000	AS SHOWN	A

P:\301-00509\02\A\DRAWINGS\KP\FOR INFORMATION\301 00509-02-000 Rev4.dwg



LAYOUT
SCALE 1: 5000

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PRIMARY DISCIPLINE	CIVIL	
DRAWN	ME	28/08/2015
DRAWING CHECK	TM & JZ	28/08/2015
DESIGN	RG	28/08/2015
DESIGN CHECK	AS	28/08/2015
PROJECT ENGINEER	AS	–

REVISION

REV.No.	DATE	DESCRIPTION	DRAWN	CHKD.	APPD.
A	22.01.16	ISSUED FOR INFORMATION	ME	MM	AS

REFERENCE DRAWINGS

DRAWING No.	MAKERS No.	TITLE
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MIMOSA TSF DESIGN
GENERAL ARRANGEMENT

DRAWING NUMBER	SCALE	REV.
301-00509/02-001	AS SHOWN	A

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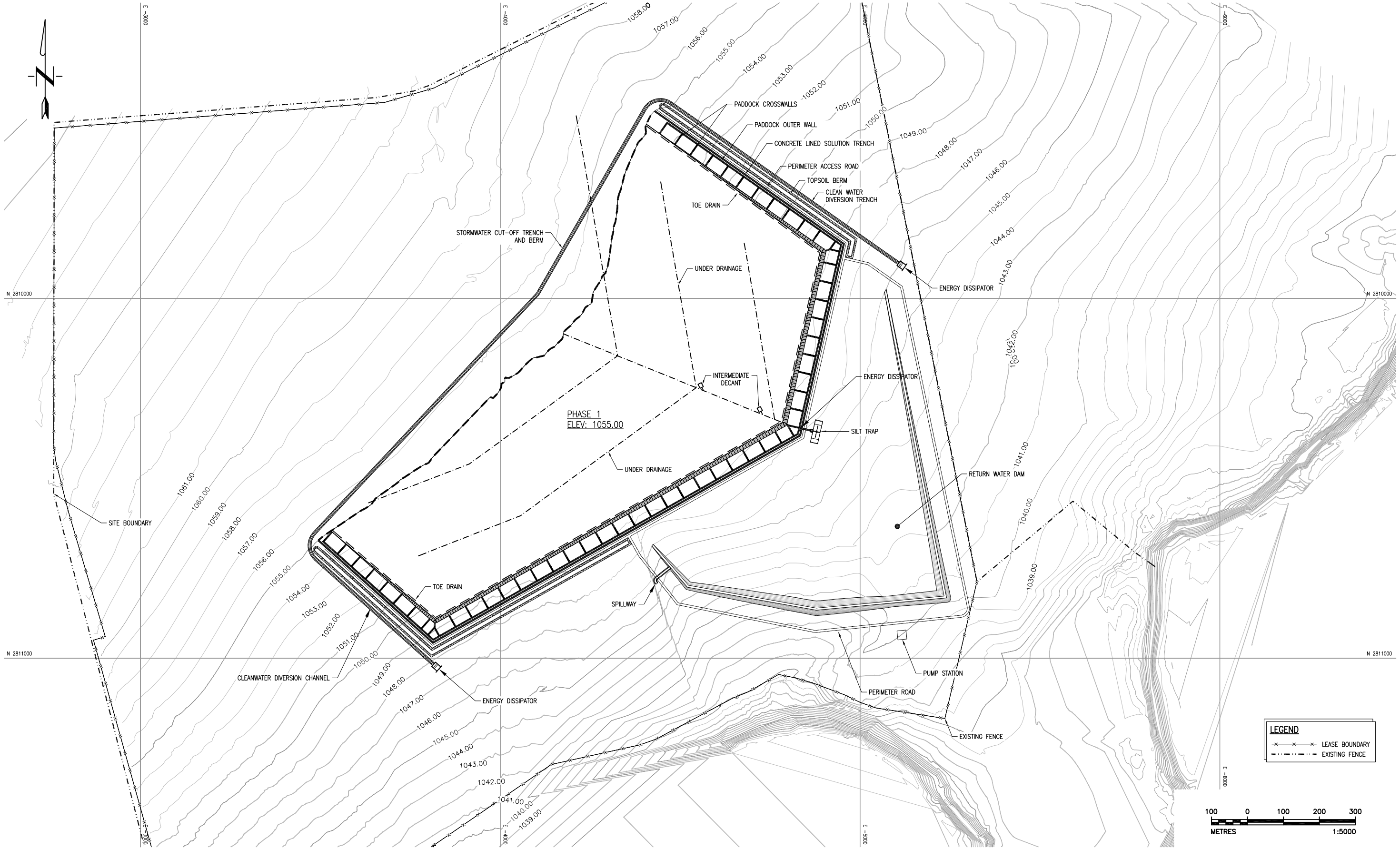

Knight Piésold CONSULTING

PRIMARY DISCIPLINE	CIVIL	
DRAWN	ME	28/08/2015
DRAWING CHECK	TM & JZ	28/08/2015
DESIGN	RG	28/08/2015
DESIGN CHECK	AS	28/08/2015
PROJECT ENGINEER	AS	–

REVISION

REV.No.	DATE	DESCRIPTION	DRAWN	CHKD.	APPD.
A	22.01.16	ISSUED FOR INFORMATION	ME	MM	AS

REFERENCE DRAWINGS

DRAWING No.	MAKERS No.	TITLE
–	–	–

WESIZWE PLATINUM LTD.
MIMOSA TSF DESIGN
PROJECTED CONSTRUCTION
PHASE 1
LAYOUT

DRAWING NUMBER	SCALE	REV.
301-00509/02-002	1: 5000	A

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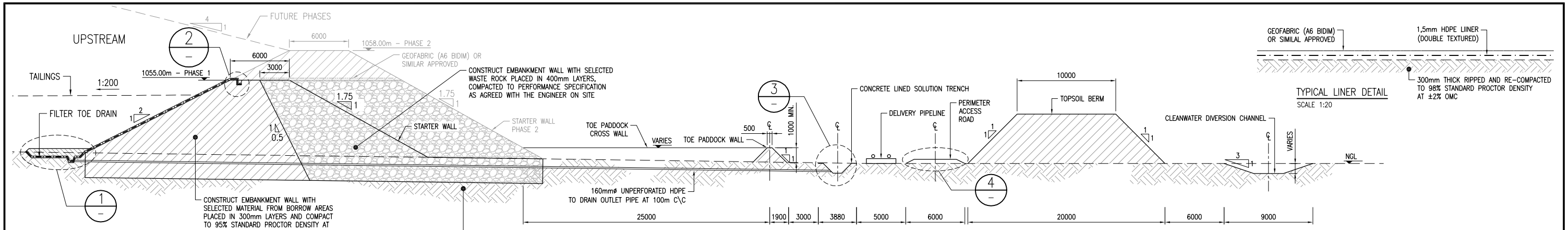
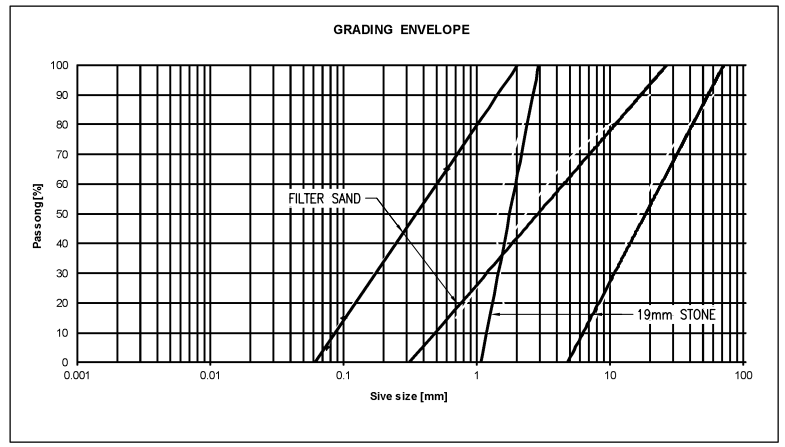
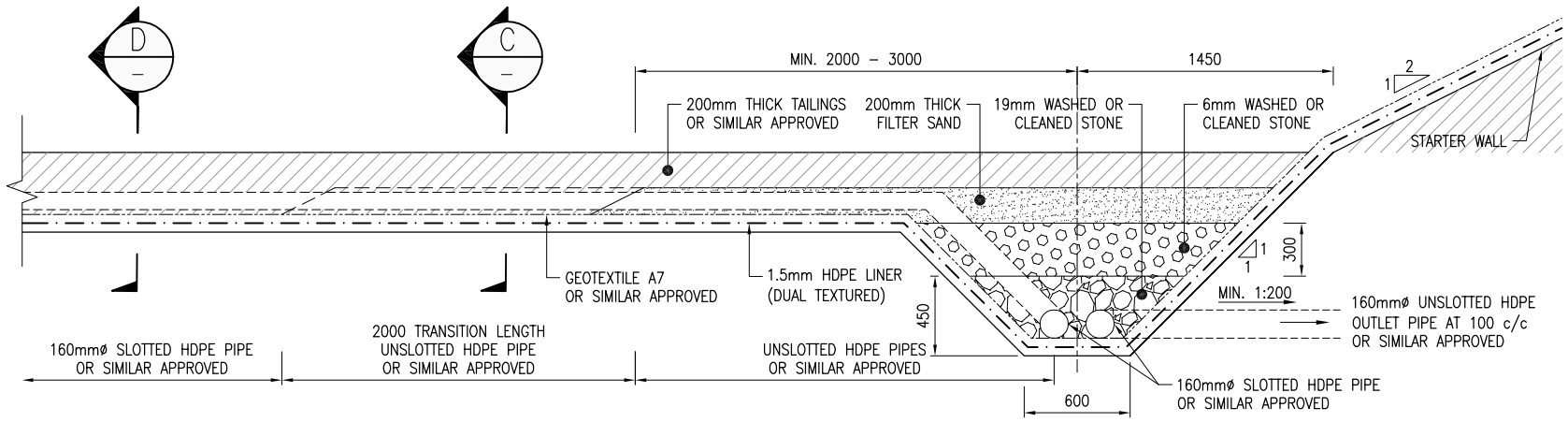


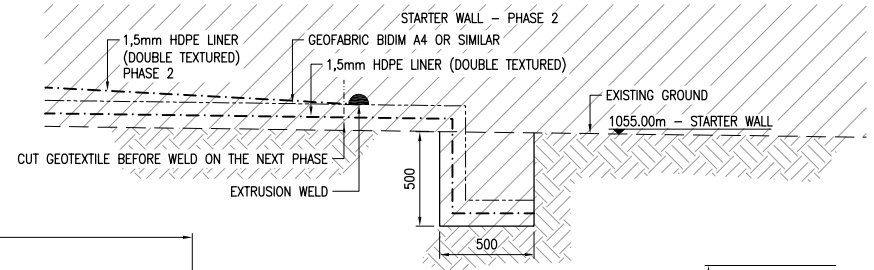
TYPICAL LINER DETAIL
SCALE 1:20

A 002 PHASE 1 – TYPICAL SECTION
SCALE 1:200

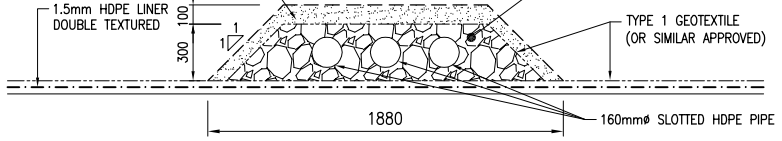




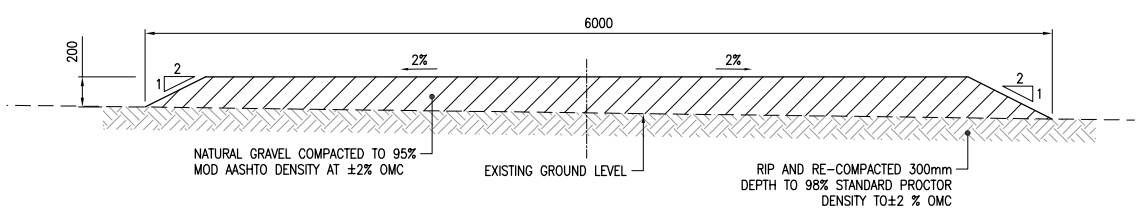
1 – TYPICAL DETAIL AT FILTER TOE DRAIN
SCALE 1:25



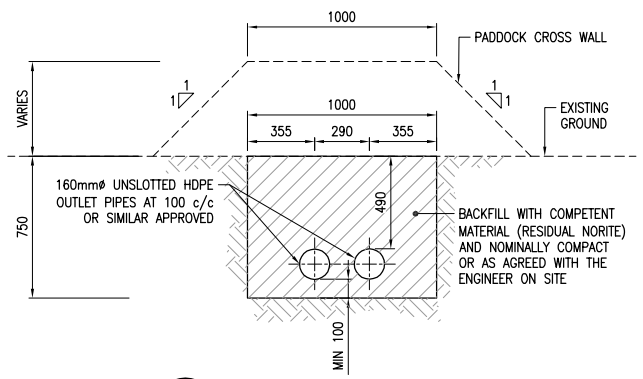
2 – TYPICAL ANCHOR TRENCH DETAIL
SCALE 1:20



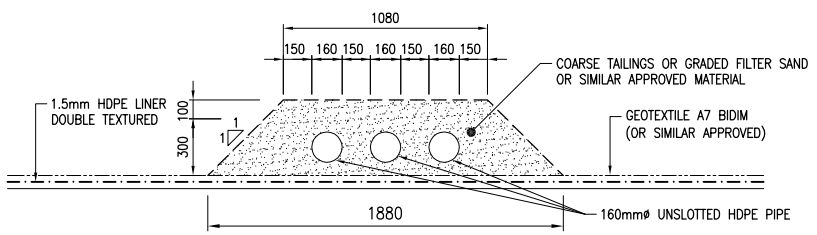
D – TYPICAL HERRING BONE DRAINS
SCALE 1:20



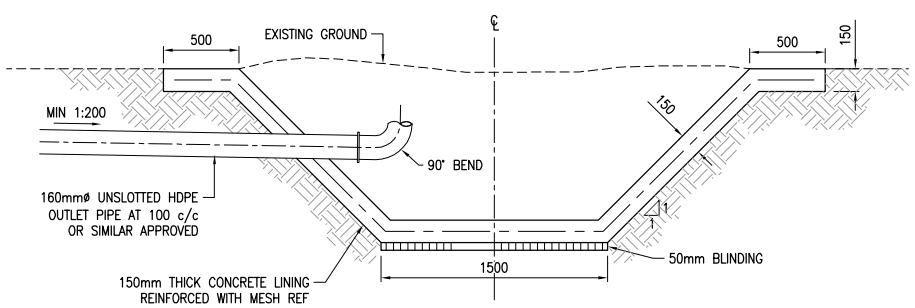
4 – TYPICAL PERIMETER ACCESS ROAD DETAIL
SCALE 1:25



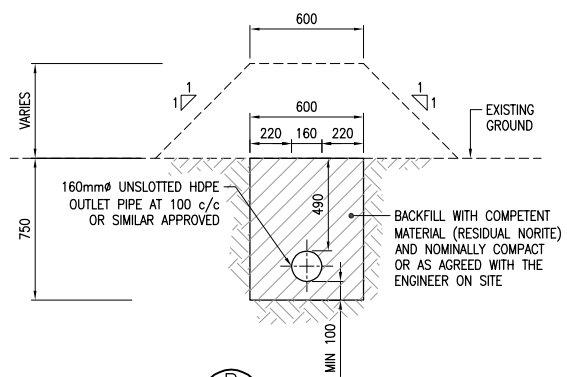
C 002 TYPICAL HERRING BONE DRAINS OUTLET PIPE
SCALE 1:20



C – TYPICAL HERRING BONE DRAINS AT TRANSITION ZONE
SCALE 1:20



3 – TYPICAL CONCRETE SOLUTION TRENCH DETAIL
SCALE 1:25



B 002 TYPICAL TOE DRAIN OUTLET PIPE
SCALE 1:20

500 0 500 1000 1500
MILLIMETRES 1:20

500 0 500 1000 1500
MILLIMETRES 1:25

5 0 5 10 15
METRES 1:200

Knight Piésold CONSULTING

PRIMARY DISCIPLINE	CIVIL	
DRAWN	ME	28/08/2015
DRAWING CHECK	TM & JZ	28/08/2015
DESIGN	RG	28/08/2015
DESIGN CHECK	AS	28/08/2015
PROJECT ENGINEER	AS	–

REVISION						
REV.No.	DATE	DESCRIPTION	DRAWN	CHKD.	APPD.
A	22.01.16	ISSUED FOR INFORMATION	ME	MM	AS

REFERENCE DRAWINGS		
DRAWING No.	MAKERS No.	TITLE
–	–	–

WESIZWE PLATINUM LTD.
MIMOSA TSF DESIGN
PHASE 1
EARTHWORKS AND FILTER DRAIN
DETAILS AND SECTIONS

DRAWING NUMBER	SCALE	REV.
301-00509/02-003	AS SHOWN	A

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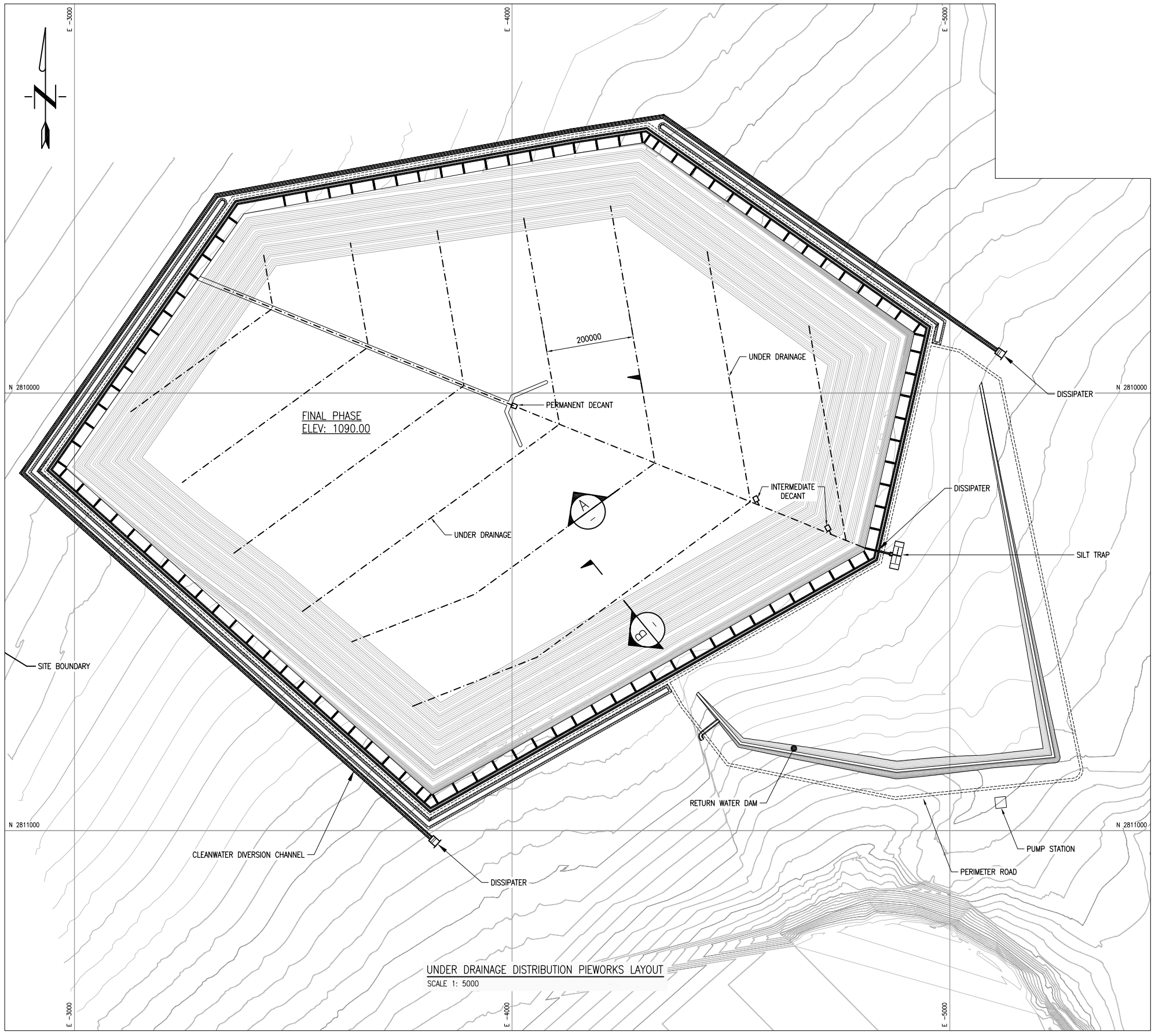
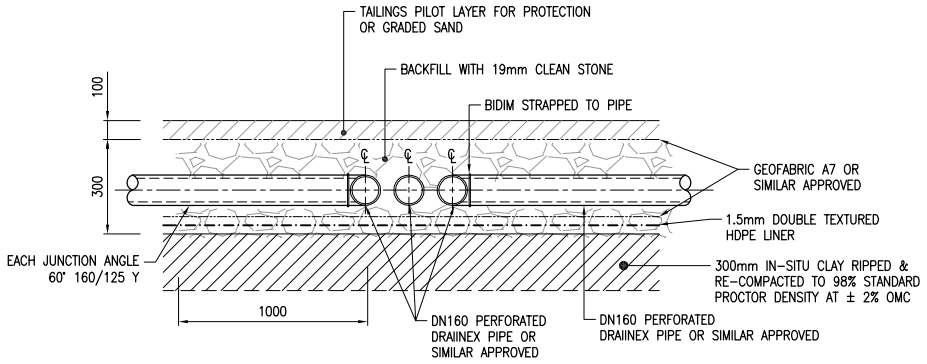
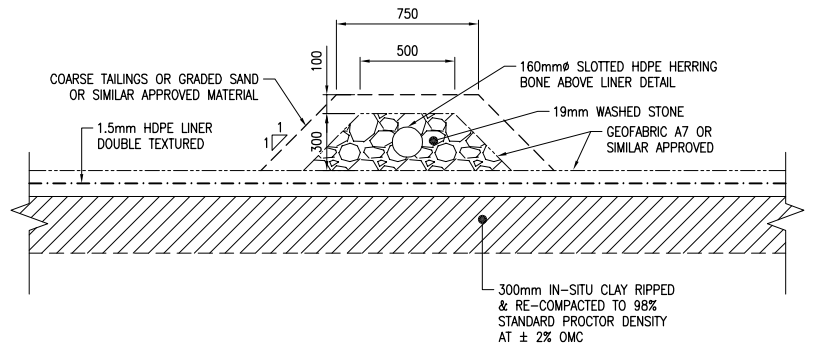


UNDER DRAINAGE DISTRIBUTION PIEWORKS LAYOUT
SCALE 1: 5000



A — TYPICAL UNDER DRAINAGE JUNCTION SECTION
SCALE 1:20



B — TYPICAL LINER DETAIL WITH DRAINS
SCALE 1:20

NOTE:
HERRING BONE DRAIN TIE INTO TOE DRAIN

500 0 500 1000 1500
MILLIMETRES 1:20

100 0 100 200 300
METRES 1:5000

Knight Piésold CONSULTING

PRIMARY DISCIPLINE	CIVIL	
DRAWN	ME	28/08/2015
DRAWING CHECK	TM & JZ	28/08/2015
DESIGN	RG	28/08/2015
DESIGN CHECK	AS	28/08/2015
PROJECT ENGINEER	AS	–

REVISION

REV.No.	DATE	DESCRIPTION	DRAWN	CHKD.	APPD.
A	22.01.16	ISSUED FOR INFORMATION	ME	MM	AS

REFERENCE DRAWINGS

DRAWING No.	MAKERS No.	TITLE
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WESIZWE PLATINUM LTD.
MIMOSA TSF DESIGN
UNDER DRAINAGE LAYOUT
SECTIONS AND
LINER DETAILS

DRAWING NUMBER	SCALE	REV.
301-00509/02-004	AS SHOWN	A

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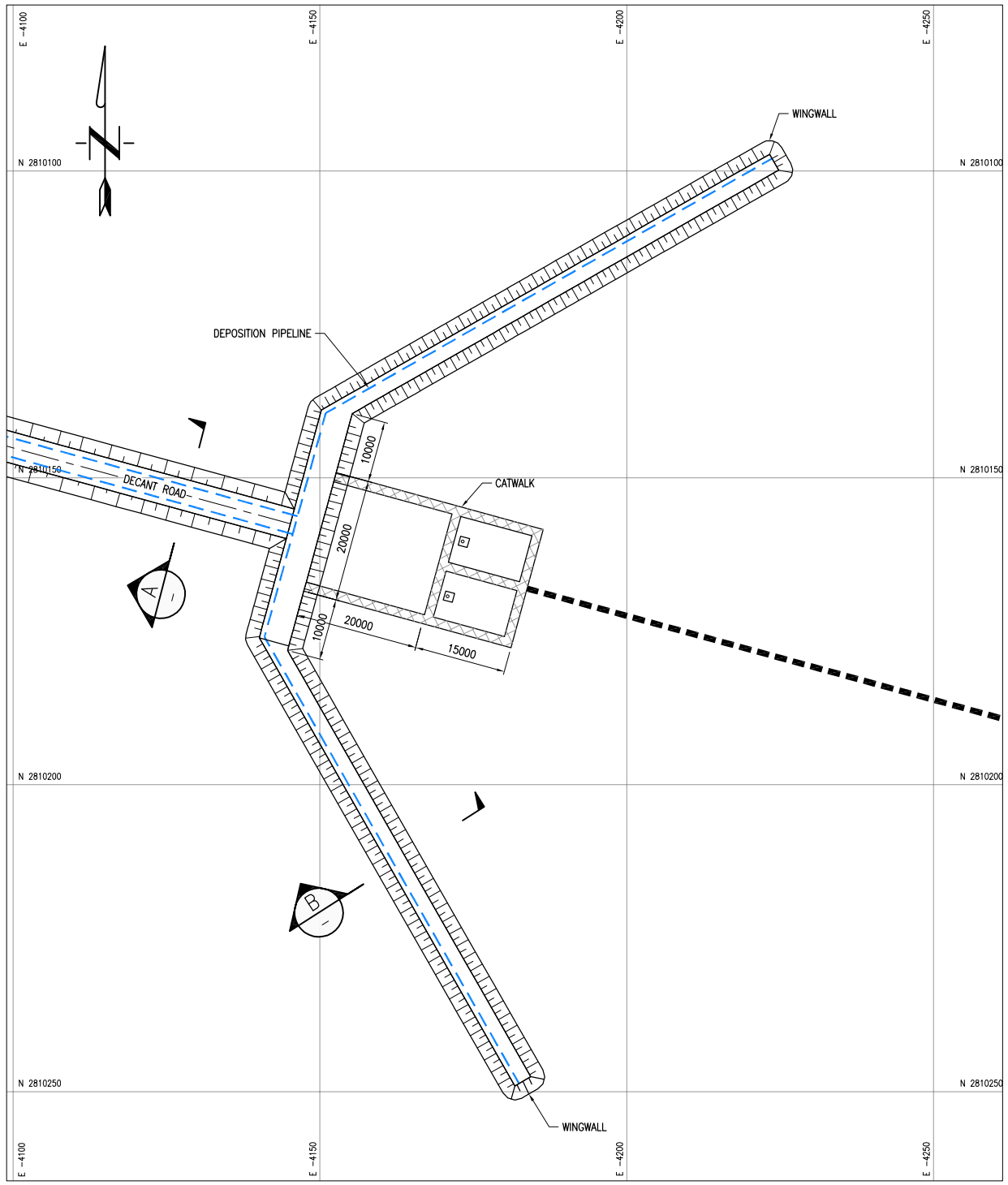
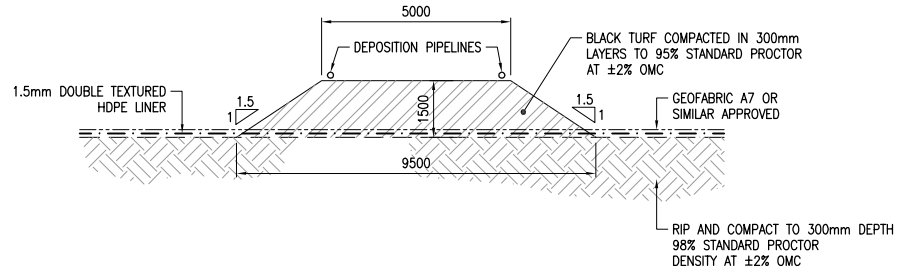
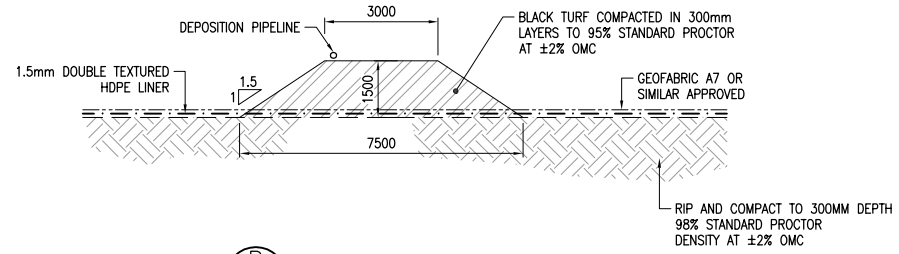


1 / 013 PERMANENT DECANT ACCESS ROAD DETAIL
SCALE 1: 500



A / – TYPICAL DECANT ACCESS ROAD SECTION
SCALE 1:100



B / – TYPICAL DECANT WINGWALL SECTION
SCALE 1:100

2500 0 2500 5000 7500
MILLIMETRES 1:100

10 0 20 40
METRES 1:500

Knight Piésold CONSULTING

PRIMARY DISCIPLINE	CIVIL	
DRAWN	ME	28/08/2015
DRAWING CHECK	TM & JZ	28/08/2015
DESIGN	RG	28/08/2015
DESIGN CHECK	AS	28/08/2015
PROJECT ENGINEER	AS	–

REVISION

REV.No.	DATE	DESCRIPTION	DRAWN	CHKD.	APPD.
A	22.01.16	ISSUED FOR INFORMATION	ME	MM	AS
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REFERENCE DRAWINGS

DRAWING No.	MAKERS No.	TITLE
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WESIZWE PLATINUM LTD.
MIMOSA TSF DESIGN
TRAINING WALL
SECTIONS
AND LAYOUT

DRAWING NUMBER	SCALE	REV.
301-00509/02-005	AS SHOWN	A

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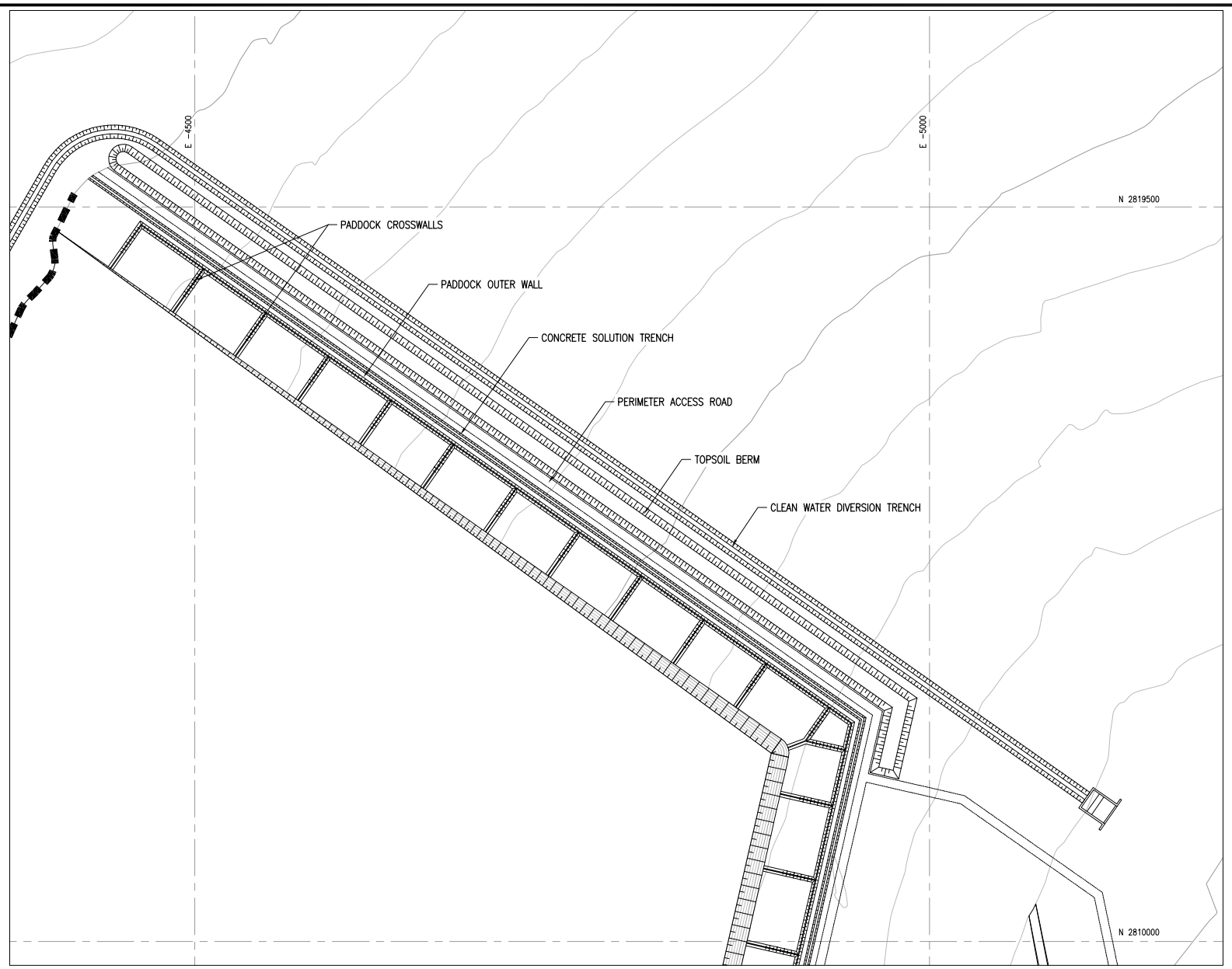
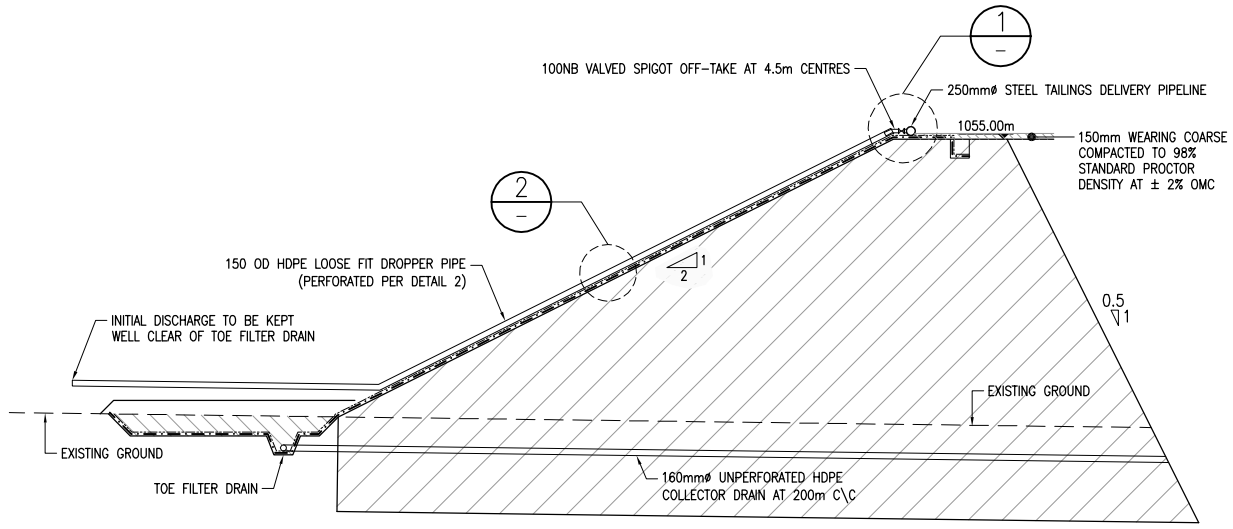
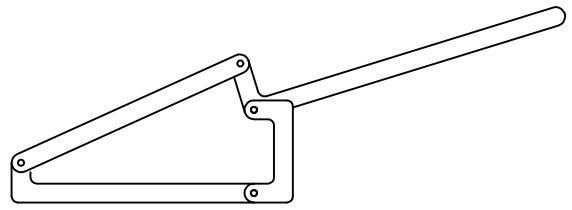


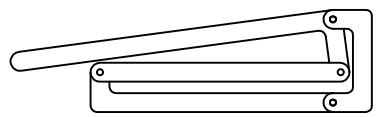
LAYOUT
SCALE 1: 5000



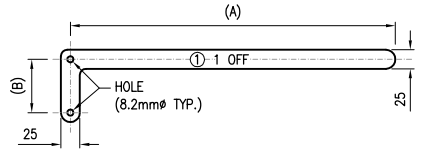
1 TYPICAL TAILINGS SPIGOT DELIVERY PIPE DETAIL
SCALE 1:100



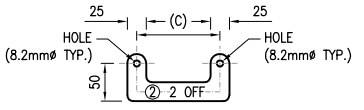
SPIGOT CLAMP – OPEN POSITION



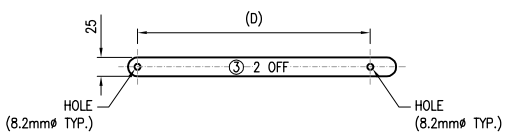
SPIGOT CLAMP – CLOSED POSITION



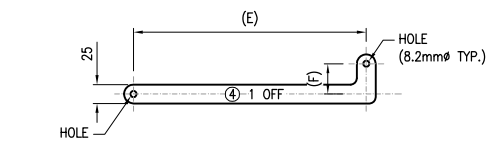
PART 1 – COMPONENT FABRICATION DETAILS
SCALE 1:5000



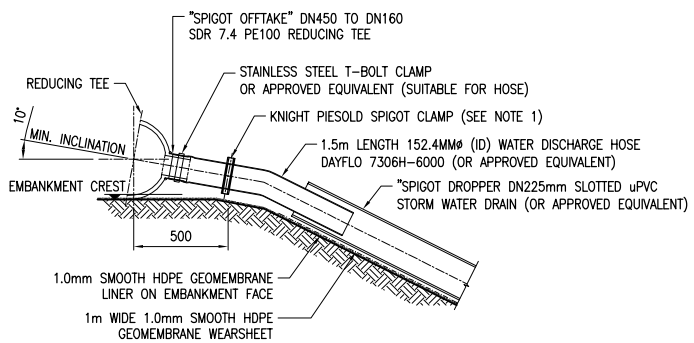
PART 2 – COMPONENT FABRICATION DETAILS
SCALE 1:5000



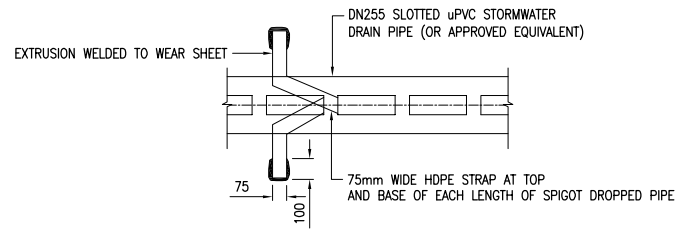
PART 3 – COMPONENT FABRICATION DETAILS
SCALE 1:5000



PART 4 – COMPONENT FABRICATION DETAILS
SCALE 1:5000



SPIGOT PIPEWORK
SCALE 1:20



SPIGOT PIPEWORK
SCALE 1:20

100 0 200 400
MILLIMETRES 1:5

250 0 250 500 750
MILLIMETRES 1:10

2500 0 2500 5000 7500
MILLIMETRES 1:100

100 0 100 200 300
METRES 1:5000

Knight Piésold CONSULTING

PRIMARY DISCIPLINE	CIVIL	
DRAWN	ME	28/08/2015
DRAWING CHECK	TM & JZ	28/08/2015
DESIGN	RG	28/08/2015
DESIGN CHECK	AS	28/08/2015
PROJECT ENGINEER	AS	–

REVISION					
REV.No.	DATE	DESCRIPTION	DRAWN	CHKD.	APPD.
A	22.01.16	ISSUED FOR INFORMATION	ME	MM	AS

REFERENCE DRAWINGS		
DRAWING No.	MAKERS No.	TITLE
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WESIZWE PLATINUM LTD.
MIMOSA TSF DESIGN
PHASE 1
SLURRY DISTRIBUTION
PIPEWORK AND DETAILS

DRAWING NUMBER	SCALE	REV.
301-00509/02-006	AS SHOWN	A

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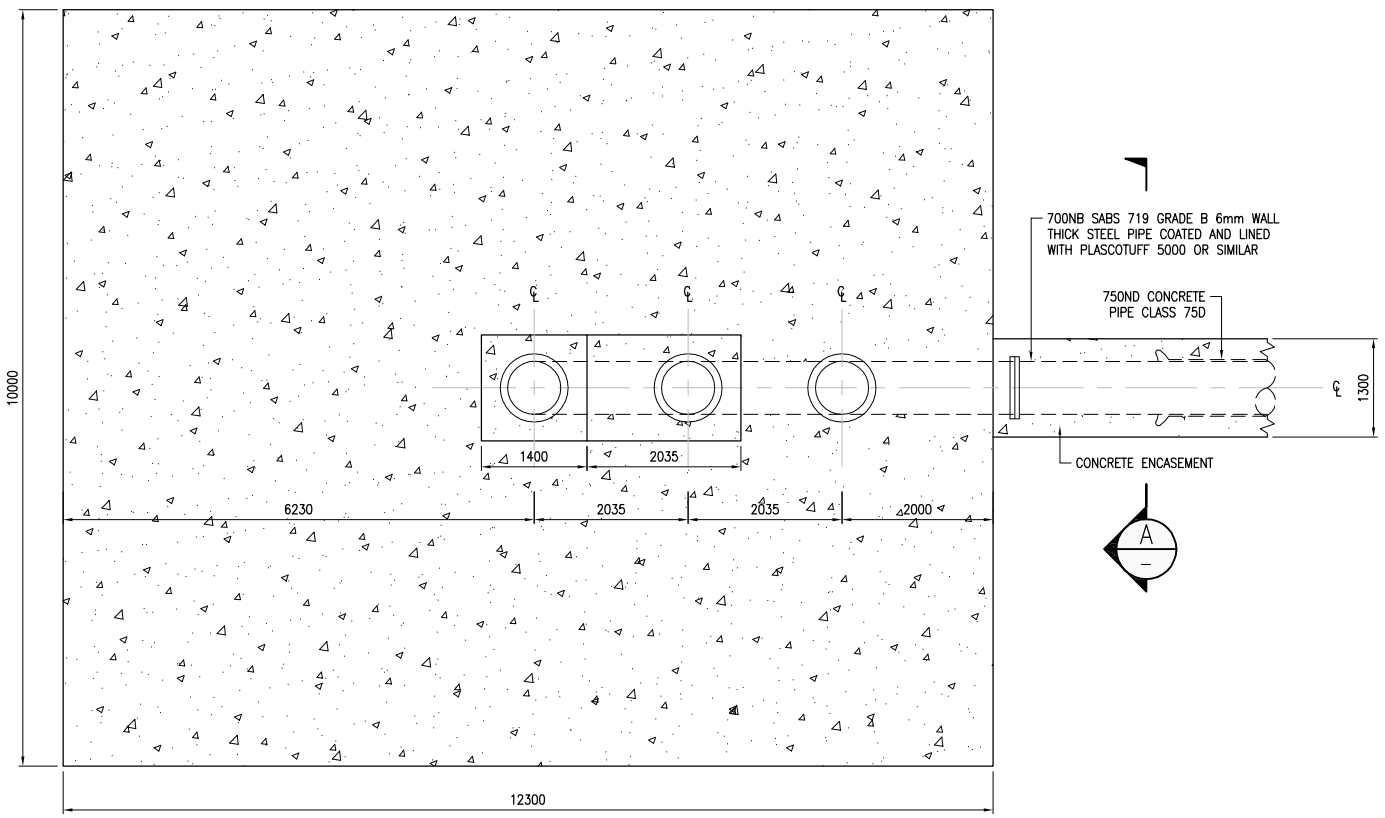
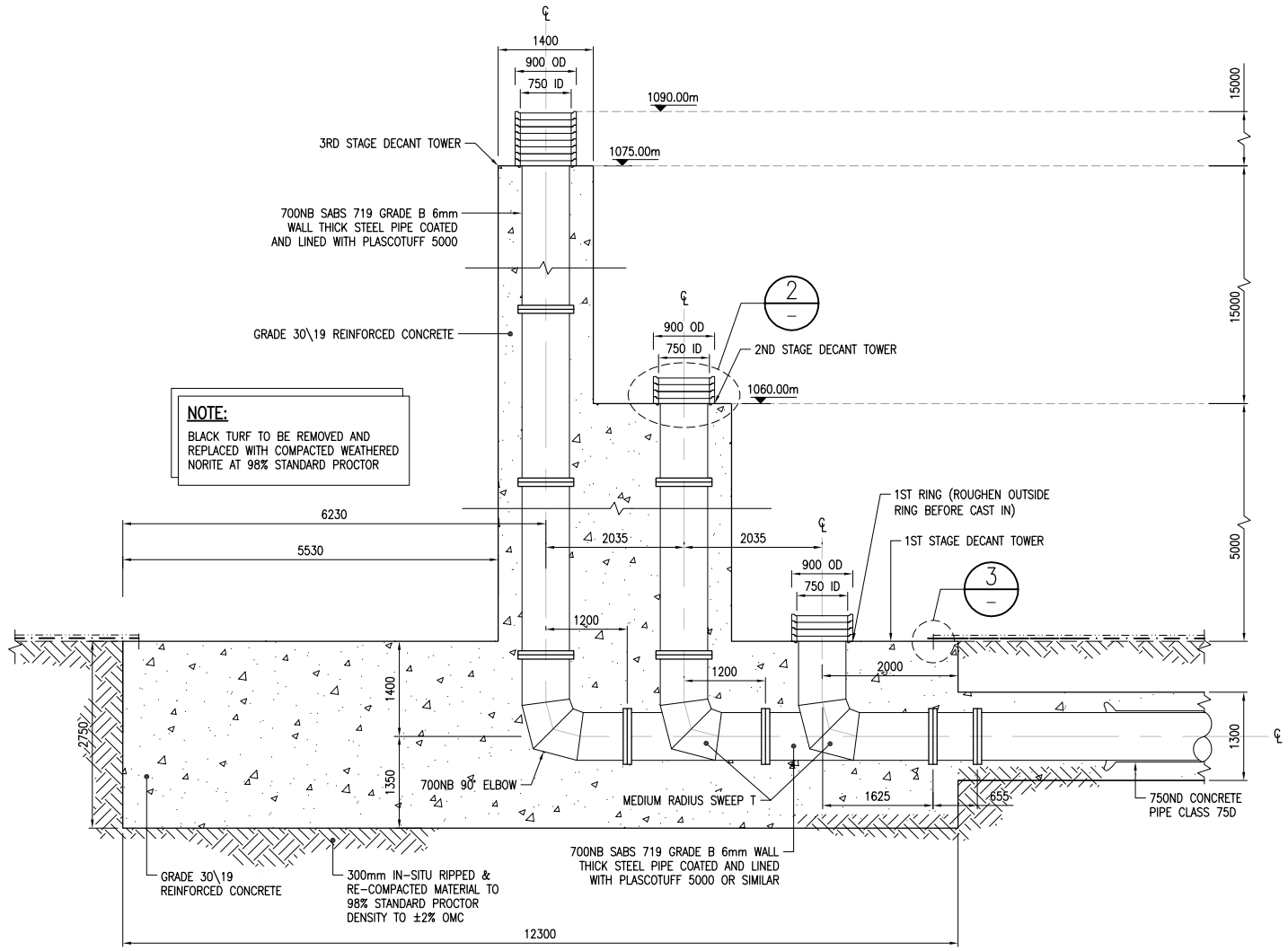
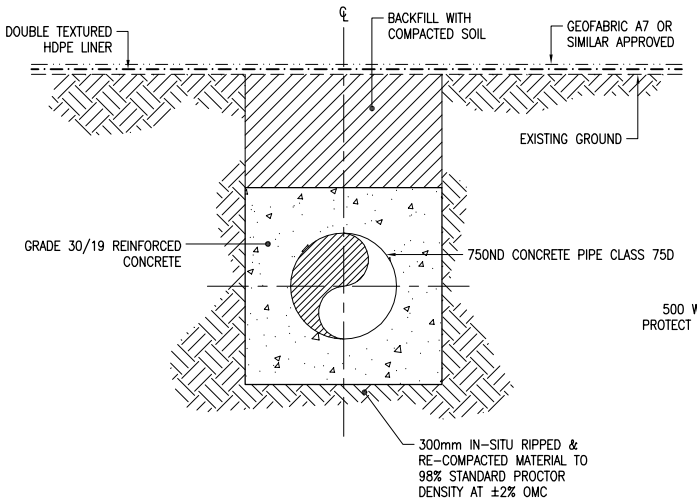


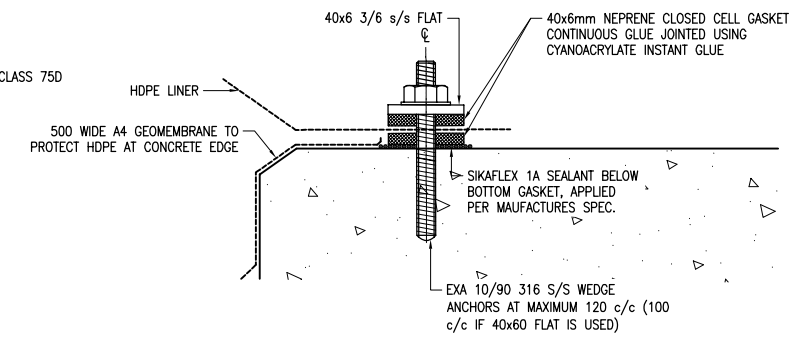
PERMANENT DECANT PLAN VIEW
SCALE 1:50



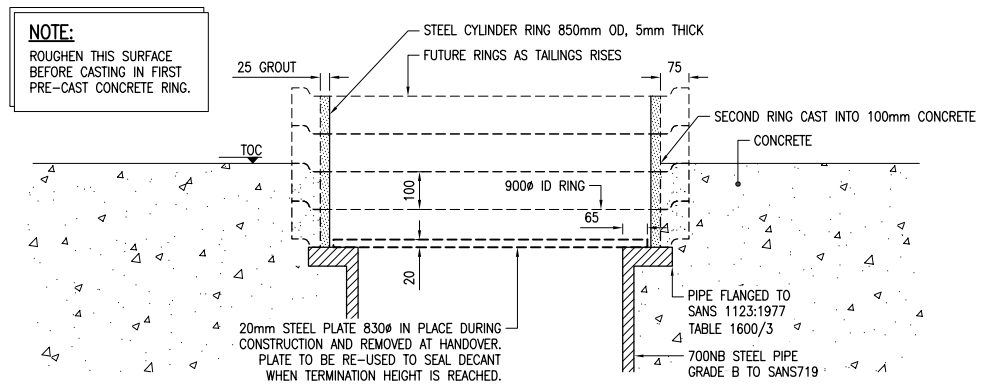
TYPICAL PERMANENT DECANT DETAILS
SCALE 1:50



A TYPICAL CONCRETE ENCASING SECTION
SCALE 1:25



3 TYPICAL CONCRETE LINER INTERFACE
SCALE 1:2



2 TYPICAL DECANT CONCRETE LIFT DETAIL
SCALE 1:10

250 0 250 500 750
MILLIMETRES 1:10

500 0 500 1000 1500
MILLIMETRES 1:20

500 0 500 1000 1500
MILLIMETRES 1:25

1000 0 2000 4000
MILLIMETRES 1:50

PRIMARY DISCIPLINE	CIVIL	
DRAWN	ME	28/08/2015
DRAWING CHECK	TM & JZ	28/08/2015
DESIGN	RG	28/08/2015
DESIGN CHECK	AS	28/08/2015
PROJECT ENGINEER	AS	–

REVISION

REV.No.	DATE	DESCRIPTION	DRAWN	CHKD.	APPD.
A	22.01.16	ISSUED FOR INFORMATION	ME	MM	AS
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REFERENCE DRAWINGS

DRAWING No.	MAKERS No.	TITLE
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WESIZWE PLATINUM LTD.
MIMOSA TSF DESIGN
PERMANENT
DECANT TYPICAL SECTIONS
AND DETAILS

DRAWING NUMBER	SCALE	REV.
301-00509/02-007	AS SHOWN	A

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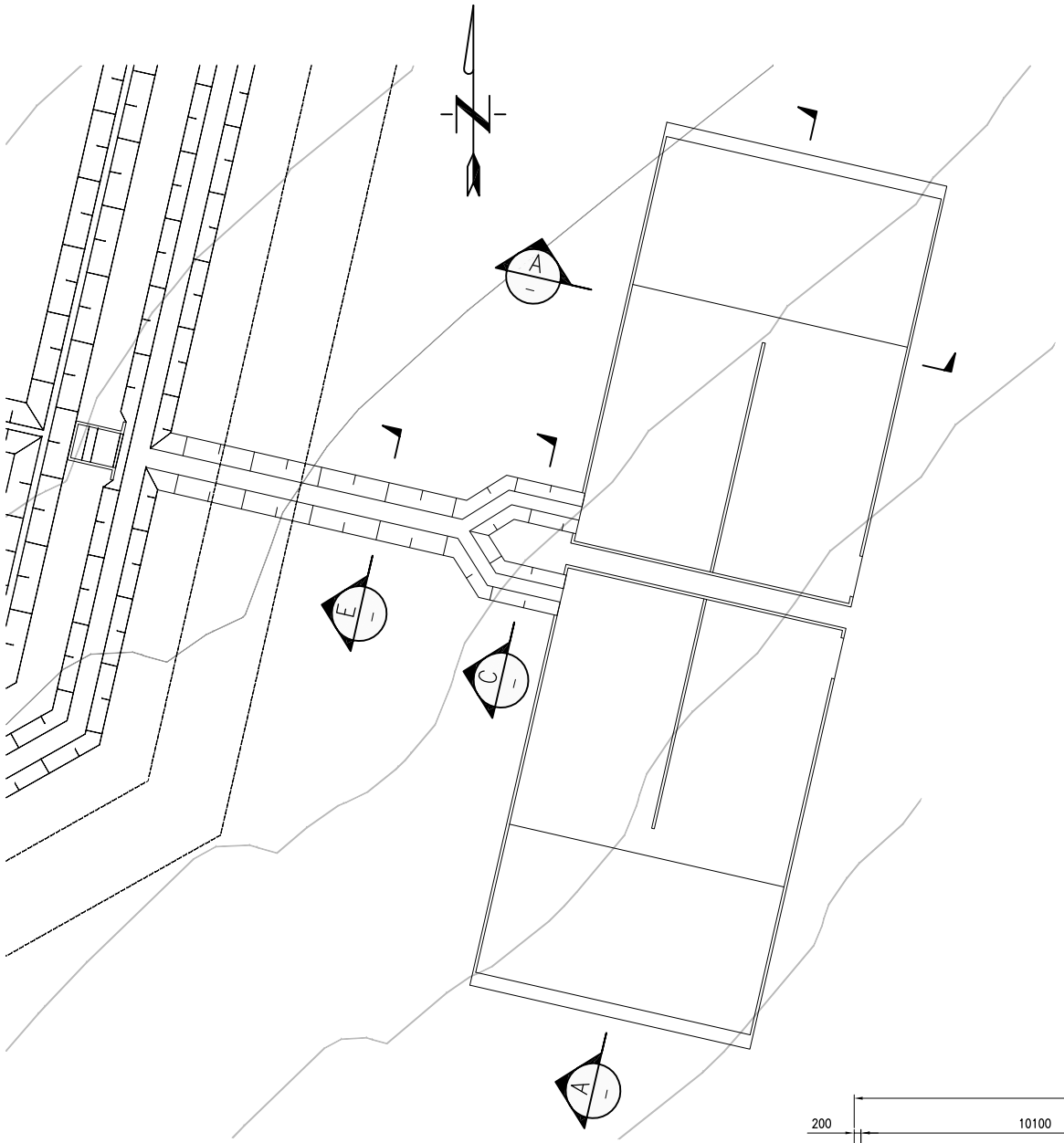
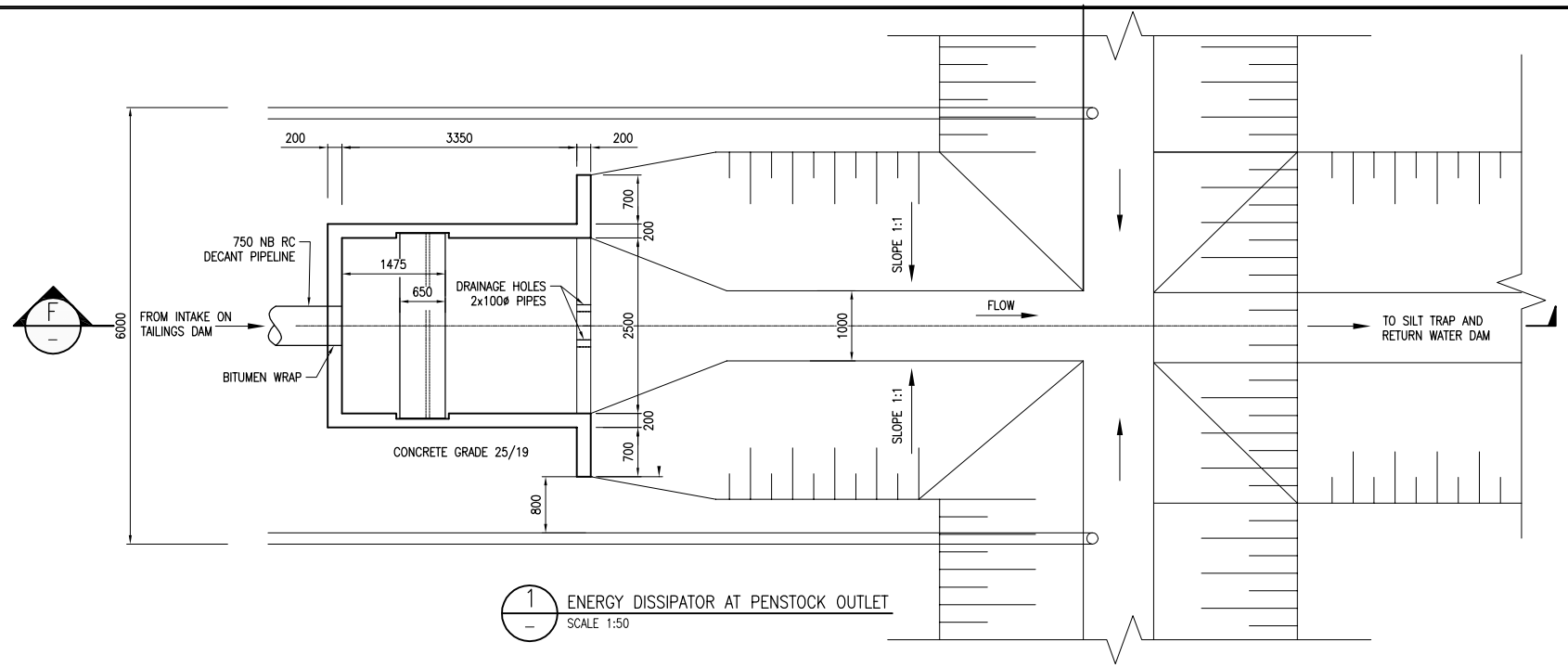
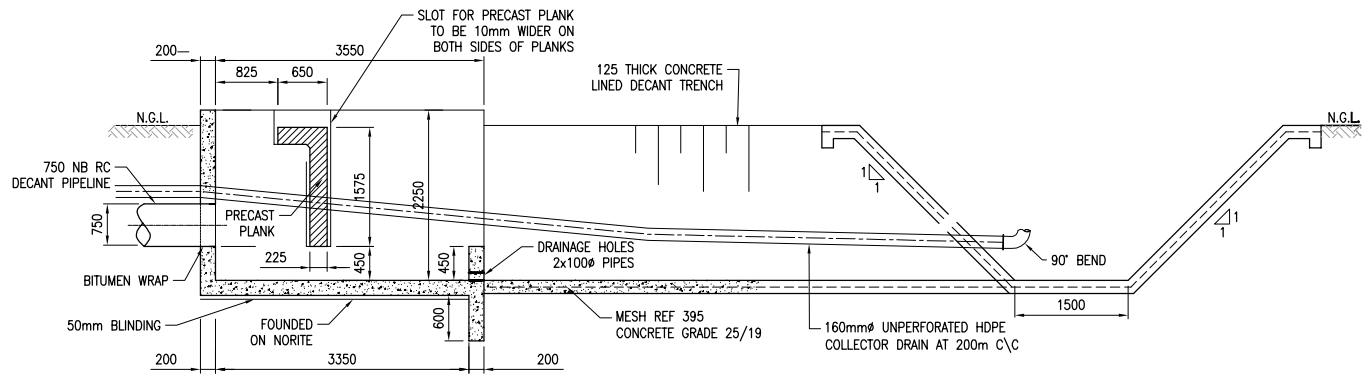
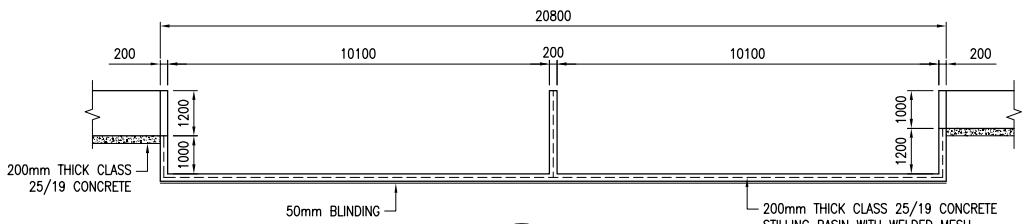




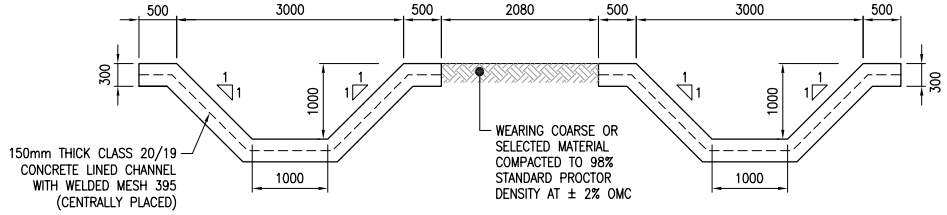
1 ENERGY DISSIPATOR AT PENSTOCK OUTLET
SCALE 1:50



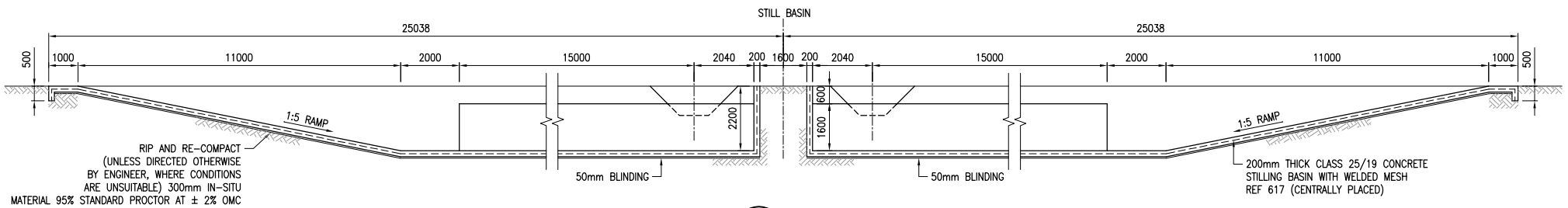
F TYPICAL SECTION
SCALE 1:50



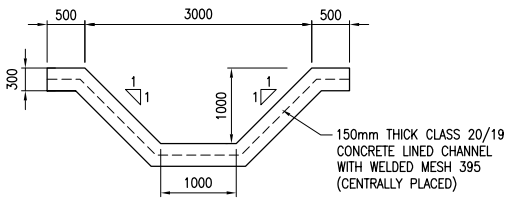
B TYPICAL SECTION
SCALE 1:100



C TYPICAL SECTION
SCALE 1:50



A TYPICAL SECTION
SCALE 1:100



E TYPICAL SECTION THROUGH CONCRETE CHANNEL
SCALE 1:50

1000 0 2000 4000
MILLIMETRES 1:50

2500 0 2500 5000 7500
MILLIMETRES 1:100

5 0 5 10 15
METRES 1:200

Knight Piésold CONSULTING

PRIMARY DISCIPLINE	CIVIL	
DRAWN	ME	28/08/2015
DRAWING CHECK	TM & JZ	28/08/2015
DESIGN	RG	28/08/2015
DESIGN CHECK	AS	28/08/2015
PROJECT ENGINEER	AS	–

REVISION

REV.No.	DATE	DESCRIPTION	DRAWN	CHKD.	APPD.
A	22.01.16	ISSUED FOR INFORMATION	ME	MM	AS
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REFERENCE DRAWINGS

DRAWING No.	MAKERS No.	TITLE
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WESIZWE PLATINUM LTD.
MIMOSA TSF DESIGN
SILT TRAP
DETAILS
AND SECTIONS

DRAWING NUMBER	SCALE	REV.
301-00509/02-008	AS SHOWN	A

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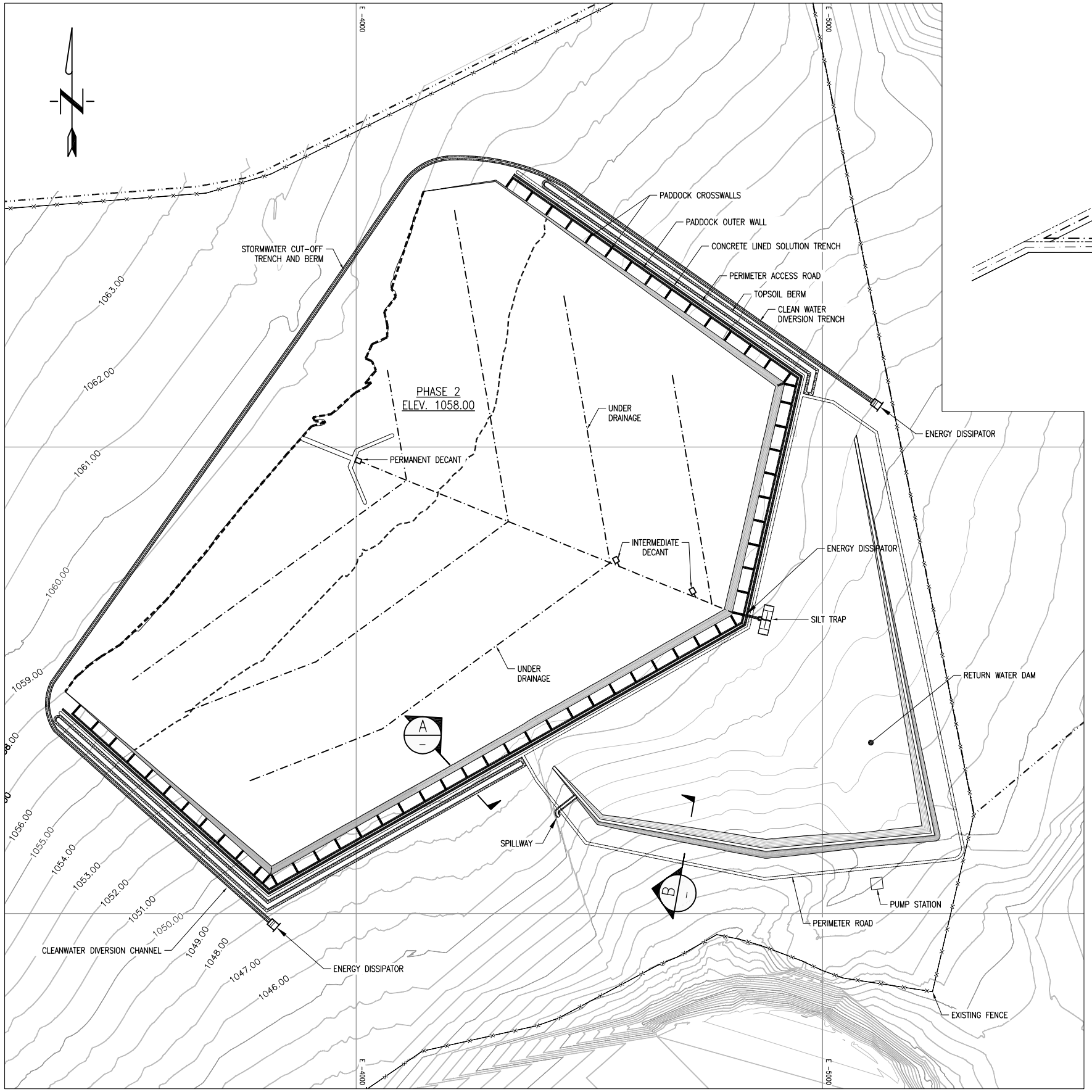
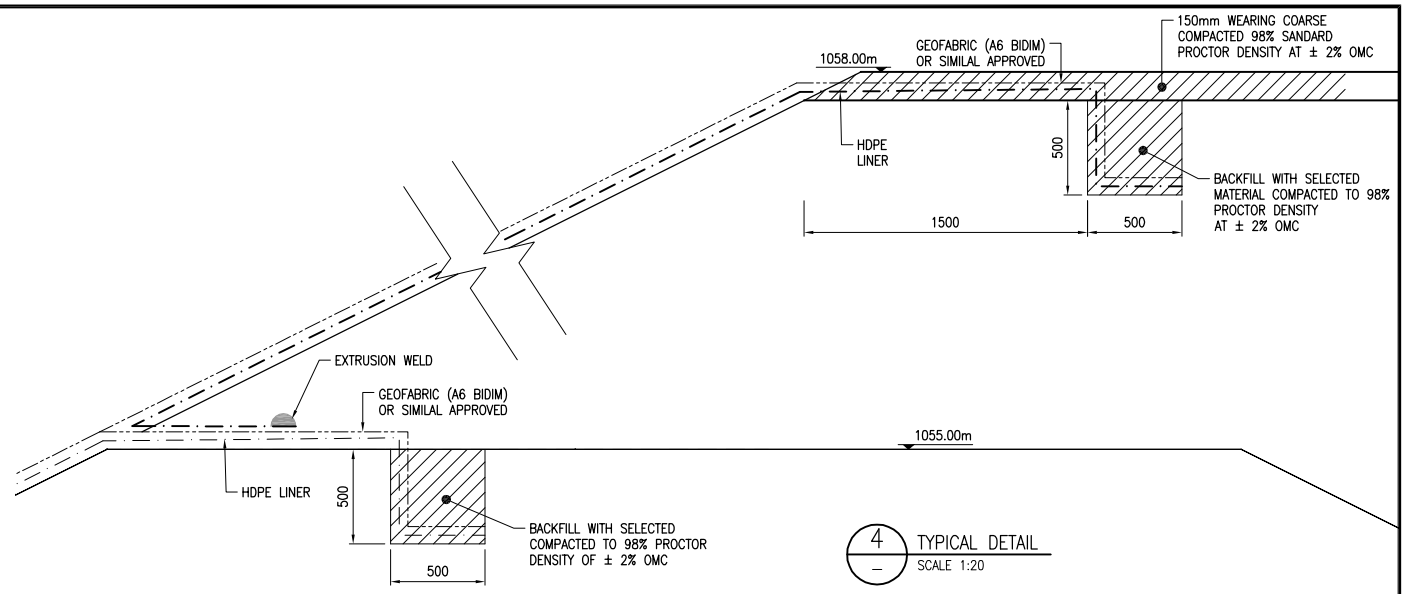
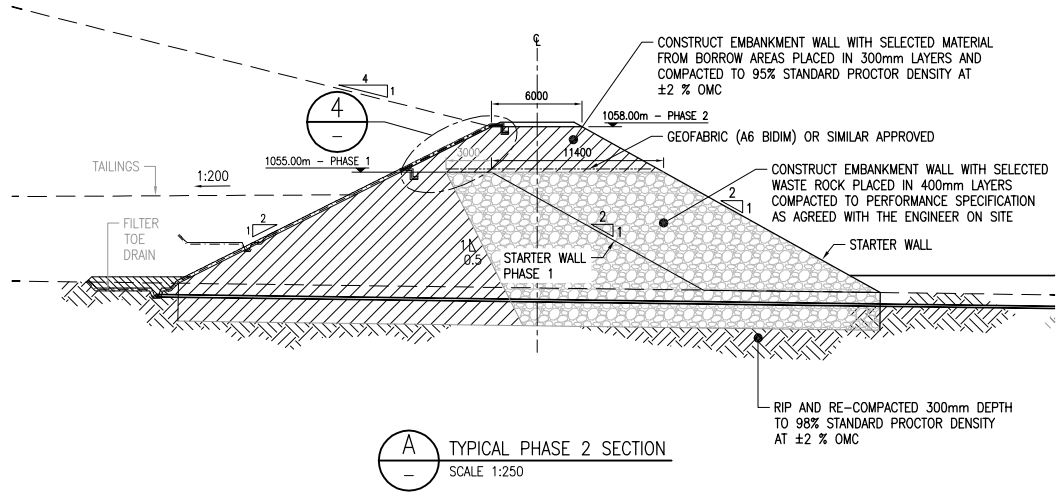
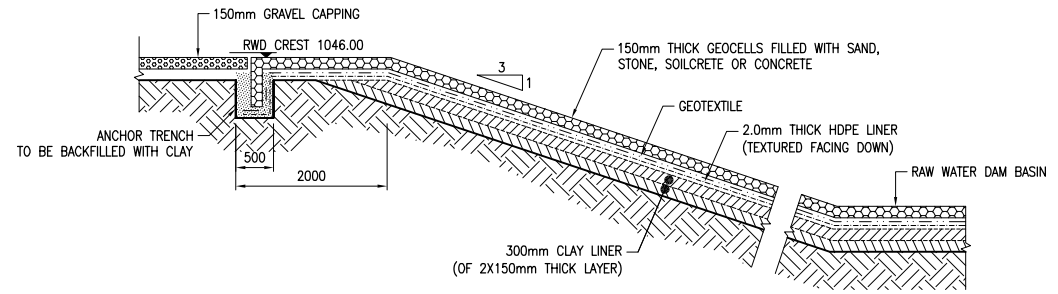




4 TYPICAL DETAIL
SCALE 1:20



A TYPICAL PHASE 2 SECTION
SCALE 1:250



B TYPICAL SECTION
SCALE 1:50

LEGEND
LEASE BOUNDARY
EXISTING FENCE

5 0 10 20
METRES 1:250

100 0 100 200 300
METRES 1:5000

Knight Piésold CONSULTING

PRIMARY DISCIPLINE	CIVIL	
DRAWN	ME	28/08/2015
DRAWING CHECK	TM & JZ	28/08/2015
DESIGN	RG	28/08/2015
DESIGN CHECK	AS	28/08/2015
PROJECT ENGINEER	AS	–

REVISION

REV.No.	DATE	DESCRIPTION	DRAWN	CHKD.	APPD.
A	22.01.16	ISSUED FOR INFORMATION	ME	MM	AS
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REFERENCE DRAWINGS

DRAWING No.	MAKERS No.	TITLE
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WESIZWE PLATINUM LTD.
MIMOSA TSF DESIGN
PROJECTED CONSTRUCTION
PHASE 2
LAYOUT AND SECTIONS

DRAWING NUMBER	SCALE	REV.
301-00509/02-009	AS SHOWN	A

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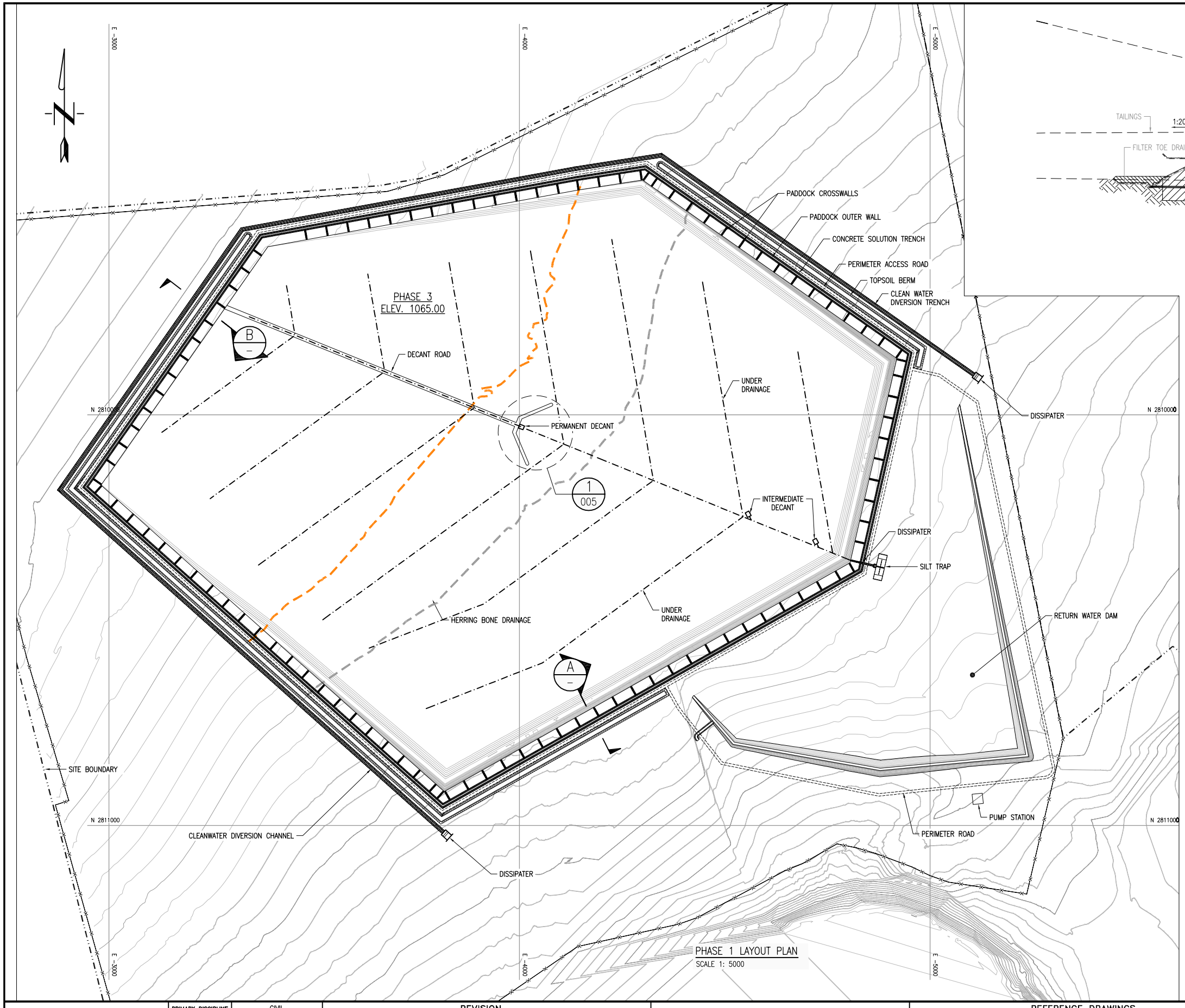
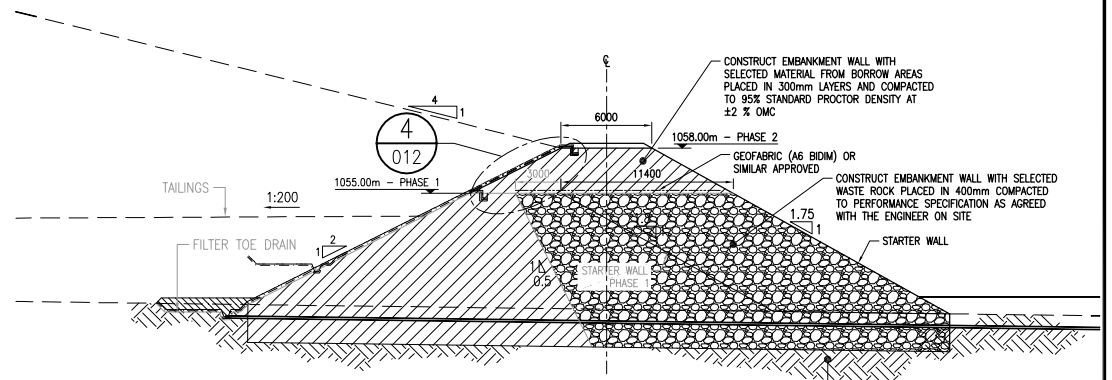
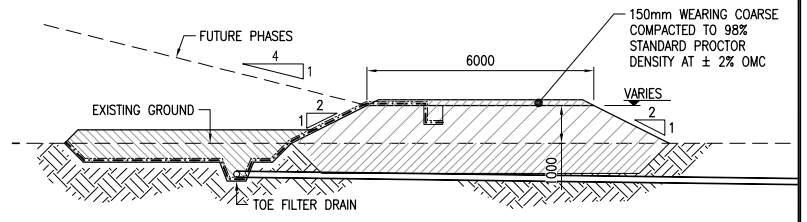


PHASE 1 LAYOUT PLAN
SCALE 1: 5000



A TYPICAL PHASE 3 SECTION
SCALE 1:250



B TYPICAL PHASE 3 SECTION
SCALE 1: 100

LEGEND
LEASE BOUNDARY
EXISTING FENCE

2500 0 2500 5000 7500
MILLIMETRES 1:100

5 0 10 20
METRES 1:250

100 0 100 200 300
METRES 1:5000

Knight Piésold CONSULTING

PRIMARY DISCIPLINE	CIVIL	
DRAWN	ME	28/08/2015
DRAWING CHECK	TM & JZ	28/08/2015
DESIGN	RG	28/08/2015
DESIGN CHECK	AS	28/08/2015
PROJECT ENGINEER	AS	–

REVISION

REV.No.	DATE	DESCRIPTION	DRAWN	CHKD.	APPD.
A	22.01.16	ISSUED FOR INFORMATION	ME	MM	AS

REFERENCE DRAWINGS

DRAWING No.	MAKERS No.	TITLE
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WESIZWE PLATINUM LTD.
MIMOSA TSF DESIGN
PHASE 3
PROJECTED CONSTRUCTION
LAYOUT AND SECTIONS

DRAWING NUMBER	SCALE	REV.
301-00509/02-010	AS SHOWN	A

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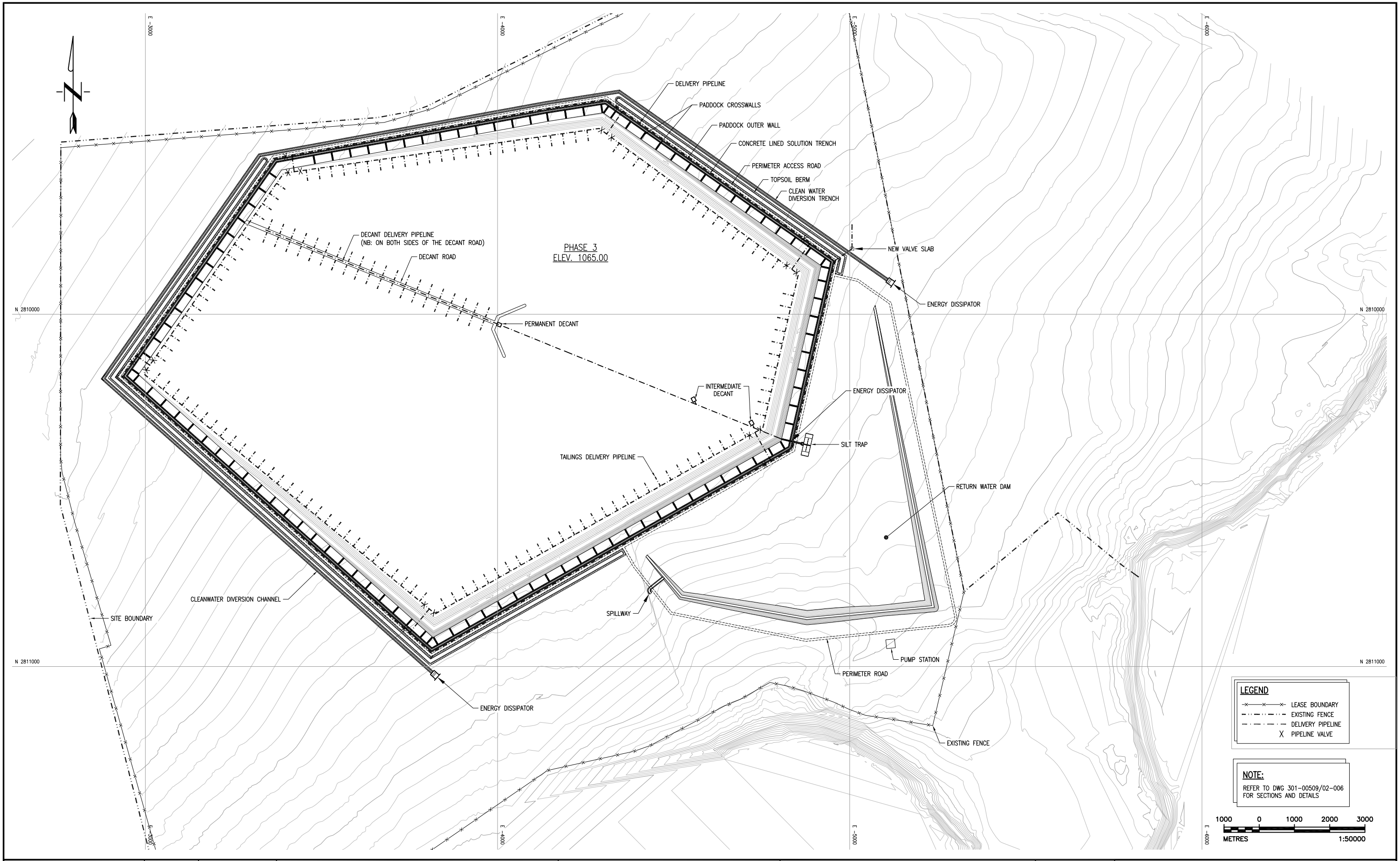

Knight Piésold CONSULTING

PRIMARY DISCIPLINE	CIVIL	
DRAWN	ME	28/08/2015
DRAWING CHECK	TM & JZ	28/08/2015
DESIGN	RG	28/08/2015
DESIGN CHECK	AS	28/08/2015
PROJECT ENGINEER	AS	–

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REVISION

REV.No.	DATE	DESCRIPTION	DRAWN	CHKD.	APPD.
A	22.01.16	ISSUED FOR INFORMATION	ME	MM	AS
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REFERENCE DRAWINGS

DRAWING No.	MAKERS No.	TITLE
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WESIZWE PLATINUM LTD.
MIMOSA TSF DESIGN
PHASE 3
SLURRY DISTRIBUTION
PIPELINE LAYOUT

DRAWING NUMBER	SCALE	REV.
301-00509/02-011	AS SHOWN	A

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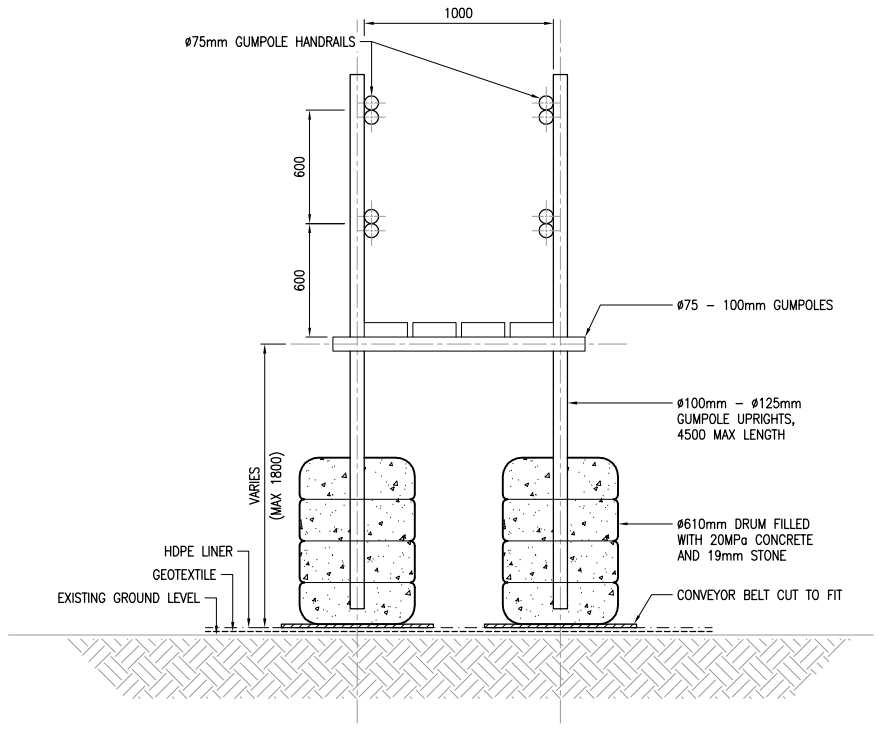
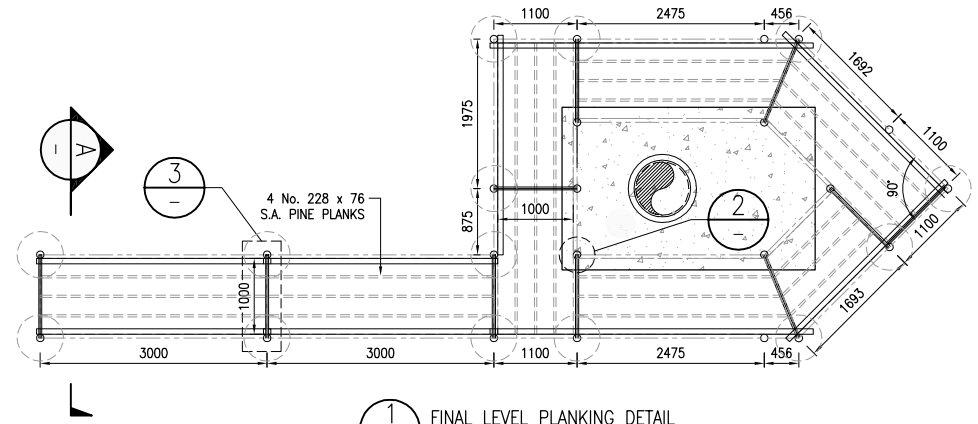
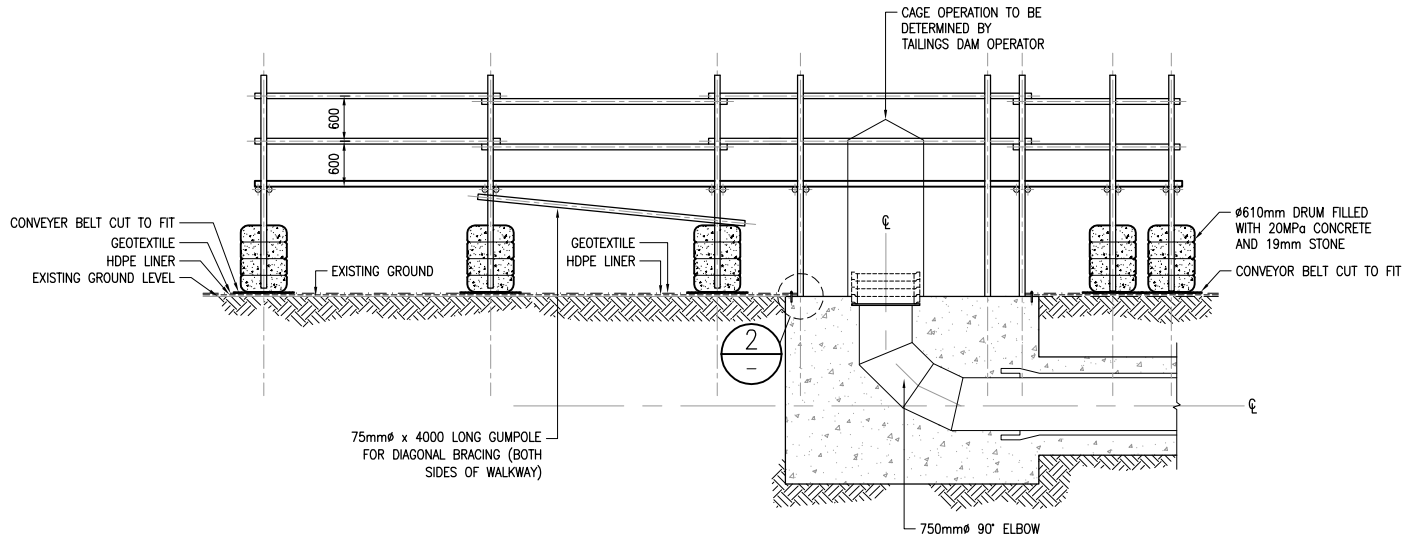


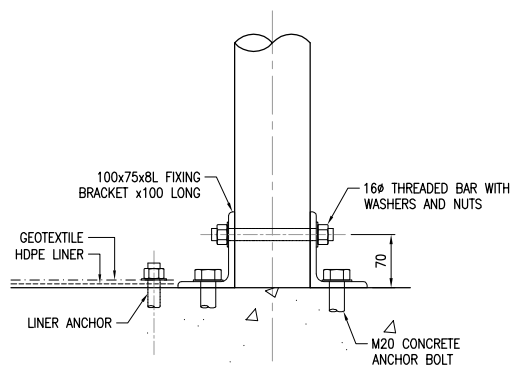
A – TYPICAL CROSS SECTION
SCALE 1:20



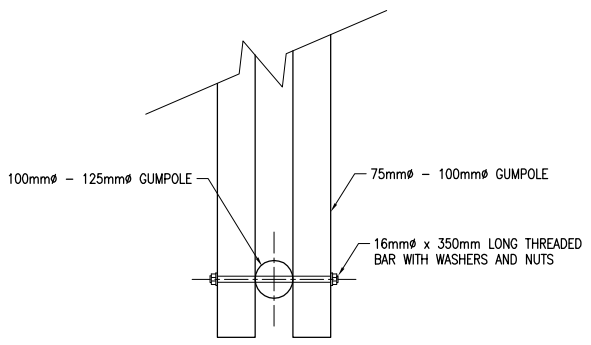
1 – FINAL LEVEL PLANKING DETAIL
SCALE 1:50



PERMANENT DECANT SECTION
SCALE 1:50



2 – CONCRETE FIXING DETAIL
SCALE 1:5



3 – TYPICAL DETAIL
SCALE 1:10

NOTE:

ALL WALKWAY PLANKS SHALL BE PRE–DRILLED THROUGH BEFORE NAILING TO SUPPORT GUMPOLES

100 0 200 400
MILLIMETRES 1:5

250 0 250 500 750
MILLIMETRES 1:10

500 0 500 1000 1500
MILLIMETRES 1:20

1000 0 2000 4000
MILLIMETRES 1:50

Knight Piésold CONSULTING

PRIMARY DISCIPLINE	CIVIL	
DRAWN	ME	28/08/2015
DRAWING CHECK	TM & JZ	28/08/2015
DESIGN	RG	28/08/2015
DESIGN CHECK	AS	28/08/2015
PROJECT ENGINEER	AS	–

REVISION

REV.No.	DATE	DESCRIPTION	DRAWN	CHKD.	APPD.
A	22.01.16	ISSUED FOR INFORMATION	ME	MM	AS

REFERENCE DRAWINGS

DRAWING No.	MAKERS No.	TITLE
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WESIZWE PLATINUM LTD.
MIMOSA TSF DESIGN
INTERMEDIATE
DECANT CATWALK
AND WALKWAY DETAILS

DRAWING NUMBER	SCALE	REV.
301–00509/02–012	AS SHOWN	A

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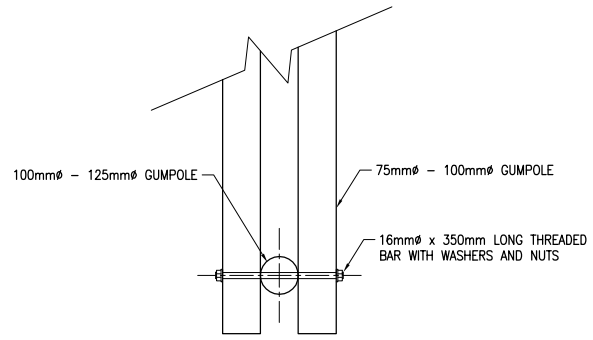
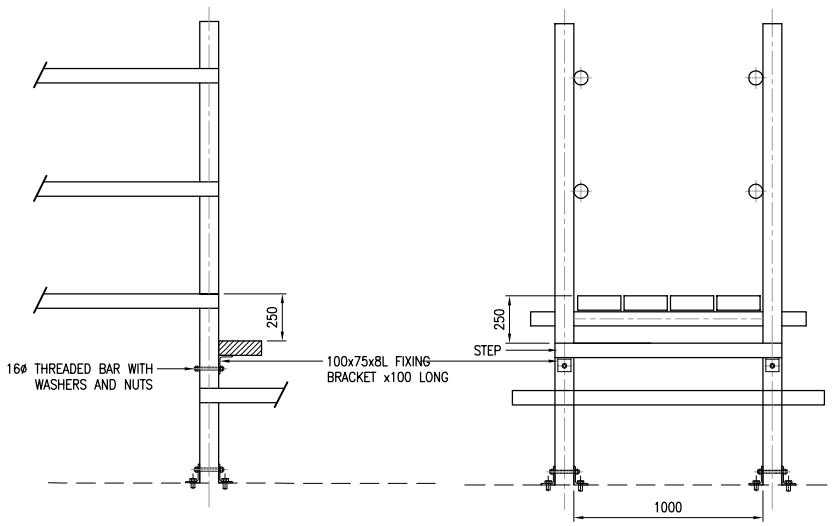
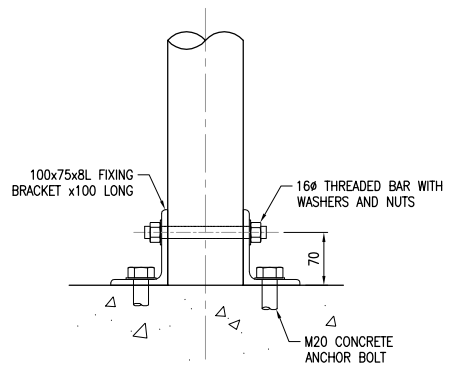


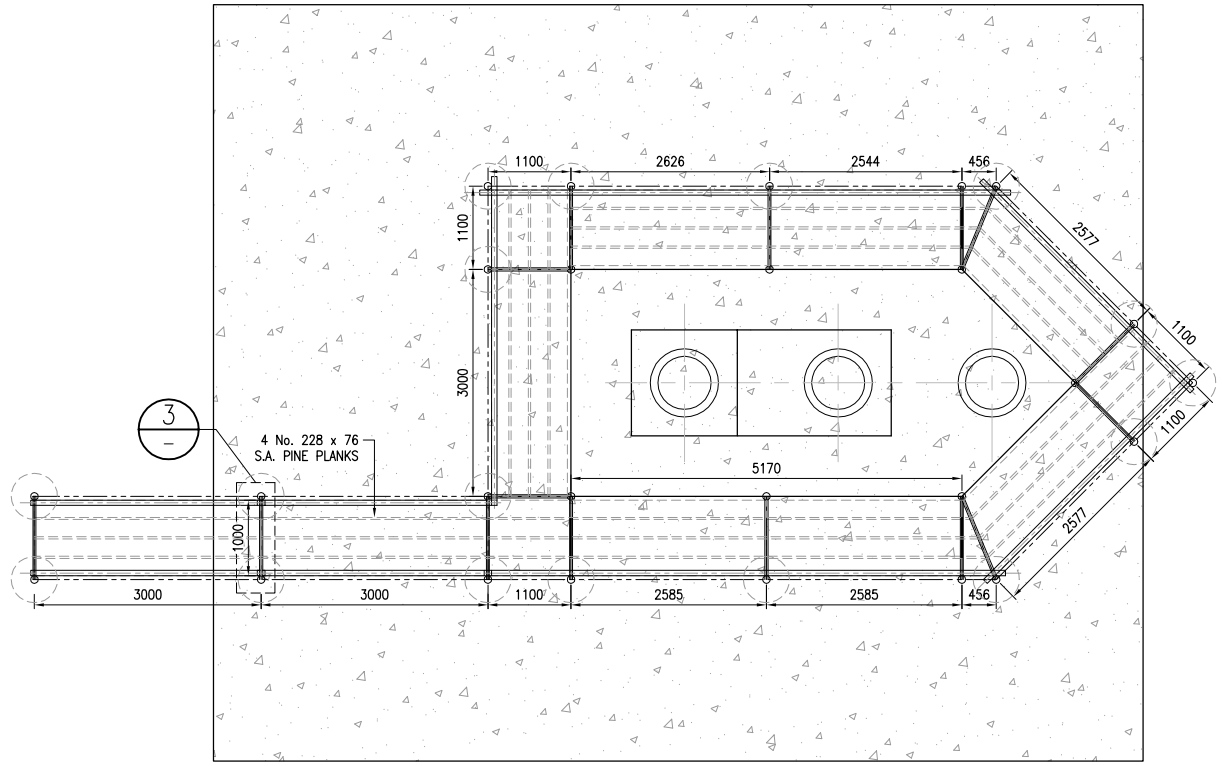
3 — TYPICAL DETAIL
SCALE 1:10



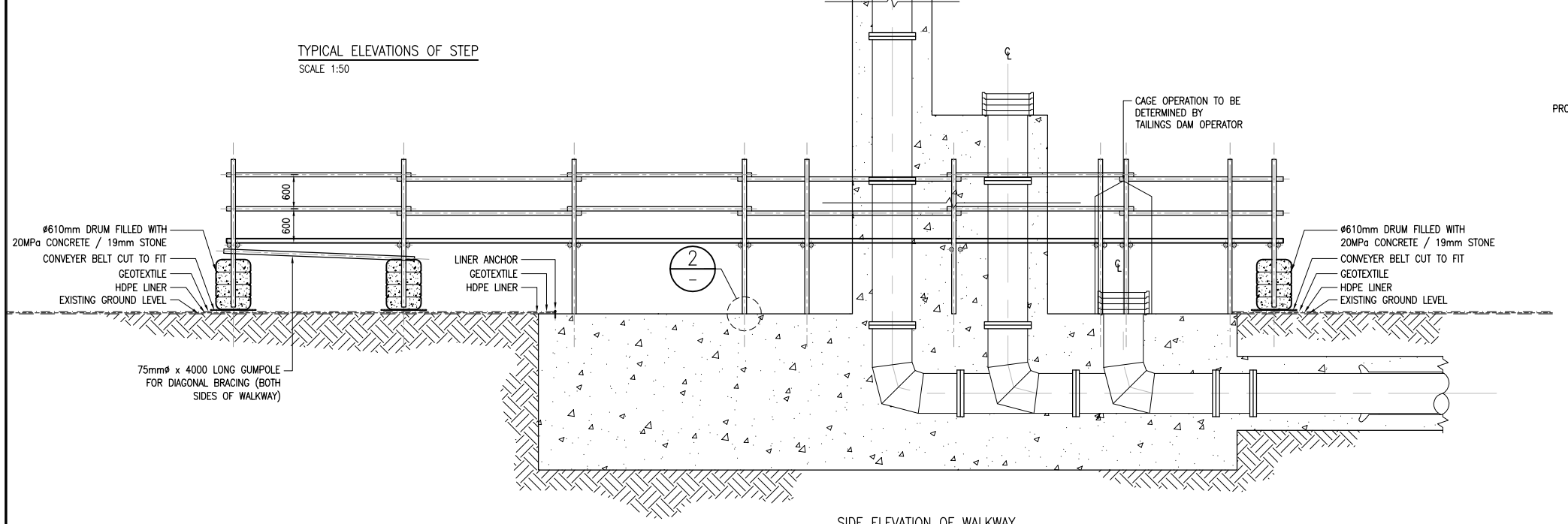
TYPICAL ELEVATIONS OF STEP
SCALE 1:50



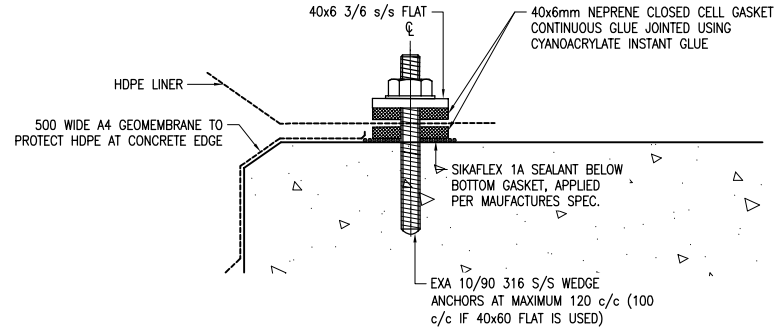
2 — TYPICAL CONCRETE FIXING DETAIL
SCALE 1:5



1 — FINAL LEVEL PLANKING DETAIL
SCALE 1:50



SIDE ELEVATION OF WALKWAY
SCALE 1:50



TYPICAL CONCRETE LINER INTERFACE
SCALE 1:2

NOTE:

ALL WALKWAY PLANKS SHALL BE PRE-DRILLED THROUGH BEFORE NAILING TO SUPPORT GUMPOLES

100 0 200 400 MILLIMETRES 1:5

250 0 250 500 750 MILLIMETRES 1:10

1000 0 2000 4000 MILLIMETRES 1:50

Knight Piésold CONSULTING

PRIMARY DISCIPLINE	CIVIL	
DRAWN	ME	28/08/2015
DRAWING CHECK	TM & JZ	28/08/2015
DESIGN	RG	28/08/2015
DESIGN CHECK	AS	28/08/2015
PROJECT ENGINEER	AS	–
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REVISION

REV.No.	DATE	DESCRIPTION	DRAWN	CHKD.	APPD.
A	22.01.16	ISSUED FOR INFORMATION	ME	MM	AS
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REFERENCE DRAWINGS

DRAWING No.	MAKERS No.	TITLE
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WESIZWE PLATINUM LTD.
MIMOSA TSF DESIGN
PERMANENT
DECANT CATWALK
AND WALKWAY DETAILS

DRAWING NUMBER	SCALE	REV.
301-00509/02-013	AS SHOWN	A

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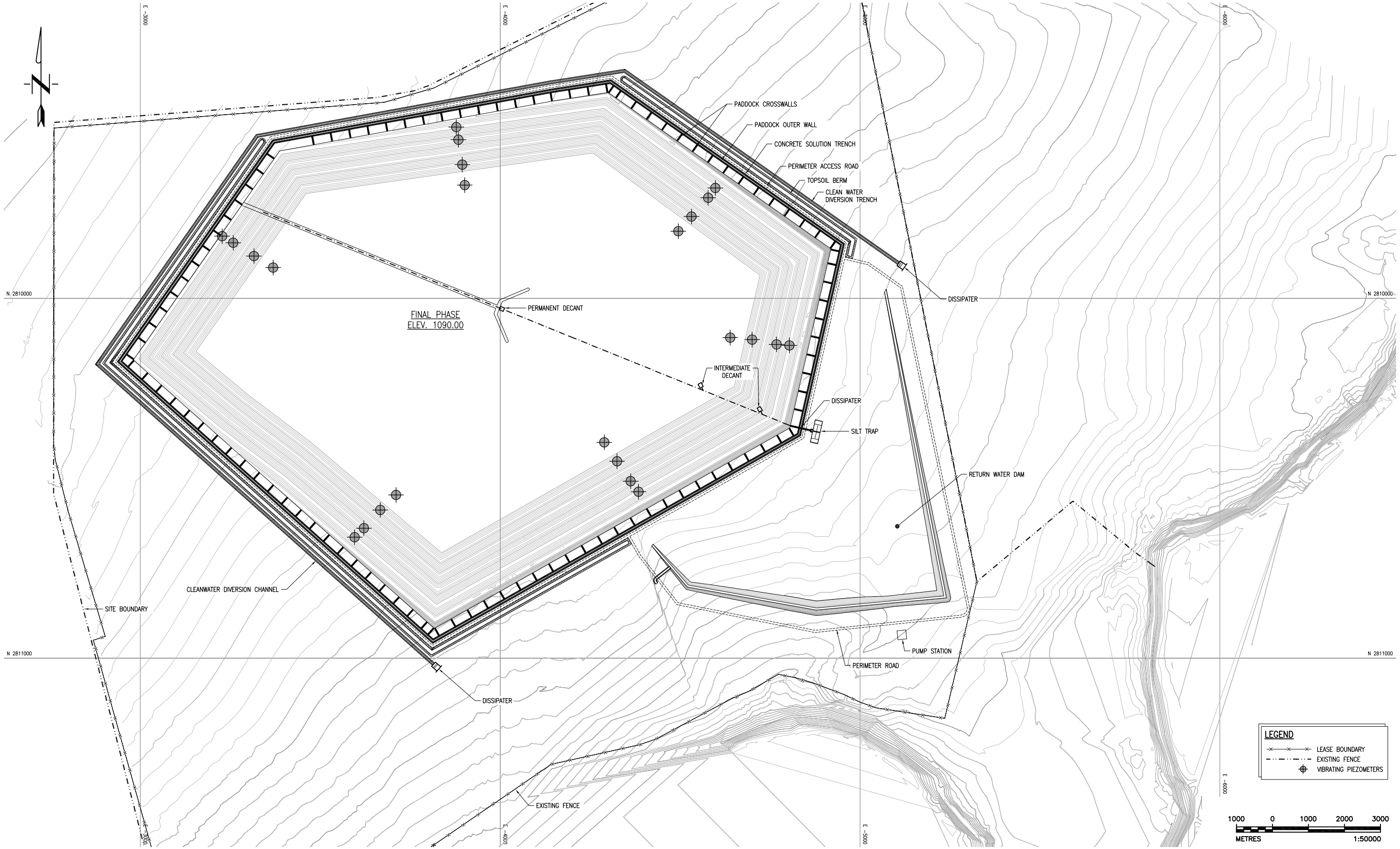

Knight Piésold CONSULTING

PRIMARY DISCIPLINE	CIVIL	
DRAWN	ME	28/08/2015
DRAWING CHECK	TM & JZ	28/08/2015
DESIGN	RG	28/08/2015
DESIGN CHECK	AS	28/08/2015
PROJECT ENGINEER	AS	–

REVISION

REV.No.	DATE	DESCRIPTION	DRAWN	CHKD.	APPD.
A	22.01.16	ISSUED FOR INFORMATION	ME	MM	AS
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REFERENCE DRAWINGS

DRAWING No.	MAKERS No.	TITLE
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WESIZWE PLATINUM LTD.
MIMOSA TSF DESIGN
INSTRUMENTATION
LAYOUT

DRAWING NUMBER	SCALE	REV.
301-00509/02-014	AS SHOWN	A

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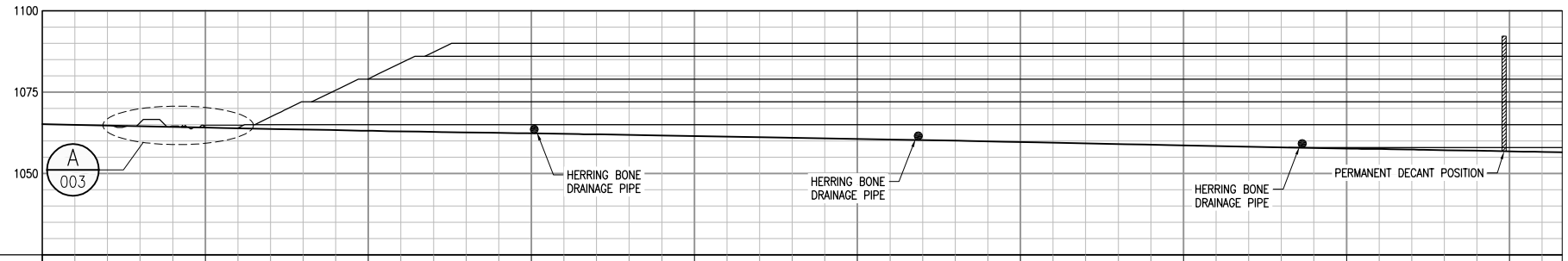
SCALES:
Horizontal 1:2000
Vertical 1:1000

DATUM 1025.00



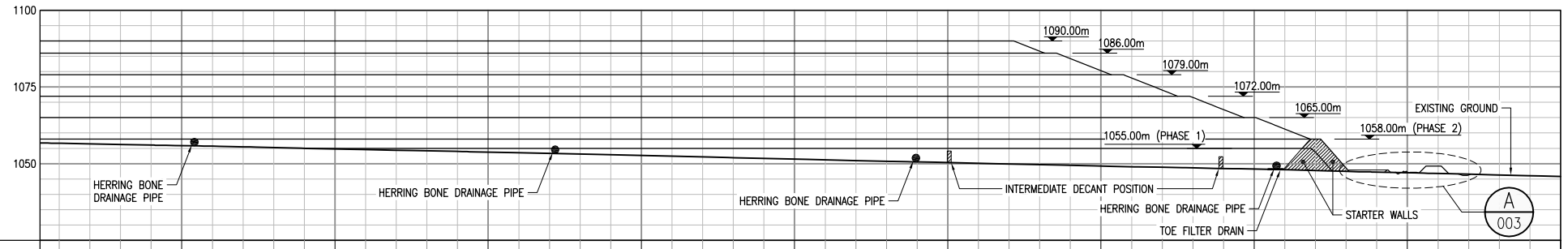
CHAINAGE (m)	20.00	40.00	60.00	80.00	100.00	120.00	140.00	160.00	180.00	200.00	220.00	240.00	260.00	280.00	300.00	320.00	340.00	360.00	380.00	400.00	420.00	440.00	460.00	480.00	500.00	520.00	540.00	560.00	580.00	600.00	620.00	640.00	660.00	680.00	700.00	720.00	740.00	760.00	780.00	800.00	820.00	840.00	860.00	880.00	900.00	920.00
EXISTING GROUND LEVELS (m)	1064.94	1064.74	1064.53	1064.32	1064.11	1063.91	1063.71	1063.51	1063.32	1063.13	1062.94	1062.78	1062.63	1062.47	1062.31	1062.17	1062.02	1061.84	1061.67	1061.49	1061.31	1061.14	1060.96	1060.78	1060.60	1060.43	1060.25	1060.07	1059.87	1059.67	1059.46	1059.25	1059.04	1058.83	1058.63	1058.44	1058.24	1058.04	1057.85	1057.66	1057.52	1057.37	1057.18	1057.00	1056.81	1056.64

LONGITUDINAL SECTION CH: 0.00m – 920.00m

SCALE HOR – 1: 2000 VER – 1:1000

SCALES:
Horizontal 1:2000
Vertical 1:1000

DATUM 1025.00



CHAINAGE (m)	920.00	940.00	960.00	980.00	1000.00	1020.00	1040.00	1060.00	1080.00	1100.00	1120.00	1140.00	1160.00	1180.00	1200.00	1220.00	1240.00	1260.00	1280.00	1300.00	1320.00	1340.00	1360.00	1380.00	1400.00	1420.00	1440.00	1460.00	1480.00	1500.00	1520.00	1540.00	1560.00	1580.00	1600.00	1620.00	1640.00	1660.00	1680.00	1700.00	1720.00	1740.00	1760.00	1780.00	1800.00	1820.00	1840.00	1860.00	1880.00	1900.00
EXISTING GROUND LEVELS (m)	1056.64	1056.45	1056.25	1056.05	1055.87	1055.70	1055.50	1055.26	1055.01	1054.80	1054.59	1054.40	1054.20	1053.99	1053.78	1053.56	1053.34	1053.12	1052.90	1052.66	1052.43	1052.20	1051.96	1051.72	1051.48	1051.24	1051.00	1050.78	1050.58	1050.36	1050.13	1049.91	1049.68	1049.45	1049.23	1049.02	1048.82	1048.63	1048.44	1048.23	1048.02	1047.76	1047.50	1047.29	1047.06	1046.81	1046.56	1046.33	1046.09	1045.81

LONGITUDINAL SECTION CH: 920.00m – 1900.00m

SCALE HOR – 1: 2000 VER – 1:1000

NOTE:

REFER TO DRG. 301-00509\02-001 FOR ALIGNMENT

25 0 25 50 75
METRES 1:1000

50 0 50 100 150
METRES 1:2000

Knight Piésold CONSULTING

PRIMARY DISCIPLINE	CIVIL	
DRAWN	ME	28/08/2015
DRAWING CHECK	TM & JZ	28/08/2015
DESIGN	RG	28/08/2015
DESIGN CHECK	AS	28/08/2015
PROJECT ENGINEER	AS	–

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REVISION

REV.No.	DATE	DESCRIPTION	DRAWN	CHKD.	APPD.
A	22.01.16	ISSUED FOR INFORMATION	ME	MM	AS
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REFERENCE DRAWINGS

DRAWING No.	MAKERS No.	TITLE
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WESIZWE PLATINUM LTD.
MIMOSA TSF DESIGN
LONGITUDINAL SECTIONS
CH. 0.00M – 1920.00

DRAWING NUMBER	SCALE	REV.
301-00509/02-015	AS SHOWN	A

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