Technical Construction Specifications
Phase 2 West Dry Stack Tailings Facility Project
Keno Hill Mine, YT



PRESENTED TO

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Tetra Tech Canada Inc.
14940 - 123 Avenue
Edmonton, AB T5V 1B4 CANADA
Tel 780.451.2121 Fax 780.454.5688

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Prepared by:
Sheridan Zampou, E.I.T.
Geotechnical Engineer-in-Training
Direct Line: 587.460.3622
Sheridan.Zampou@tetratech.com

Reviewed by:
Gary Koop, M.Eng., P.Eng.
Principal Consultant – Arctic Region
Direct Line: 587.460.3542
Gary.Koop@tetratech.com

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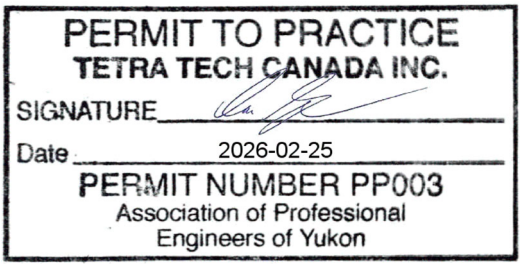

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1.0 SITE PREPARATION

1.1 General

1.1.1 Description

.1 This section specifies the following requirements for the Phase 2 West (P2W) Dry Stack Tailings Facility (DSTF) Project:

- .a Clearing and grubbing;
- .b Removal of ice-rich permafrost; and
- .c Disposal of unsuitable material.

1.1.2 Definitions

.1 Clearing consists of cutting, piling, removing, and disposing of trees, brush, stumps, logs and roots, and debris from construction areas.

.2 Grubbing consists of the excavation and removal of all roots, stumps, buried wood, root mats, and other objectionable subsurface organic material below existing ground elevation.

.3 Ice-rich permafrost comprises frozen ground having a minimum ice content (visible or nonvisible) of 20 percent by weight.

.4 Unsuitable material consists of soft or yielding foundation soils with deformation exceeding 50 mm under an articulated haul truck wheel load.

1.1.3 Reference Standards

.1 ASTM D 4643, Standard Test Method for Determination of Water Content of Soil and Rock by Microwave Oven Heating.

1.2 Materials

.1 Not Used.

1.3 Execution

1.3.1 Clearing

.1 Cut all trees and vegetation larger than 50 mm in diameter with minimal disturbance to the organic surface.

.2 Place tree debris at the allocated timber storage locations shown in the Work Area Management Plan.

.3 Do not burn or bury tree debris.

.4 Leave in place and/or mulch trees and vegetations smaller than 50 mm in diameter.

.5 Remove vegetation such that stumps are flush with the surrounding organic mat or surrounding ground.

.6 Contain debris from clearing operations within the limits of the areas to be cleared. Do not deposit debris on adjacent undisturbed areas.

1.3.2 Grubbing

.1 Excavate vegetation and organics to expose mineral soil.

.2 Stockpile surface organic material as indicated in the Work Area Management Plan.

1.3.3 Excavation of Ice-Rich Permafrost

.1 Ice-rich permafrost will be evaluated as follows:

.a Divide the area of suspected ice-rich permafrost into 200 m^2 parcels.

.b For each parcel excavate a testpit 1.5 m in depth minimum. The testpit will be logged by the QA Construction Monitor and samples collected at regular intervals for moisture content testing.

.c If estimated visible ice content exceeds 20 precent or moisture content exceeded 25% continue testpit excavation beyond the 1.5 m depth until ice-poor material is visually encountered.

.d The QA Construction Monitor will collect samples from targeted depths and complete moisture contents testing per ASTM D4643.

.e Sub-excavation depth should extend to a depth of confirmed less than 25% moisture content.

.f Visual inspection by the QA Construction Monitor will supersede moistures (i.e. if all samples are less than 25% moisture, but estimated visible ice is greater than 20% observed in testpit walls or base), areas of visible ice will be removed.

.g The QA Construction Monitor will inspect and photograph sub-excavation after complete, and if necessary, collect representative sample from the base for additional moisture content testing, and the footprint surveyed for as-builts.

.2 Excavate ice-rich permafrost underlying embankments, berms, or sumps and replace with Coarse Bulk Fill to the lines and dimensions shown on the Construction Drawings.

.3 Store removed permafrost in areas designated in the Work Area Management Plan.

1.3.4 Unsuitable Materials

.1 Excavate unsuitable subgrade foundation soils and backfill with Coarse Bulk Fill to the lines and dimensions shown on the Construction Drawings.

.2 Store removed unsuitable material in areas designated in the Work Area Management Plan.

.3 Handle unsuitable materials carefully to minimize environmental impact.

.4 Store unsuitable materials in designated areas specified in the Work Area management Plan.

1.4 Quality

1.4.1 Quality Control

.1 None required.

1.4.2 Quality Assurance (by Owner)

.1 The QA Construction Monitor will complete visual assessment and collect samples as work progresses, as described above.

.2 The QA Construction Monitor will assess ice-rich permafrost conditions and provide recommendations for sub-excavation of ice-rich and unsuitable materials.

END OF SECTION

2.0 AGGREGATES AND TAILINGS FOR EARTHWORKS

2.1 General

2.1.1 Description

.1 This section specifies the requirements for the supply and processing for aggregates and tailings to be incorporated Keno Hill Phase 2 West Project.

.2 The term “aggregate” refers to all granular materials included in this Specification.

.3 The term “tailings” refers to filtered tailings supplied by AKHM in this Specification.

.4 Crushing, screening, and select sorting will be required to satisfy gradation requirements.

.5 Borrow sources for aggregate production will be identified by the Owner.

2.1.2 Reference Standards

.1 ASTM International (ASTM)

.a ASTM D4791-19R23, Standard Test Method for Flat Particles, Elongated Particles, or Flat and Elongated Particles in Coarse Aggregate.

.b ASTM C117-23, Standard Test Method for Material Finer than 0.075 mm (No.200) Sieve in Mineral Aggregates by Washing.

.c ASTM C136M-19, Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates.

.d ASTM D7928, Standard Test Method for Particle-Size Distribution (Gradation) of Fine-Grained Soils Using the Sedimentation (Hydrometer) Analysis.

.e ASTM D 4643, Standard Test Method for Determination of Water Content of Soil and Rock by Microwave Oven Heating.

2.2 Materials

2.2.1 Material Sources

.1 The parent rock from which all granular fill materials are derived to consist of sound, hard, durable, Non-Acid and Metals Leaching (NAML) material free from soft, thin, elongated, or laminated particles.

.2 All aggregate shall comprise hard durable particles, free from roots, frozen material, organics, and other deleterious material and foreign substances.

.3 Tailings will be provided by AKHM and sourced from the dry stack or produced from the Mill.

.4 Tailings shall be free from frozen material, organics, and other deleterious material and foreign substances.

2.2.2 500 mm Minus Coarse Bulk Fill

.1 Coarse bulk fill is select material sourced from excavations or other sources consisting of pit run granular material in an unfrozen state, free from boulders larger than 500 mm in diameter, a D50 of 100 mm, and having less than 20 percent (by mass) smaller than 0.08 mm.

2.2.3 75 mm Minus Granular Fill

.1 75 mm minus granular fill consists of stone, gravel, or sand to achieve the specified particle size distribution in Table 2-3.

Table 2-3: 75 mm Minus Granular Fill Particle Size Distribution

Particle Size (mm)	% Passing By Mass
75	100
50	75 - 100
25	55 - 100
16	45 - 80
10	35 - 68
5	22 - 55
0.63	7 - 28
0.08	0 - 15

2.2.4 50 mm Minus Granular Fill

.1 50 mm minus granular fill consists of stone, gravel, or sand to achieve the specified particle size distribution in Table 2-4.

Table 2-4: 50 mm Minus Granular Fill Particle Size Distribution

Particle Size (mm)	% Passing By Mass
50	100
25	65 - 100
16	50 - 85
10	40 - 75
5	30 - 62
0.63	12 - 36
0.08	4 - 15

2.2.5 50 mm Clean Drain Rock

.1 50 mm Clean Drain Rock is select material in an unfrozen state with a maximum particle size of 50 mm and no particles smaller than 20 mm.

2.2.6 20 mm Minus Granular Fill

.1 20 mm minus granular fill consists of stone, gravel, or sand to achieve the specified particle size distribution in Table 2-6.

Table 2-6: 20 mm Minus Granular Fill Particle Size Distribution

Particle Size (mm)	% Passing By Mass
20	90 - 100
16	80 - 100
12.5	65 - 100
5	42 - 72
0.63	12- 35
0.08	4 - 20

2.2.7 5 mm Minus Granular Fill

.1 5 mm minus granular fill consists of sand to achieve the specified particle size distribution in Table 2-7.

Table 2-7: 5 mm Minus Granular Fill Particle Size Distribution

Particle Size (mm)	% Passing By Mass
5	100
2.5	80 - 100
1.25	50 - 90
0.63	25 - 65
0.315	10 - 35
0.08	0 - 15

2.2.8 Tailings (Contained Tailings Toe Structure)

.1 Tailings (Contained Tailings Toe Structure) consist of filtered tailings supplied by AKHM that adhering to the particle size distribution outlined in AKHM's June 2025 Rev 3 Operations, Maintenance, and Surveillance (OMS) Manual.

2.3 Execution

2.3.1 Granular Fill

.1 Transport and handle aggregate materials in a manner to avoid segregation, contamination, and degradation.

.2 Prior to excavating materials for aggregate production, remove all unsuitable surface materials. Dispose of unsuitable materials in accordance with the Work Area Management Plan.

.3 Trim off and dress slopes of waste material piles and leave site in neat condition.

.4 Process aggregates uniformly using methods that prevent contamination, segregation, and degradation.

.5 Where necessary, screen, crush, and process aggregates with suitable equipment to meet requirements.

.6 Blend aggregates if required to obtain gradation requirements specified.

.7 When operating in stratified deposits use excavation equipment and methods that produce uniform, homogeneous aggregate gradation.

.8 Stockpiling:

.a Stockpiling sites to be level and well drained.

.b Stockpile aggregates far enough apart to prevent intermixing.

.c Uniformly spot-dump aggregates delivered to stockpile in trucks and build up stockpile as specified.

.d Do not cone piles or spill material over edges of piles to reduce the potential for segregation.

2.3.2 Tailings

.1 Excavate, transport, and handle tailings materials in a manner to avoid contamination and degradation.

.2 Excavation surface to be maintained at 3H:1V slope for physical stability.

.3 Maintain positive drainage away from the excavation area.

2.4 Quality

2.4.1 Quality Control

.1 Complete particle size analysis testing in accordance with ASTM C117 and C136 at the following minimum frequencies:

.a 5 mm Minus Material: 1 test per 500 m^3 of material produced or per 12 hours of material production, whichever is more frequent.

.b 20 mm Minus Material: 1 test per 150 m^3 of material produced or per 12 hours of material production, whichever is more frequent.

.c 50 mm Minus Material: 1 test per 500 m^3 of material produced or per 12 hours of material production, whichever is more frequent.

.d 50 mm Clean Drain Rock: 1 test per 150 m^3 of material produced or per 12 hours of material production, whichever is more frequent.

.e 75 mm Minus Material: 1 test per 250 m^3 of material produced or per 12 hours of material production, whichever is more frequent.

.2 For the 500 mm Minus Coarse Bulk Fill complete the following:

.a Particle size analysis testing on the 100 mm minus fraction in accordance with ASTM C117 and C136.

.b Estimate the 100 mm to 500 mm fraction using a tape measure, Wipfrag software, or other method approved by Owner.

.c Complete testing at a frequency of 1 test per 5,000 m^3 of material produced.

.d Complete flat and elongated testing in accordance with ASTM D 4791 at a frequency of 1 test per 5,000 m^3 of material produced.

.3 For the tailings complete the following:

.a 1 moisture content test in accordance with ASTM D 4643 per 300 mm thick lift placed, or per day of construction, whichever is more frequent.

2.4.2 Quality Assurance

.1 Complete particle size analysis testing in accordance with ASTM C117 and C136 at the following minimum frequencies:

- .a 5 mm Minus Material: 1 test per 1,000 m^3 of material produced or per 12 hours of material production, whichever is more frequent.
- .b 20 mm Minus Material: 1 test per 300 m^3 of material produced or per 12 hours of material production, whichever is more frequent.
- .c 50 mm Minus Material: 1 test per 1,000 m^3 of material produced or per 12 hours of material production, whichever is more frequent.
- .d 50 mm Clean Drain Rock: 1 test per 300 m^3 of material produced or per 12 hours of material production, whichever is more frequent.
- .e 75 mm Minus Material: 1 test per 500 m^3 of material produced or per 12 hours of material production, whichever is more frequent.

.2 For the tailings complete the following:

- .a 1 hydrometer test in accordance with ASTM C117 and C136 per 5,000 m^3 of material placed.

END OF SECTION

3.0 SITE GRADING

3.1 General

3.1.1 Description

.1 This section outlines the following requirements for the Phase 2 West Project:

.a Site Grading; and

.b Excavation and Subgrade Preparation.

.2 Variable ground conditions may be encountered during excavation, which could include frozen and unfrozen glacial till and/or alluvial deposits and ice-rich soils.

.3 Be prepared to excavate in variable ground conditions to facilitate construction of the Phase 2 West Project.

.4 Mechanical fracturing of frozen soil may be necessary; ensure that appropriate equipment and expertise are available.

3.1.2 Reference Standards

.1 ASTM D 698 – 07 e1, Standard Test Method for Laboratory Compaction Characteristics of Soil Using Standard Effort (600 kN-m/m^3).

.2 ASTM D 2922-01, Standard Test Methods for Density of Soil and Soil-Aggregate in Place by Nuclear Methods (Shallow Depth).

3.2 Materials

.1 Aggregates and Tailings for Earthworks – See Section 2.0.

3.3 Execution

3.3.1 Excavation and Subgrade Preparation

.1 Undertake excavations to the dimensions and alignments as specified in the Construction Drawings.

.2 Backfill and compact over-excavated areas with 500 mm Minus Coarse Bulk Fill as to the lines and dimensions shown on the Construction Drawings.

.3 All excavations to be protected from ingress of surface runoff, and maintained free of snow, ice, or deleterious materials.

3.3.2 Placement, Moisture Conditioning, and Compaction of Granular Fill and Tailings Material

.1 Place materials so that each zone is homogenous and free from:

.a Stratifications;

.b Ice chunks;

.c Snow lenses or pockets;

.d Ruts; and

.e Layers of material of differing textures.

.2 Remove and dispose of any unsuitable materials in accordance with Section 1.0 – Site Preparation.

.3 The prepared subgrade surface, including base and embankment slopes, are to be free of snow, ice, standing water, or other deleterious material prior to fill placement.

.4 Place material to the lines, grades, and elevations shown on the Construction Drawings.

.5 Grade disturbed areas surrounding construction work areas to promote positive drainage immediately following construction.

3.3.2.1 Coarse Bulk Fill Placement

.1 Place coarse bulk fill in lifts not exceeding 500 mm.

.2 Compact the lifts with a smooth-drum vibratory packer weighing at least 10,000 kg with a minimum of six full (forward and backward) passes.

.a Maximum allowable deflection of 40 mm under loaded articulated haul truck.

.b Completed surface to be free from rutting.

3.3.2.2 75 mm Minus Granular Fill Placement

.1 Place 75 mm minus granular fill in lifts not exceeding 500 mm.

.2 Moisture condition and compact with a smooth-drum packer (static only) weighing at least 10,000 kg with a minimum of six full (forward and backward) passes.

3.3.2.3 50 mm Minus Granular Fill Placement

.1 Place 50 mm minus granular fill in lifts not exceeding 300 mm.

.2 Moisture condition and compact material to at least 95 percent of SPMDD (ASTM D 698) at optimum moisture content ±2 percent.

3.3.2.4 50 mm Clean Drain Rock Placement

.1 Place drain rock in lifts not exceeding 300 mm to the lines and dimensions shown on the Drawings.

.2 Compact the lifts with a plate tamper weighing at least 450 kg with a minimum of three full (forward and backward) passes.

3.3.2.5 20 mm Minus Granular Fill Placement

.1 Place 20 mm minus granular fill in lifts not exceeding 150 mm.

.2 Moisture condition and compact material to at least 95 percent of SPMDD (ASTM D 698) at optimum moisture content ±2 percent.

3.3.2.6 5 mm Minus Granular Fill Placement

.1 Place 5 mm minus granular fill in lifts not exceeding 300 mm.

3.3.2.7 Tailings Placement

.1 Place tailings in lifts not exceeding 300 mm.

.2 Moisture condition and compact material to at least 95 percent of SPMDD (ASTM D 698) at optimum moisture content ±2 percent.

3.4 Quality

3.4.1 Finishing and Tolerances

.1 All areas to be covered with granular and tailings material are to be uniform without projections or depressions exceeding 100 mm in 3 m.

.2 Granular and tailings fill surfaces to be within ± 30 mm of design elevations but not uniformly high or low.

3.4.2 Quality Control

.1 Complete moisture density relationship testing on granular materials in accordance with ASTM D698. Complete testing at the follow frequencies:

- .a A minimum of 1 test per 500 m^3 of material produced for 20 mm Minus Granular Fill.
- .b A minimum of 1 test per 1,000 m^3 of material produced for 50 mm Minus Granular Fill.
- .c A minimum of 1 test per 1,000 m^3 of material produced for 75 mm Minus Granular Fill.
- .d A minimum of 1 test per 5,000 m^3 of material for tailings.

.2 Complete field density testing in accordance with ASTM D2922 for 20 mm granular fill, 50 mm minus granular fill, and 75 mm minus granular fill. Target compaction and moisture content for each material type are Specified in Section 3.3 – Execution. Complete testing at the following frequencies:

- .a A minimum of 1 test per 50 m^2, per lift, for 20 mm Minus Granular Fill.
- .b A minimum of 1 test per 100 m^2, per lift, for 50 mm Minus Granular Fill.
- .c A minimum of 1 test per 250 m^2, per lift, for 75 mm Minus Granular Fill.

.3 Complete proof rolling 500 mm Minus Granular Fill at a frequency of one proof roll per lift:

- .a Proof roll using a loaded haul truck with high contact wheel pressures [inflation pressures ranging from 550 kPa (80 psi) up to 1,030 kPa (150 psi)].
- .b Maintain a maximum speed of 4 km/h.
- .c Complete two coverages with the proof-rolling; one 'coverage' means that every point of the proof-rolled surface has been subjected to the tire pressure of a loaded wheel.
- .d Any areas of soft, rutted, or displaced materials detected should either be recompacted with additional fill or the existing material removed and replaced with 50 mm minus granular fill.

.4 For the tailings complete the following:

- .a Verification and documentation of the minimum number of passes based on the control strip being completed.

3.4.3 Quality Assurance

.1 Complete moisture density relationship testing on all granular materials in accordance with ASTM D698. Complete testing at the follow frequencies:

- .a A minimum of 1 test per 500 m^3 of material produced for 20 mm Minus Granular Fill.
- .b A minimum of 1 test per 1,000 m^3 of material produced for 50 mm Minus Granular Fill.
- .c A minimum of 1 test per 1,000 m^3 of material produced for 75 mm Minus Granular Fill.

.2 For the tailings complete the following:

- .a A method specification will be prepared and finalized in the field before construction to confirm the number of compactions passes and target moisture ranges using a control strip. Testing of the control strip will include a Dynamic Cone Penetrometer and sand cone testing.
- .b Complete a new control strip every 5,000 m^3 or as material visually changes.

END OF SECTION

4.0 BURIED PIPE AND DRAINAGE STRUCTURES

4.1 General

4.1.1 Description

.3 This section describes the requirements for buried pipe and drainage structure specifications for the Keno Hill Phase 2 West Project.

4.1.2 Reference Standards

.1 ASTM C518, Test for Steady-State Heat Flux Measurements and Thermal Transmission Properties by Means of the Heat Flow Meter.

.2 ASTM D638, Test Method for Tensile Properties of Plastic.

.3 ASTM D1248, Specification for Polyethylene Plastics Molding and Extrusion Materials.

.4 ASTM D1505, Test Method for Density of Plastics by the Density-Gradient Technique.

.5 ASTM D1621, Test Method for Compressive Properties of Rigid Cellular Plastics.

.6 ASTM D1622, Test Method for Apparent Density of Rigid Cellular Plastics.

.7 ASTM D2856, Test Method for Open Cell Content of Rigid Cellular Plastics by the Air Pycnometer.

.8 ASTM D2842, Test Method for Water Absorption of Rigid Cellular Plastics.

.9 ASTM D3574, Method of Testing Flexible Cellular Materials – Slab, Bonded, and Molded Urethane Foams.

.10 ASTM F714, Specification For Polyethylene (PE) Plastic Pipe or (SDR-PR) Based on Outside Diameter.

.11 ASTM D2837, Method for Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials.

.12 ASTM D3350, Specification for Polyethylene Plastic Pipe and Fittings.

.13 CSA A23.1/A23.2, Concrete Materials and Methods of Concrete.

4.2 Materials

4.2.1 HDPE Pipe

.1 Supply DR17 and DR11 HDPE pipe; pipe diameter and length as specified on the Drawings.

.a Raw material shall contain minimum two percent carbon black.

.b The pipe shall contain no recycled compound except those generated in the manufacturer's own plant, from resin of the same specification, from the same raw material supplier.

.c The cell classification shall be PE 445474C for PE 4710 materials, as per ASTM D3350/F714.

.d Material long term hydrostatic design stress is 1,000 psi (6,895 kPa) at 73°F, as defined in ASTM D2837.

.2 Provide buried utility tape to demark top of culvert.

4.2.2 Corrugated Steel Pipe (CSP)

.1 Supply galvanized CSP including couplers and appurtenances in accordance with the latest edition of Canadian Standards Association (CSA) G401 Specification.

.2 Culverts shall be constructed of new material.

.3 Supply culverts with a 68x13 mm corrugation profile and 2 mm wall thickness.

.4 Spirally corrugated metal pipe shall have ends re-corrugated to provide annular corrugations for couplers.

.5 Annular corrugated couplers shall be of sufficient width to cover at least two outside crest corrugations on each re-corrugated end. Coupler bands shall have a minimum of three bolts.

.6 Lock seams terminating at the cut edges of sloped or square ended sections shall have a 75 mm length fillet weld run along the lock seam at each cut edge. The weld and surrounding area shall be recoated with the appropriate material in accordance with CSA G401.

4.2.3 Pipe Riser Overflow

.1 Provide the following ancillary components to facilitate the pipe riser overflow installation, as shown on the Construction Drawings:

.a Stainless Steel Pipe Clamp; and

.b 50 mm x 8 mm Thick Closed Cell Neoprene Continuous.

4.2.4 Granular and Tailings Fill

.1 500 mm Minus Coarse Bulk Fill – Reference Section 2.0 Aggregates and Tailings for Earthworks.

.2 50 mm Minus Granular Fill – Reference Section 2.0 Aggregates and Tailings for Earthworks.

.3 20 mm Minus Granular Fill – Reference Section 2.0 Aggregates and Tailings for Earthworks.

.4 50 mm Clean Drain Rock – Reference Section 2.0 Aggregates and Tailings for Earthworks.

.5 Tailings (Contained Tailings Toe Structure) – Reference Section 2.0 Aggregates and Tailings for Earthworks.

4.3 Execution

4.3.1 HDPE Pipe

.1 Excavate pipe foundation to the lines and dimensions shown on the Construction Drawings.

.2 Excavate all soft, yielding or unsuitable material at this level in Accordance with Section 1.0 – Site Preparation.

.3 Construct pipe bedding with 50 mm Minus Granular fill, placed and compacted to 95 percent of the maximum dry density in accordance with Section 3.0 – Site Grading.

.4 Grade pipe base to meet the required culvert invert elevation and design slope. The surface shall be even such that voids are not created when the culvert is placed on the bedding.

.5 Place pipe on installed based, true to the design lines and grades.

.6 Fusion weld HDPE pipe as required to develop required pipe length.

.7 Place 20 mm minus granular fill up to pipe spring line as shown on the Construction Drawings. Compact material to 95 percent of the maximum dry density in accordance with Section 3.0 – Site Grading. Shovel and hand tools may be required to place the backfill under the culvert haunches.

.8 Place 50 mm minus granular fill above spring line and ensure backfill is continuous around the pipe.

4.3.2 Pipe Riser Overflow

.1 Place 5 mm Minus Granular Fill foundation in accordance with Section 3.0 – Site Grading.

.2 Place pipe riser overflow to the lines and dimensions shown on the Construction Drawings.

.3 Connect culvert sections in accordance with Manufacturer's recommendation and installation specification.

4.4 Quality

4.4.1 Finishing and Tolerances

.1 All areas to be covered with granular material are to be uniform without projections or depressions exceeding 100 mm in 3 m.

.2 Granular and tailings fill surfaces to be within ± 30 mm of design elevations but not uniformly high or low.

.3 Excavation surfaces to be within ± 100 mm of excavation elevations but not uniformly high or low.

.4 HDPE pipe vertical position to be within ± 50 mm with no sags in the pipe or alignment that will produce stagnant flow.

4.4.2 Quality Control

.1 Complete field density testing in accordance with ASTM D2922 for 20 mm granular fill at the following frequency:

.a 1 test per 20 m of liner trench; or

.b 1 test per 50 m^2.

.2 Complete field density testing in accordance with ASTM D2922 for 50 mm granular fill at the following frequency:

.a 1 test per 20 m of liner trench; or

.b 1 test per 50 m^2.

4.4.3 Quality Assurance

.1 No required testing.

END OF SECTION

5.0 LINER SYSTEM SUPPLY

5.1 General

5.1.1 Description

.1 This section describes the requirements for the supply non-woven geotextile, and LLDPE geomembrane for the Keno Hill Phase 2 West Project.

.a Non-woven geotextile, and 80 mil LLDPE are to be used for the P2W DSTF project.

5.1.2 Reference Standards

.1 American Society for Testing Materials – Geotextile Standards

.a ASTM D 4632, Standard Test Method for Grab Breaking Load and Elongation of Geotextiles.

.b ASTM D 4533, Standard Test Method for Trapezoid Tearing Strength of Geotextiles.

.c ASTM D 5261, Standard Test Method for Measuring Mass per Unit Area of Geotextiles.

.d ASTM D 4491, Standard Test Methods for Water Permeability of Geotextiles by Permittivity.

.e ASTM D 4751, Standard Test Methods for Determining Apparent Opening Size of a Geotextile.

.f ASTM D 6241, Standard Test Method for Static Puncture Strength of Geotextiles and Geotextile Related Product Using a 50-mm Probe.

.2 American Society for Testing and Materials – Geomembrane

.a ASTM D 746, Standard Test Method for Brittleness Temperature of Plastics and Elastomers by Impact.

.b ASTM D 792, Standard Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement.

.c ASTM D 1004, Standard Test Method for Initial Tear Resistance of Plastic Film and Sheeting.

.d ASTM D 1204, Standard Test Method for Linear Dimensional Changes of Non Rigid Thermoplastic Sheeting or Film at Elevated Temperature.

.e ASTM D 1603, Standard Test Method for Carbon Black in Olefin Plastics.

.f ASTN D 4218, Standard Test Method for Determination of Carbon Black Content in Polyethylene Compounds by the Muffle-Furnace Technique.

.g ASTM D 4833, Test Method for Index Puncture Resistance of Geotextiles, Geomembranes, and Related Products.

.h ASTM D 5596, Standard Practice for Microscopical Examination of Pigment Dispersion in Plastic Compounds.

.i ASTM D 5994, Standard Test Method for Measuring Nominal Thickness of Textured Geomembranes.

.j ASTM D 6993, Standard Test Method for Determining Tensile Properties of Nonreinforced Polyethylene and Nonreinforced Flexible Polypropylene Geomembranes.

5.2 Materials

5.2.1 Non-Woven Geotextile Properties

.1 Non-woven geotextile shall comprise needle punch polypropylene fabric made of 100 percent polypropylene staple fibers conforming to the properties in Table 5-1.

.2 All non-woven geotextile shall have a weight of at least 540 g/m^2.

.3 The manufacturer shall, prior to shipment of materials, provide to the Engineer, a signed manufacturing certification that materials to be shipped to site have test values that meet or exceed the requirements listed in Table 5-1.

Table 5-1: Minimum Geotextile Properties

Material Property	ASTM Test Method	Material Specifications
Fabric Weight - MARV	ASTM D 5261	540 g/m^2 (16 oz/yd^2)
Grab Tensile	ASTM D 4632	1,690 N (380 lb)
Grab Elongation	ASTM D 4632	50%
Trapezoidal Tear	ASTM D 4533	620 N (139 lb)
CBR Puncture	ASTM D 6241	4,560 N (1,025 lb)

5.2.2 Linear Low-Density Polyethylene (LLDPE) Liner

.1 The liner material produced shall be free of blisters, holes, undispersed raw materials, or any sign of contamination by foreign matter.

.2 The LLDPE liner material shall be liner low-density polyethylene (LLDPE) geomembrane and have the minimum property values indicated in Table 5-2.

.3 The liner material shall be textured on both sides.

.4 Extrusion resin used for extrusion joining of sheets and for repairs shall be LLDPE from the same resin as the sheet resin. Physical properties shall be the same as the liner sheets.

Table 5-2: Minimum LLDPE Geomembrane Properties

Test Parameter	ASTM Test Method	Required Specifications
Minimum Average Thickness (mm / mil)	D5994	2 / 80
Density (g/ml)	D792	0.92
Tensile Strength at Break (N/mm, ppi)	ASTM D6693	53 / 304
Elongation at Break (%)	ASTM D6693	800
Tear Resistance (N / lbs)	ASTM D 1004	780 / 176
Puncture Resistance (N / lbs)	ASTM D 4833	500 / 112
Carbon Black (min)	ASTM D4218	2-3%
Carbon Black Dispersion	ASTM D 5596	9/10 in CAT 1 or 2; 1 in CAT 3

5.3 Execution

.1 Not used, refer to Section 7.0.

5.4 Field Quality

.1 Not Used.

END OF SECTION

6.0 LINER SYSTEM INSTALLATION

6.1 General

6.1.1 Description

.1 This section describes the requirements for the installation of non-woven geotextile, and LLDPE geomembrane for the Keno Hill Phase 2 West Project.

6.1.2 Reference Standards

.1 American Society for Testing and Materials – LLDPE Geomembrane

.a ASTM D 4437, Standard Practice for Determining the Integrity of Field Seams Used in Joining Flexible Polymeric Sheet Geomembranes.

.b ASTM D 5641, Standard Practice for Geomembrane Seam Evaluation by Vacuum Chamber.

.c ASTM D 5820, Test Method for Air Testing.

.d ASTM D 5820-95, Pressurized Air Channel Test for Dual Seamed Geomembranes.

.e ASTM D 6365, Standard Practice for the Nondestructive Testing of Geomembrane Seams using The Spark Test.

.2 Geosynthetic Research Institute (GRI):

.a GRI GM 9 Cold Weather Seaming of Geomembranes.

.b GRI GM 12 Measurement of the Asperity Height of Textured Polyethylene Geomembranes Using a Depth Gage.

.c GRI GM 13 Test Properties, Testing Frequency for Smooth and Textured Geomembranes.

.d GRI GM 14 Selecting Variable Intervals for Taking Geomembrane Destructive Seam Samples Using the Method of Attributes.

.e GRI GM 19 Seam Strength and Related Properties of Thermally Bonded Polyolefin Geomembranes.

6.2 Materials

.1 Non-Woven Geotextile – Reference Section 6.0 – Liner Supply System.

.2 LLDPE Geomembrane – Reference Section 6.0 – Liner Supply System.

6.3 Execution

6.3.1 Non-Woven Geotextile

6.3.1.1 Installation

.1 Prepare area to be covered by geotextile to be smooth and free of sharp objects or surface protrusions that could puncture the geotextile and damage the overlying geomembrane liner.

.2 Place geotextile following subgrade approval.

.3 Do not damage or comprise geotextile during installation.

.4 Do not place geotextile during periods of adverse weather conditions.

.5 Place geotextile with a minimum overlap of 150 mm and connected at the seam by heat bonding. Horizontal seams should be kept to a minimum on the side slopes, corners, and other regions of geometric irregularities.

.6 Utilize sufficient temporary anchorage shall be used to hold the Geotextile in place during placement of the other elements of the liner system.

6.3.1.2 Repair Procedures

.1 Record all areas requiring repair due to damage during shipping, handling, deploying, or manufacturing flaws as well as installation.

.2 Repair any tears or holes made in the Geotextile by placing a patch of geotextile on the defect and fastening it by heat bonding.

.3 Extend all repairs made by the placement of a patch of the same material over the damage shall be at least 500 mm beyond the flaw or damage in every direction.

6.3.2 Linear Low-Density Polyethylene (LLDPE) Liner

6.3.2.1 General

.1 LLDPE Geomembrane shall be free of holes, pinholes, bubbles, blisters, excessive contamination by foreign matter, and nicks and cuts on roll edges.

.2 Horizontal seams on slopes are not permitted, unless no other option is available and only as approved by the Owner.

6.3.2.2 Liner Deployment

.1 Prepare geomembrane area to be smooth and free of sharp objects or surface protrusions that could puncture geomembrane liner.

.2 Deploy materials to minimize handling, damage, and contamination during installation.

.3 Provide sufficient anchorage against uplift due to wind. Use of sandbags are preferred.

.4 Incorporate adequate thermal slack in all layers of geomembrane.

.5 Information to be documented on the liner throughout the installation shall be clearly visible to such point that the material is covered, or construction is complete and will include:

.a On each panel, the panel number, material roll number, and date deployed. A panel number will be a simple and logical identifying code.

.b Give all repairs an identification number; the welder, welder operator, and date shall be recorded with the identification number.

.c Identify all destructive sample locations by an identifying number and date removed.

.d All non-destructive test data and date of test.

.6 Key liner system (geomembrane liner and geotextile) completely down along the side and to the back of the anchor trench, as shown on the Construction Drawings.

.7 Do not allow heavy vehicular traffic directly on geomembrane or geotextile.

.8 Maintain the minimum liner cover thicknesses indicated in Table 6-1 when operating equipment on the liner. Temporary fill, exceeding those shown on the Construction Drawings, may be required to permit some equipment to work over the liner.

.9 Do not perform hard turning maneuvers with equipment on top of the geomembrane liner until there is at least 900 mm of material above the liner.

Table 6-1: Minimum Lift Thickness for Equipment Operating Over Liner

Minimum Backfill Thickness	Allowable Ground Pressure/Placement Equipment
No Backfill	Foot traffic
150 mm or less	Hand placement
300 mm	25 to 60 kPa (D3, D4 – D6 style Cat, Bobcat (skid-steer))
600 mm	60 to 110 kPa (D7 – D9 style Cat)
900 mm	Loaded scrapers, motor graders
1,200 mm	Loaded tandem axle trucks

6.3.2.3 Seams and Joints

.1 Field weld joints between liner sheets using the manufacturer's recommended procedures and equipment.

.a Perform seaming using either the extrusion or double wedge automatic fusion welding equipment and techniques, as recommended by the manufacturer of the liner membrane. Extrusion welding to be used where double wedge fusion welding is not possible such as for patches and repairs.

.b The weld area shall be free of all dirt, dust, moisture, or other foreign materials. Surfaces to be welded shall be wiped with oil free rags when required to remove any contamination by oil, grease, or excessive dirt.

.c If necessary, grind the liner material prior to welding as per the manufacturer's recommendations. Complete welding immediately after preparation and cleaning is complete. Check the temperature of the welding apparatus a minimum of once every hour during welding.

.d Weld the liner panels together through the anchor trench.

.2 An overlap line, a minimum of 150 mm from the edge of the underlying sheet, will be clearly identified on the underlying panel of every fusion seam.

.3 Provide overlap sufficient to leave a loose flap of geomembrane at least 25 mm wide adjacent to both sides of the seam.

.4 Stagger cross and toe seams a minimum of 1 m.

.5 Completed seams and joints will have a minimum bonded seam strength as follows:

.a For LLDPE Geomembrane:

- Completed seams shall have a minimum strength in shear of at least 21 N/mm at yield when tested in accordance with ASTM D 4437.
- Completed seams shall have a minimum strength in peel of at least 17.5 N/mm at yield, and break as a film tear bond or a minimum of 10 percent adhesion break when tested in accordance with ASTM D 4437.

.6 Implement cold weather installation methodology if ambient air temperature or adverse weather conditions jeopardize the integrity of the liner installation (ambient air temperature below 5°C). Demonstrate that acceptable seaming can be performed by completing acceptable trial welds.

.7 Defects and Repairs

.a Examine all seams and non-seam areas of the geomembrane for defects, holes, blisters, undispersed raw materials, and any sign of contamination by foreign matter.

.b Repair and non-destructively test each suspect location in both seam and non-seam areas. Do not cover geomembrane at locations which have been repaired until test results with passing values are available.

.8 Seaming and repairs will be completed in the presence of the Owner.

6.3.2.4 Welding

.1 Provide welding equipment and accessories meeting the following requirements.

.a Gauges showing temperatures in apparatus extrusion welders (preheat and barrel) or wedge welders (wedge temperature; travel speed).

.b Provide an adequate number of welding apparatus to avoid delaying work.

.c Provide a power source capable of providing constant voltage under combined line load.

.2 Qualification of Welders

.a Perform trial, or qualification welds, in the presence of the Owner, on geomembrane samples to verify welding equipment is operating properly.

.b Do not perform production welds until equipment and welders have successfully completed a trial weld.

.c Perform trial welds prior to use and at a minimum 4-hour frequency throughout each operating day, or as the origin (existing or new) of the liner panels to be seamed changes.

.d If any welder settings are changed, or maintenance is required other than routine cleaning, the welder will have to be prequalified.

.3 Trial Welds

.a Make trial welds under the same surface and environmental conditions as the production welds, (i.e., in contact with subgrade and at similar ambient temperature).

.b Trial welds of existing material from representative locations to new material will be required as directed by the Construction Supervisor.

.c Each trial weld shall be a minimum of 1.5 m in length.

.d Cut five, 25 mm wide by 150 mm long test strips from the trial weld. Quantitatively test four specimens for peel adhesion, and then one for bonded seam strength (shear).

.e Repeat the trial weld, in its entirety, when any of the trial weld samples fail in either peel or shear.

.4 Extrusion Welding

.a Hot-air bond adjacent pieces together using procedures that do not damage the geomembrane, or underlying material.

.b Purge welding apparatus of heat-degraded extrudate before welding.

.c Do not discard extrudate tails on any geosynthetic surface while still hot and do note leave discarded on or below the liner.

.d Clean geomembrane surfaces according to the appropriate manufacturer approved procedures before welding, and weld shortly after.

.5 Wedge Welding

.a Welding apparatus shall be a self-propelled device equipped with an electronic controller which displays applicable temperatures.

.b Protect against moisture build-up between sheets.

.c Continuously clean seam area of dust, mud, moisture, and debris immediately ahead of the hot wedge welder.

6.3.2.5 Repair Procedures

.1 Repair any liner area showing damage due to excessive scuffing, puncture, or distress from any cause by replacing or repairing with an additional piece of the same type of liner welded over the defective area. All patches shall extend a minimum of 150 mm from the affected area.

.2 Remove damaged geomembrane and replace it with acceptable geomembrane materials if damage cannot be satisfactorily repaired.

.3 Complete all repairs within 24 hours from when they are identified.

.4 Repair any portion of unsatisfactory geomembrane or seam area failing a destructive or non-destructive test. Installer shall be responsible for repair of damaged or defective areas. Confirm required repair method with the Construction Supervisor. Procedures available include the following:

.a Patching: Used to repair large holes, tears, undispersed raw materials, and contamination by foreign matter.

.b Abrading and Re-welding: Used to repair small seam sections.

.c Spot Welding: Used to repair pinholes or other minor, localized flaws or where geomembrane thickness has been reduced.

.d Capping: Used to repair large lengths of failed seams.

.e Flap Welding: Used to extrusion weld the flap (excess outer portion) of a fusion weld in lieu of a full cap.

.f Removing the unacceptable seam and replace with new material.

.5 Repair Verification

.a Number and log each patch repair.

.b Non-destructively test each repair using methods identified in this Specification.

6.4 Quality

6.4.1 Quality Control

.1 Welder Qualifications

.a Demonstrate an ability to perform by having previously successfully installed a minimum of 100,000 m^2 of similar type flexible liners.

.b Provide full time onsite liner supervisor having installed a minimum of 50,000 m^2 of similar type flexible liner.

.2 Complete visual inspections of the liner panels and joints as the installation progresses and again upon completion of the liner. Mark and repair defective and questionable areas.

.3 Test all joints and repairs in the LLDPE liner by vacuum testing or pressurized dual seams testing (for double hot wedge welds only).

.4 Perform a vacuum test on all extrusion welded seams and repairs, in the following manner:

.a The area to be tested shall be cleaned of all dirt, debris, and other foreign matter and then a soap and water solution shall be applied.

.b The vacuum box consists of a rigid housing with a clear viewing window, soft neoprene gasket, valve assembly, vacuum gauge, pressure controlled vacuum pump, and container of soapy solution. Vacuum box and procedures should be in accordance with ASTM D-5641.

.c A vacuum of 35 kPa shall be induced and held for a minimum of 5 seconds or long enough for the area to be thoroughly examined.

.d Examine the geomembrane through the viewing window for the presence of soap bubbling, all areas where leaks are identified shall be marked and repaired.

.e Any portion of an extrusion seam or repair that cannot be vacuum tested, must be pick tested.

.5 Perform pressurized testing of all double wedge weld seams, regardless of length, in the following manner:

.a Seal both ends of the seam to be tested.

.b Insert a needle with pressure gage, or other approved pressure feed device equipped with a pressure gauge, into the channel produced in the middle of the double wedge weld.

.c Pressurize the channel to 200 kPa to allow the seam to stretch and stabilize before beginning the test. Maintain pressure for a period no shorter than 5 minutes.

.d If the loss of pressure exceeds 28 kPa during the testing period or does not stabilize, then the seam will either be repaired entirely, or the faulty area will be located and repaired.

.e If blockage is present, locate and test seam on both sides of blockage.

.f Remove needle or other approved pressure feed device and seal all penetration holes by extrusion welding.

.6 Conduct destructive testing on completed seams as follows:

.a Sampling procedure:

- Cut samples at locations designated as the installation progresses in order to obtain laboratory test results before the geomembrane is covered.
- Number each sample and mark sample number and location on the installation layout drawing.
- Repair all holes in the geomembrane resulting from destructive sampling. Repair and test the continuity of the repair in accordance with these Specifications.
- Samples shall be 200 mm wide and a minimum length of 700 mm, with the seam centered lengthwise.

.b Location and frequency of testing of wedge welded seams.

- One test per 150 m of welded seams.
- Coordinate destructive samples to be extracted from end of seams to be discarded and above the designed maximum fluid level.
- Test locations will be determined after seaming.

6.4.2 Failed Seam Procedures

.1 The following procedure will be used when there is a destructive test failure.

.a Follow one of two options:

- Reconstruct the seam, or seams between any two passed test locations.
- Track the poor weld by extracting additional samples from either side of the failed sample. These samples must be taken a minimum of 3 m from the failed sample in both directions from the location of the failed test.

.b Check next seam welded using same welding device if required to obtain additional sample (i.e., if one side of the seam is fewer than 3 m long).

.c If any subsequent sample fails, the process shall be repeated to establish the zone in which the seam shall be reconstructed.

.d Acceptable seams shall be bound by two locations from which samples have passed destructive tests.

6.4.3 Quality Assurance

.1 No required testing.

END OF SECTION