2017 Design, Operations, and Closure Plan

Upland Landfill

Campbell River, British Columbia

Upland Excavating Ltd.

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Symbols and Abbreviations

%	Percent
AMSL	Above Mean Sea Level
BC	British Columbia
BTU	British thermal unit
BOD	Biological Oxygen Demand
C&D waste	Construction and Demolition Waste
Ca	Calcium
CCA	Copper Chromium Arsenate
cfm	Cubic Feet Per Minute
CH_4	Methane
CHI	Computational Hydraulics International
City	City of Campbell River
CLS	Contaminating Life Span
cm/sec	centimetre per second
CO_2	Carbon Dioxide
COC	Contaminant of Concern
COD	Chemical Oxygen Demand
CSR	Contaminated Sites Regulation
DOCP	Design, Operations, and Closure Plan
DW	Drinking Water
EFW	Energy from Waste
EMA	Environmental Management Act
EMP	Environmental Monitoring Program
Fe	Iron
FOS	Factor of Safety
FWAL	Fresh Water Aquatic Life
GCL	Geosynthetic Clay Liner
H2S	Hydrogen Sulfide
Ha	Hectare
HDPE	High Density Polyethylene
HEC-HMS	Hydrologic Engineering Centre-Hydrologic Modelling System
HELP	Hydrologic Evaluation of Landfill Performance
HHCR	Hydrogeology and Hydrology Characterization Report, GHD May 2017
Hp	horsepower

HWR	Hazardous Waste Regulation
ID	Identification Number
IDF	Intensity-Duration-Frequency
km	kilometre
Landfill	Upland Landfill
Landfill Criteria	Second Edition Landfill Criteria for Municipal Solid Waste, dated June 2016
LCP	Leachate Collection Pipe
LFG	Landfill Gas
LTF	Leachate Treatment Facility
m	Metre
m^2	Square Metre
m^3	Cubic Metre
mm	Millimetre
mm^2	Square millimetre
mm/yr	Millimetre per year
MDL	Method Detection Limit
Mg	Magnesium
MOE	British Columbia Ministry of Environment
MOLO	Manager of Landfill Operations
MSW	Municipal Solid Waste
NBCC	National Building Code of Canada
N_2	Nitrogen
O_2	Oxygen
OC	Operational Certificate
PAHs	Polycyclic Aromatic Hydrocarbons
PCBs	Polychlorinated Biphenyls
Permit	Permit PR-10807
Pit	Upland Sand and Gravel Pit
Ppm	Parts Per Million
Property	Upland Excavating Ltd. - 7295 Gold River Highway
PVC	Polyvinyl Chloride
QA/QC	Quality Assurance and Quality Control
scfm	standard cubic feet per minute
Site	Upland Excavating Ltd. – 7295 Gold River Highway
SRD	Strathcona Regional District
SWANA	Solid Waste Association of North America

SWMP	Surface Water Management Plan
TAC	Transportation Association of Canada
TDG	Transportation of Dangerous Goods
TDS	Total Dissolved Solids
TEH	Total Extractable Hydrocarbons
US	United States
USEPA	United States Environmental Protection Agency
VOCs	Volatile Organic Hydrocarbons
WBM	Water Balance Method
WDA	Waste Discharge Application
WQG	Water Quality Guidelines
Zn	Zinc

1. Introduction

GHD Limited (GHD) was retained by Upland Excavating Ltd. (Upland) to prepare a Design, Operations, and Closure Plan (DOCP), for the Upland Landfill (Landfill). The DOCP will form part of the Waste Discharge Application submitted to the British Columbia Ministry of Environment (MOE) to obtain an Operational Certificate (OC) for the Landfill. The DOCP has been prepared in general accordance with the MOE's "Landfill Criteria for Municipal Solid Waste, Second Edition", dated June 2016.

1.1 Site Location

The Landfill is located at 7295 Gold River Highway (Site or Property) within the city limits of the City of Campbell River (City), British Columbia. The Site is located approximately 7 kilometres (km) west of the City centre. The Site's southern property coincides with the boundary between the City and the Strathcona Regional District (SRD). The Gold River Highway and McIvor Lake are located to the north and west of the Site. The legal description is Lot A, District Lot 85, Plan 30709, Sayward District. The total area of the Site is approximately 48.2 hectares (ha). A Site location map is presented in Figure 1.1.

1.2 Site Zoning and Adjacent Land Use

The Site is currently an active sand and gravel pit owned and operated by Upland. The Upland sand and gravel extraction operations have been ongoing since 1969. The Site is zoned as I-3 as defined by the City of Campbell River Zoning Bylaw No. 3250 dated 2006; last amended June 9, 2015.

The current land uses in proximity to the Site include residential, industrial and resource extraction activities (logging and gravel extraction). The area surrounding the Site is not serviced by a municipal sanitary sewer system or water distribution system. Gold River Highway, also referred to as Highway 28, is located to the north of the Site.

Specific current adjacent land use is presented in Figure 1.2. To the north and west, on the opposite side of the Gold River Highway, lakeshore residential properties line the McIvor Lake shore. To the immediate west surrounding Rico Lake are Upland owned industrial properties, including the K&D Contracting storage yard on the industrial property north of Rico Lake. There is also a lakeshore residential property west of the Site just north of Rico Lake. To the northeast of the Site on the opposite side of Argonaut Road, there are a number of industrial activities including a gravel extraction pit, concrete redi-mix manufacturer, wood recycling and processing facility and the municipal waste management facility. To the east of the Site on the same side of Argonaut Road is an area of industrial land uses including gravel extraction activities; further east is a large undeveloped rural area that extends generally uninterrupted to the Quinsam River. The property located at the northeast corner of the Site on the same side of Gold River Highway and Argonaut Road is crown land occupied by a telecommunication tower. The Site is bound to the south by forested Upland Resource land located within the administrative boundaries of Strathcona Regional District.

1.3 Legal Survey

Upland provided the topographic and legal land surveys for the Site. A copy of the original legal survey plan is provided in Appendix A.

1.4 Definitions

In this report the term “Landfill” refers to the Upland Landfill or Discharge Area as designed and described within this DOCP the terms “Site” and "Property" refer to the property located at 7295 Gold River Highway.

1.5 Regulatory Setting

1.5.1 Existing Permit

The Site is currently authorized to accept and discharge inert municipal refuse under existing Permit PR-10807, dated June 01, 1992 (Permit). The Permit allows open burning of wood waste. A copy of the Permit is provided in Appendix B. The inert municipal solid waste (refuse) permitted for discharge includes:

- Tree stumps
- Trees
- Land clearing waste
- Selected building demolition debris
- Residue from combustion of open burning of wood waste

The sand and gravel extraction operations are conducted under Mines Act Permit G-8-114 issued December 1989, last amended in February 2014.

1.5.2 Provincial Regulations

The following provincial regulations are applicable to the design, operations, and monitoring of non-hazardous, solid waste landfill in BC and have been considered in the preparation of the DOCP:

- Environmental Management Act
- Comox Strathcona Waste Management - 2012 Solid Waste Management Plan, December 2012
- Second Edition Landfill Criteria for Municipal Solid Waste, June 2016 (hereinafter referred to as “Landfill Criteria”)
- Guidelines for Environmental Monitoring at Municipal Solid Waste Landfills, January 1996 (hereinafter called the “Environmental Monitoring Guidelines”)
- A Compendium of Working Water Quality Guidelines for British Columbia
- Contaminated Sites Regulation
- Hazardous Waste Regulation

1.6 Objectives and Scope

The objectives of the DOCP are as follows:

- Present the conceptual design of the Landfill including base liner system, surface water management systems, leachate collection and treatment systems, and final cover.
- Present groundwater flow model and water quality impact assessment
- Present the operational procedures for waste acceptance and landfilling.
- Present the environmental monitoring and Landfill monitoring plans
- Present the closure and post-closure requirements for the Landfill.
- Demonstrate that the Landfill design, operations, and closure will meet the requirements of the Landfill Criteria.
- Support the Waste Discharge Application.

1.7 Report Organization

The DOCP is organized into the following sections:

- Section 1 - General introduction including Site location, the current regulatory setting applicable to the Site, the objectives and scope, and the general organization of the DOCP.
- Section 2 - Site characteristics including Site topography, geology, hydrogeology, and hydrology.
- Section 3 - Landfill design including base contours, final waste contours, Site life, available airspace, final cover, and existing and Site layout.
- Section 4 - Site development and materials requirements.
- Section 5 – Lifespan Analysis include Landfill layout, total Landfill volume, waste acceptance, and airspace consumption.
- Section 6 - Site operation including hours, Site security, authorized waste, traffic volumes, operation personnel, equipment requirements, cover requirements, nuisance controls, record keeping requirements, health and safety.
- Section 7 –Summary of geotechnical conditions, settlement analysis, seismic evaluation, and slope stability analysis for the Landfill.
- Section 8 - Surface water management including objectives and design criteria, surface water controls, hydrological analysis, sediment and erosion control, and surface water infiltration requirements.
- Section 9 - Leachate management including objectives and design criteria, leachate quality and quantity forecasts, leachate handling treatment and disposal requirements, leachate management systems and leachate monitoring.
- Section 10 – Landfill gas (LFG) management including LFG production, LFG generation assessment, and LFG monitoring and safety.

- Section 11 - A Closure Plan, including final cover design, progressive closure strategy, end use options, and post closure requirements.
- Section 12 – Contaminating lifespan assessment.
- Section 13 – Groundwater and surface water impact assessment including compliance requirements, on-site groundwater flow characterization, leachate leakage into aquifer, treated leachate infiltration into aquifer, aquifer modelling.
- Section 14 - Environmental Monitoring Plan including surface water monitoring, groundwater monitoring, leachate monitoring, landfill gas monitoring, inspection and reporting requirements.
- Section 15 – Fire safety and emergency response plan.
- Section 16 – References

2. Site Physical Characteristics

The Site physical characteristics are detailed in GHD's report entitled Hydrogeology and Hydrology Characterization Report, (HHCR), GHD May 2017. A summary of the Site's physical characteristics is provided below.

2.1 Site Topography and Drainage

2.1.1 Surface Water Features On-Site

No permanent surface water features are located on Site.

2.1.2 Topography

The Site is located on a terrace partially surrounded by mountainous terrain to the south, southwest, and northwest. The terrace gradually slopes towards the Quinsam River located 3.8 kilometres (km) to the southeast of the east Site boundary. The Quinsam River channel is at an elevation approximately 100 meters below the Site.

On-Site, the topography is relatively level at approximate elevation 190 mAMSL with the exception of the Pit located in the centre of the Site. The Pit area has been excavated to a depth of approximately 170 mAMSL, 20 m below the surrounding land surface. Along the western Site boundary, above the Pit wall where gravel extraction has not occurred, a ridge of elevated surface topography, created by an elevated bedrock ridge, discussed below, is present. Further to the west, the bedrock ridge dips towards Rico Lake. Along the eastern Site boundary surface topography dips to the east towards the adjoining property also operating as a gravel extraction pit.

Prominent topographic features on and in the vicinity of the Site include a small mountain near the southwestern Site boundary that stands approximately 100 m above Site, a large bedrock outcrop at the base of this mountain and multiple bedrock outcrops delineating a bedrock ridge extending from the base of this small mountain to the northern portion of the adjoining K&D property and continuing northwest of the Site towards McIvor Lake.

2.1.3 Drainage & Watercourses

Local drainage information is based on topography and watershed information provided by BC Water Resource Atlas, on-site topographic data, and the results of the HHCR (GHD, May 2017). The area in the vicinity of the Site is divided between two watersheds: The Campbell River Watershed and the Quinsam River Watershed.

The Campbell River watershed covers an area of 182,000 ha and is intersected by three manmade dams which form Upper Campbell Lake, Campbell Lake and John Hart Lake. The Quinsam River watershed covers an area of 20,900 ha and is bound to the north and west by a mountainous divide that isolates it from the Campbell River watershed (Blackmun, Lukyn, McLean & Ewart, 1985). The last segment of the Quinsam River (approximately 25 km long) flows east and then north toward the confluence with Campbell River. The Site is located approximately 4 km west of this portion of the Quinsam River.

Two lakes are located in close proximity to the Site. McIvor Lake, which is contiguous with Campbell Lake, is located approximately 50 to 150 m north of the northern Site property boundary. Rico Lake is located approximately 10 to 15 m west of the western Site property boundary and approximately 280 m west of the Landfill.

Lost Lake (also known as Hidden Lake) is located 2 km to the northeast of the Site. Lost Lake drains through Cold Creek which feeds the Quinsam Hatchery before discharging into the Quinsam River to the northeast of the Site. The Cold Creek watershed is located northeast of the Site.

To the east and southeast of the Site, there are several ephemeral creeks that provide drainage locally. These creeks drain into the Quinsam River, which is located approximately 4 km to the east of the Landfill footprint. To the southwest of Site, two ephemeral creeks are located south of the Site. The first, flows west to east-southeast and was identified approximately 100 m south of the southern Site boundary flowing to an area 375 m south of the southern Site boundary where it infiltrates into a gravel borrow area. The second creek was identified approximately 310 m south of the southern Site boundary flowing from west to southeast where it flows into a tributary of the Quinsam River. Both water courses flow from an elevation of approximately 219 to 185 mAMSL. Both water courses are sourced from a small wetland swamp located approximately 300 m southwest of the Site on a plateau within the highlands. Recharge of the wetland swamp is inferred to occur via run-off from the surrounding highlands. Flow from the wetland swamp is likely seasonal.

The Site is located in the Quinsam River Watershed, with the exception of a southwest portion of the Site located outside of the Pit. The Pit has no surface water outflow and all precipitation that falls into the Pit infiltrations into the Pit floor reaching the groundwater flow system, which flows to the southeast and eventually discharges into the Quinsam River Watershed.

2.2 Geology

2.2.1 Regional Geology

The Site is located on the eastern portion of central Vancouver Island approximately 7 km southwest of Campbell River, BC. Vancouver Island is part of the Wrangellia Terrane, which includes most of Vancouver Island, the Queen Charlotte Islands and parts of central Alaska. The

Wrangellia Terrane is composed mostly of widespread, late Triassic aged flood basalts, including the Karmutsen Formation. The Karmutsen Formation consists mostly of submarine flood basalts up to 6 km in thickness. Vancouver Island is extensively faulted with thrust faults associated with the subduction of the Juan de Fuca Plate under the North American Plate (MOE and Guthrie, 2005) (Greene, Scoates & Weis, 2005). The outcrop of rock on the southwestern portion of the Site and the bedrock encountered in boreholes advanced below the overburden is Karmutsen basalt.

At several time periods during the Pleistocene Epoch, Vancouver Island was glaciated with ice thicknesses to 2,000 metres. During the recession of the last glaciation approximately 14,000 years ago, glacial and glacio-fluvial sediments were deposited, and in some cases reworked and redeposited, to make up many of the present surficial deposits of Vancouver Island. These deposits consist of till, which is deposited directly by glacial activity and consist of larger clasts supported in a matrix of fine grained sediment, and of glacial outwash, which consists primarily of poorly sorted, coarse grained (sand and gravel) sediments deposited by glacial melt water (Greene, Scoates & Weis, 2005). The overburden at the site consists of glacio-fluvial and outwash deposits of sand and gravel. (McCammon, 1977).

2.2.2 Site Geology

The understanding of the Site geology presented in the following sections is based on field investigations and documents reviewed by GHD. Field investigations included, but were not limited to, borehole advancement, test pit excavations, examination of the Pit sidewalls and outcrop identification. Field investigations are detailed in the HHCR (GHD, May 2017). Documents reviewed included regional mapping, previous reports, and well completion logs from nearby private water supply wells

2.2.3 Overburden Geology

With the exception of the southwest portion of Site, stratigraphy on-Site is characterized as follows (in order from shallowest to deepest):

1. A native interbedded sand and gravel unit is present throughout the Site. The thickness of this unit is highly variable due to the sharp easterly dip of the bedrock surface along the western portion of the Site. This bedrock dip is described in greater detail below. In the south-eastern portion of the Site, the sand and gravel unit is greater than 47 m thick (based on the Pit sidewall geology).
   A substantial sand unit was encountered in the central portion of Site and in the southeast portion of Site. This sand unit ranges in depth and thicknesses from approximately 12 m to greater than 33 m. This sand unit varies in composition from sand with gravel to silty sand/sandy silt.
   Water supply well records from the north to northeast of the Site indicate the presence of sand and gravel beneath the maximum depths reached during the HHCR investigations (GHD, May 2017).
2. Fractured bedrock composed of igneous basaltic rock underlies the unconsolidated overburden

The structure of the overburden unit is consistent with glacio-fluvial and outwash depositional sources.

The overburden stratigraphy in the southwestern area of the Site, and the adjoining properties west of Site, where bedrock is present at surface or shallow depths is variable but can be generally characterized as follows:

1. On the property west of the Site (K&D property) the following stratigraphy was encountered:
   a. Granular fill consisting primarily of sand and gravel was encountered in several of the investigative locations. A maximum thickness of 4.7 m was encountered.
   b. A thin topsoil layer underlain by sand with varying degrees of silt and/or gravel was encountered beneath the fill materials or where fill was absent, at surface.
   c. Bedrock composed of igneous basaltic rock was encountered at surface or at a maximum depth of 11.6 m.
2. In the southwest corner of the Site above the Pit area, the following stratigraphy was encountered:
   a. A discontinuous, interbedded sand and silt unit consisting of layers of sand with silt, silty sand, or silt with clay was observed underlying a sand and gravel fill unit. The thickness of the interbedded layers was approximately 2.1 m. The interbedded unit was not present 85 m east of the southeast corner and is thus, discontinuous.
   b. Bedrock composed of igneous basaltic rock underlies the unconsolidated overburden in the south-western corner of the Site.

2.2.3.1 Bedrock Geology

Bedrock within the Pit area of the Site consists of fine grained, porphyritic, igneous rock of the Karmutsen Formation which varies in colour from blueish black to dark grey and green to dark grey and pink to dark brown (Golder 2014). Fractures of various sizes, densities and orientations (vertical, horizontal, and oblique) were observed in bedrock encountered in the central portion of the Pit area. Evidence of weathering (i.e. iron staining) and secondary mineralization was observed in some fractures. Bedrock in the southwest corner and west of the Site is relatively competent with few water bearing fractures.

Bedrock topography is highly variable near the Site. Bedrock ranges from at surface near the southwest and west Site boundaries and the northern portion of the adjoining K&D property, to greater than 47.9 mBGS near the eastern Site boundary.

The HHCR (GHD, May 2017), shows that there is a bedrock ridge extending from the base of the small mountain near the southwest Site boundary to the northern portion of the adjoining K&D property. This ridge continues to the northwest towards McIvor Lake wrapping around the northern boundary of Rico Lake.

East of the bedrock ridge, bedrock is inferred to plunge steeply towards the Pit area to approximately 150 mAMSL in the west side of the Pit. The bedrock surface continues to dip sharply to the east and was not encountered during the field investigations in the eastern-most portions of the Site.

West of the bedrock ridge, near the southwestern Site boundary, bedrock slopes downward towards Rico Lake which is located within a depression in the local bedrock surface.

2.3 Hydrogeology

2.3.1 Site Hydrogeology

In general, the geologic units identified in the previous sections may be grouped into the following hydrogeologic units:

1. A sand and gravel aquifer
2. A shallow aquifer

The hydrogeologic properties and division of these aquifers are discussed in the following sections.

2.3.1.1 Groundwater Divide

There is a notable topographic difference between the bedrock ridge and the remainder of the Site. The ridge is composed of competent bedrock and is interpreted to form a barrier to groundwater flow. East of the bedrock ridge, the principal groundwater flow zone is through the sand and gravel aquifer in a southeasterly direction from McIvor Lake towards the southeast Site boundary. West of the bedrock ridge groundwater flow is controlled by bedrock surface topography. Flow in this area occurs from points of high bedrock elevation within the ridge to areas of low elevation.

Precipitation that falls east of the bedrock ridge infiltrates into the subsurface, flowing to the southeast as saturated flow within the sand and gravel aquifer. Precipitation that falls to the west of the bedrock ridge (watershed and groundwater) will runoff of areas of bedrock outcrop, infiltrate into the subsurface or infiltrated directly into the subsurface and flow through the thin layer of overburden towards areas of low topography.

2.3.1.2 Sand and Gravel Aquifer (East of the Groundwater Divide)

An unconfined, sand and gravel aquifer is present within the overburden unit in boreholes advanced across the Site. The aquifer consists of coarse grained materials, primarily sand and gravel of varying degrees, with occasional seams of sand and silty sand. Based on the consistency and spatial distribution of borehole locations, this aquifer is continuous across much of the Site (with the exception of the bedrock ridge area in the western portion of Site).

The sand and gravel aquifer is identified as the principal groundwater flow zone at the Site and has been identified in the BC Water Resource Atlas as aquifer 975 IIA (10).

Groundwater elevations within the sand and gravel aquifer, (measured on April 6, 2017), ranged from 172.8 mAMSL along the northern Site boundary to 150.1 mAMSL near the southeastern property boundary. Groundwater within the sand and gravel aquifer flows from northwest to southeast (i.e. from McIvor Lake to the southeast corner of the Site).

The static water elevation within McIvor Lake is significantly higher than the static groundwater elevations within the sand and gravel aquifer on-Site. McIvor Lake recharges the sand and gravel aquifer and is not a receptor of groundwater from the Site.

2.3.1.3 Shallow Aquifer

Throughout the investigative activities, a relatively thin, discontinuous zone of shallow saturated overburden materials was encountered along the bedrock ridge (where overburden is present) to the west of the groundwater divide throughout the K&D property, as well as in the southeast corner of the Site (along the eastern flank of the groundwater divide at MW5A/B-15). The following subsections describe the groundwater flow in these areas which are collectively referred to as the shallow aquifer.

2.3.1.4 Shallow Aquifer (West of Groundwater Divide)

Shallow groundwater was identified on the K&D property and along the western flank of the bedrock ridge. Based on the presence of the competent bedrock ridge to the east and southeast, groundwater flow within the shallow aquifer is directed from high bedrock to points of lower topography (Rico Lake or McIvor Lake) and is interpreted to be largely controlled by bedrock surface topography.

Bedrock in this area is characterized as being relatively competent, thus, while some infiltration and groundwater flow will occur through bedrock, it will be limited. Primary flow in the bedrock ridge area and west of the Site will be through the overburden soil or, where overburden is not present, by overland flow.

The low hydraulic conductivity measured in the bedrock ridge between the Pit and Rico Lake significantly restricts movement of groundwater between these two features. Any hydraulic relationship between the Pit and Rico Lake is necessarily weak and flow will be from Rico Lake to the Pit. Rico Lake is not a receptor to the sand and gravel aquifer.

2.3.1.5 Shallow Aquifer (East of the Groundwater Divide)

Groundwater within the shallow aquifer east of the groundwater divide is present within a thin overburden layer overlying competent bedrock. Based on the presence of a mountain to the south, groundwater will likely flow downwards (potentially daylighting as seepage or through overburden materials as unsaturated flow) towards the Pit area where it will ultimately join the principal flow zone, flowing to the southeast. Flow is expected to be limited.

2.4 Climate

The climate of the east coast of mid-Vancouver Island, where the Site is located, is marked by wet and mild winters, and warmer drier summers.

Data associated with climatic conditions for the Site were based upon Environment Canada's Climate Normals measured between 1980 and 2010 at the Campbell River Airport (Climate ID: 1021261). The average total monthly precipitation data and average daily temperature records are presented in Table 2.1. The average annual precipitation is reported to be

1,489 millimetres with over 75 percent of the precipitation occurring between October and March. November and December experience the most precipitation with an average of 232 and 226 millimetres, respectively. On average 84 millimetres worth of snowfall is recorded per year.

The Pacific Climate Impacts Consortium Plan2Adapt tool was used to estimate the potential climate impacts that may be observed in the Campbell River area during the life of the Landfill as a result of climate change. The tool was used to model current climate change predictions in terms of precipitation rates. The model results for the Strathcona Region are summarized in the table below.

Plan2Adapt tool estimated change in precipitation (2050)

		Projected Change from 1961-1990 Baseline to 2050s (2040-2069) Study Period	
	Season	Ensemble Median	Range (10^{th} to 90^{th} Percentile)
Precipitation (%)	Annual	+6%	-1% to +10%
	Summer	-14%	-23% to +1%
	Winter	+6%	-4% to +13%

3. Landfill Design

3.1 Design and Siting Criteria

The Landfill design is based on the design requirements outlined in the Landfill Criteria. The following design criteria were utilized in developing this DOCP:

- Minimum 50 metre (m) buffer zone between limit of refuse and the property boundary.
- Minimum 30 m of natural or landscaped screening (berms and/or vegetative screens) adjacent to the property boundary.
- Minimum 500 m buffer zone between the limit of refuse and an existing or planned sensitive land use. Sensitive land uses include, but are not limited to: schools, residences, hotels, restaurants, cemeteries, food processing facilities, churches and municipal parks.
  - One residence is approximately 450 meters upgradient from the Landfill footprint. As the waste will not contain significant quantities of organic material, the potential for nuisance impacts from odour or birds will not occur, as further discussed in Section 6.8
- Minimum 100 m buffer zone between the limit of refuse and a heritage or archaeological site.
- Minimum 8 kilometer (km) buffer zone between the limit of refuse and an airport.
  - The airport is located approximately 6.5 km from the Site; however, it is not anticipated that this will cause a problem as birds will not be attracted to the non-putrescible waste to be deposited at the Site.
- Minimum 300 m buffer zone between the limit of refuse and a water supply well or water supply intake.

- Minimum 500 m buffer zone between the limit of refuse and a municipal or other high capacity water supply well.
- Minimum 100 m buffer zone between the limit of refuse and a geologically unstable area.
- Minimum 100 m buffer zone between the limit of refuse and an environmentally sensitive area.
- Minimum 100 m buffer zone between the limit of refuse and surface water.
- Minimum 100 m buffer zone between the limit of refuse and the sea level maximum high tide or seasonal high watermark of an inland lake shoreline.
- Landfill base shall be a minimum 1.5 m above groundwater.
- Primary liner: 1.5 millimetre (mm) thick HDPE geomembrane liner.
- Secondary liner: Geosynthetic Clay Liner (GCL) or 0.75 m thick compacted clay liner with a minimum hydraulic conductivity of 1 x 10-7 cm/sec.
- Minimum base slope of 2 percent.
- 300 mm thick stone drainage blanket with perforated collector pipes with protective geotextile layers.
- Stone drainage blanket shall be constructed of 50 mm diameter clear stone with minimal fines.
- Final cover comprising of 0.6 m, measured perpendicular to the slope, of low permeability (less than 1 x 10-7 cm/s) compacted soil or equivalent.
- Placement and vegetation of a minimum 150 mm of topsoil.
- Minimum top slope of 10H:1V (10 percent).
- Maximum side slope of 3H:1V (33 percent).

3.2 General Requirements

The Landfill shall be developed and operated in accordance with this 2016 DOCP. Any changes to the 2016 DOCP must be reviewed and accepted by the Director prior to being implemented.

3.3 Use of Soil

3.3.1 Final Cover Soil

Soil utilized for the Landfill final cover will meet the industrial level soil quality standards as defined in the Contaminated Sites Regulation. The final cover must meet the criteria discussed in Section 6.3.

3.3.2 Waste Soil disposed of in the Landfill

Soil disposed of in the Landfill must meet the requirements for authorized waste as discussed in Section 6.1 and 6.3.

3.3.3 Daily Cover Soil

Soil with contaminant concentrations above the industrial level, as defined in the Contaminated Sites Regulation (CSR), but that is not classified as Hazardous Waste, as defined in the Hazardous Waste Regulation, may be utilized for daily cover, temporary access roads within the limit of waste, and temporary berms within the limit of waste, and where are precipitation that comes in contact with these soils will be collected and managed as leachate The daily cover soils must meet the criteria discussed in Section 6.3.

3.3.4 Other Soil Uses

Soil utilized for Site development such as road construction, berm construction, fire breaks, and other applications outside of the limit of waste, and soil used for intermediate cover will be virgin material sourced from the on-site gravel production operations and will meet the industrial land use soil quality standards as defined in the CSR.

3.4 Site Layout

The Site consists of the active sand and gravel extraction Pit, as such that the Site layout is designed to facilitate both the Landfill operations and gravel extraction operations.

The Site access to Gold River Highway is located in the northwest corner of the Site. A Site office, weigh scale, and operations shop is located near the entrance. An access road descends from the entrance area into the adjacent Pit, which is currently excavated to a depth of approximately 20 m below the surrounding topography. The Pit is not intended to be further excavated beyond the current bottom elevation for the purposes of gravel extraction. Near the centre of the Pit an aggregate wash plant has been installed. The current gravel excavation activities are taking place in the southwest portion of the Site, as shown on Drawing C-02A, labelled as ‘production area’. The existing conditions are presented on Drawing C-01.

The Landfill footprint location is shown on Drawing C-02A. The footprint is in the centre east-west on the property, and located 50 metres north of the southern boundary to provide a buffer zone in accordance with the Landfill Criteria.

The leachate treatment pond and treated effluent infiltration pond will be located immediately east of the Landfill footprint. A third pond (contingency pond) is shown on Drawings C-02A. This contingency pond is discussed in Section 9.8.3.

Surface water infiltration areas will be located north of the Landfill at the base of the Pit, away from the landfilling and gravel extraction operations.

3.5 Base Contours

The base contours will have a grade of two percent north to south along the leachate collection pipes, which will act as the primary drainage path. The base contours will have a grade of one percent along the secondary drainage path, or perpendicular to the leachate collection pipes. The southern portion of the Landfill will be constructed on the slope of the Pit. The slope will be excavated to two horizontal to one vertical (2H:1V). The leachate collection system will extend up this slope.

The maximum drainage path leachate will travel will be less than 50 m towards the nearest leachate collection pipe. The maximum grade along this drainage path is approximately 2.2 percent.

The base contours will be constructed on the in-situ sand, gravel, and bedrock material. The geotechnical characteristics of the in-situ soils are discussed in Section 7 of this report.

The base contours extend to a maximum depth of approximately three metres below the existing Pit floor elevation, with the exception of the leachate sump which extends deeper than the surrounding base contours, as discussed in Section 3.7. The maximum depth is located along the northern edge of the Landfill footprint. The base contours extend to the existing Pit floor elevation toward the south of the Landfill footprint, just north of the interface with the 2H:1V slope. The excavation required as part of the construction of the Landfill cells is shown in Drawings C-06 through to C-09. The base contours are a minimum of 1.5 m above the elevation of the sand and gravel aquifer as required by the Landfill Criteria. The base contours ranges from two to over 10 metres above the high groundwater level.

3.6 Base Liner

The Landfill base liner will be comprised of a primary HDPE geomembrane liner and a secondary liner consisting of a geosynthetic clay liner. This base liner system is the recommended system by the Landfill Criteria, and provides a substantial reduction in liner leakage compared to a single liner system (CCME 2016). The HDPE geomembrane liner will meet or exceed the following specifications:

- Minimum thickness of 1.5 mm (60 mil)
- Minimum service life of 100 years
- High quality seams

A leak detection survey will be completed on the HDPE geomembrane after installation to ensure a quality installation.

The geosynthetic clay liner will have equivalent performance to the following compacted clay liner specifications:

- Soil will contain minimum 25 percent clay and minimum 60 percent silt and clay by weight
- Minimum compacted thickness of 0.75 m
- Maximum compacted hydraulic conductivity of 1 x 10-7 cm/sec
- Minimum organic carbon content of 0.1 percent

A QA/QC program conducted by a qualified professional will be implemented during the construction of the base liner system to minimize the occurrence of defects. The QA/QC program will include non-destructive testing of each seam.

3.7 Leachate Collection System

The leachate collection system for the Landfill includes the following components:

- 300 mm thick, 50 mm diameter, clear, round stone drainage blanket, with minimal fines
- Perforated leachate collection pipes (LCP) with minimum diameter of 150 mm wrapped in protective geotextile layers within the stone drainage blanket
- Maximum 15 m lateral spacing between leachate collection pipes (LCP) running south to north
- Maximum 50 m drainage path for leachate to travel before it is intercepted by a LCPs
- Minimum 2 percent slope along primary flow path of the LCPs
- Minimum 1 percent slope along the secondary flow path to the LCPs
- Clean-outs at each end of the LCPs
- Maximum leachate head of 0.3 m at any point on the Landfill base liner
- Leachate collection header pipe at the north end of the Landfill running towards a central leachate collection sump at a minimum slope of 1 percent
- A sump with bottom dimension of 3,900 mm^2
- Two leachate sump riser pipes with minimum diameters of 450 mm

3.8 Perimeter Containment Berms

A perimeter containment berm will be constructed on all sides of the Landfill. The purpose of the perimeter containment berm is to:

1. Ensure containment of the leachate within the Landfill. The perimeter containment berm will be lined consistent with the base liner to ensure leachate from within the waste is contained and directed to the leachate collection system. The berm will ensure that precipitation that comes in contact with the side slope of waste and/or daily cover, will not enter the clean surface water perimeter ditching. The berm will separate the runoff within the Landfill and the clean surface water outside of the Landfill. The berm will direct all runoff from within the Landfill to the leachate collection system.
2. Provide an embankment to facilitate construction of perimeter ditching, the Site perimeter maintenance road, and the intermediate/final cover tie-in. After placement of intermediate or final cover, surface water run-off will be directed to the perimeter ditch outside of the containment berm.
3. Prevent surface water run-on to the Landfill from the adjacent aggregate pit side slopes and the upper portion of the Site above the Pit. The southern perimeter containment berm will extend on top of the Landfill and will direct surface water run-off from south of the Pit to the east. This surface water berm will extend beyond the limit of waste in the east and west direction, as shown in Drawing C-05,
4. Provide a geotechnical support for the toe of slope of the waste mass.

Details of the berms are presented on Drawing C-13 and C-14 as part of the perimeter tie-in details.

3.9 Final Contours

The final contours (top of waste) are presented in Drawing C-05. The final contours were designed in accordance with the Landfill Criteria, and provide a maximum side slope of 3H:1V (33 percent) and minimum top slope of 10H:1V (10 percent). The top slope should be confirmed during the detail design phase based on the actual waste landfilled to confirm the slope is appropriate for the amount of settlement anticipated. The top final cover will have a crest elevation of 192 m AMSL, and a peak elevation of 195 m AMSL.

The final cover ties into the top of the perimeter berm to minimize the potential for leachate seepage from the Landfill. By constructing the perimeter berm and final cover in this manner, the perimeter ditching and maintenance road may be constructed independently of the final cover and therefore effectively manage storm water run-off at the Site during waste placement activities.

3.10 Surface Water Management Works

The surface water management works will be designed and constructed to meet the following criteria:

- Prevent surface water run-on onto the Landfill footprint
- Minimize the potential for erosion of cover soils
- Control surface water flow from the clean soil covers from the Landfill
- Design storm water ditching for the conveyance of 1:100-year, 24-hour storm event
- Include allowances for additional precipitation due to climate change, snow-melt, and multi-day precipitation events.

The surface water management works are described in Section 8.

3.11 Landfill Gas Management Works

The Landfill gas (LFG) management works will be designed to meet the following criteria:

- Soil gas concentrations at the Landfill boundary will not exceed the lower explosive limit of methane
- Combustible gas concentrations in on-site buildings will not exceed 20 percent of the lower explosive limit of methane at any time
- To meet the requirements of LFG Management Regulations and WorkSafeBC requirements
- All federal, provincial and local ambient air quality objectives for LFG emissions

Generally, the LFG management works will include a passive LFG venting system within the Landfill footprint and Landfill site perimeter soil gas monitoring probes. The LFG generation assessment and forecasted management works are described in Section 10.

3.12 Final Cover

Final Cover will be applied to the Landfill to achieve the following objectives:

- Prevent exposure of humans and wildlife to the waste
- Control infiltration of precipitation
- Minimize the uncontrolled release of methane to the atmosphere
- Limit erosion and release of sediment to the surrounding area
- Control the release of odours
- Minimize oxygen infiltration and fire risks
- Provide compatibility with the planned Site end use

The Final Cover is designed to minimize the post-closure leachate generation rate and maximize the evapo-transpirative potential.

Topsoil with a minimum thickness of 150 mm and vegetation will be placed on the final cover to promote runoff, evapo-transpiration, and reduce erosion of the cover soil. Topsoil will be comprised of suitable soil to support growth of local vegetation. The vegetation selected will consist of non-invasive plant species with root depths that will not compromise the integrity of the final cover barrier system.

The final cover characteristics are discussed in Section 6.5.3.

3.13 Site Security and Fencing

The Site will be fenced along Gold River Highway to prevent unauthorized access to the Site outside of the Landfill operating hours. The security fencing along the Highway will include 2 m high chain link fencing. The Site entrance is secured with a gate and vandal proof locking mechanism.

3.14 Access Roads

The existing Site layout includes a network of safe all-weather access roads to various parts of the Site. The same access roads will be maintained throughout the Landfill operations to provide access to the on-site facilities and to allow for inspection and maintenance.

3.15 Vector and Wildlife Management and Nuisance Controls

Vector, wildlife, and nuisance management strategies will be employed at the Landfill as discussed in Section 6.9.

4. Life Span Analysis

4.1 Landfill Layout Criteria

The Landfill has been designed for an approximate lifespan of 20 years as shown on Table 4.1. The area of the limit of waste is approximately 180 m by 200 m (Landfill footprint).

A 50 m buffer zone separates the southern limit of waste and the south property boundary. The buffer zone to the west, north, and east is greater than 250 m.

4.2 Total Site Volume and Airspace Consumption

The Landfill has a total airspace volume of approximately 506,000 m^3 for waste and cover material. The Landfill is expected to have a lifespan of 20 years based on an average annual airspace consumption of approximately 25,300 m^3. The assumed apparent density, as discussed in Section 4.4, is 1.3 tonnes per m^3, which results to a forecasted annual average of 32,890 tonnes of waste disposed in the Landfill.

4.3 Waste Acceptance

The accepted waste will be comprised of select municipal solid waste, as defined by the Environmental Management Act, and will include the following:

- Construction and demolition waste
- Land clearing debris
- Non-hazardous contaminated soil, as defined by the Hazardous Waste Regulations (HWR)

4.4 Apparent Density

The apparent waste density, which is utilized airspace consumption, is not a true density but a relationship that represents the mass of waste discharged into each m^3 of landfill air space. The apparent waste density is a more accurate measure of the efficiency of landfilling since cover soil is excluded from the ratio. The apparent waste density is based on the comparison of the tonnage landfilled and the airspace consumed. Soil used as daily and intermediate cover is excluded from consideration since an increase in cover soil usage can increase the true density and provide a skewed representation of landfilling efficiency. In contrast, an increase in cover soil usage will reduce the apparent density.

The forecasted apparent density at the Site is interpolated by comparing typical apparent densities of the two sources of waste streams to be accepted at the Site. Generally, the apparent density observed at waste soil landfills are in the range of 1.5 to 1.8 tonnes per m^3. The apparent density observed at construction and demolition landfills is generally in the range of 0.6 to 1.0 tonne per m^3. As it is anticipated at this time that approximately half of the waste disposed of in the Landfill will originate from each waste stream, an average apparent density of 1.3 tonnes per m^3 is forecasted for the Site.

5. Development Plan

The Landfill development plan has been designed to minimize the area of the active cell, maintain access for operations, and allow for progressive closure of the Landfill. The general north to south filling allows the continued gravel extraction in the southern Landfill footprint while landfilling commences in the north. The base liner will be constructed in three stages. Similarly, the final closure will be placed in a minimum of three applications.

The conceptual Landfill development plan is presented in Drawings C-07 through to C-09. The conceptual Landfill development plan includes a three phase approach. Each phase will contain three stages of filling. The Sections below describe the development plan. A summary of the Landfill Stages and corresponding airspace is presented in Table 5.1. Table 5.2 provides a material requirement summary for each phase.

5.1 Phase 1

Phase 1 contains three stages, 1A, 1B, 1C as presented on Drawings C-07. The total estimated airspace is 201,600 m^3. The major construction activities during this phase are as follows:

- Construction of the northern most lined cell including perimeter berm to north, west, and east, and required excavation
- Construction of temporary divider berm to south of first cell
- Construction of leachate collection pipes, leachate header pipes and sump
- Construction of associated leachate management systems, including pump station, leachate treatment facility and infiltration pond
- Filling in Stage 1A
- Construction of the second cell to the south including required excavation and perimeter berms
- Filling in Stage 1B and application of intermediate cover over Stage 1A
- Removal of intermediate cover over Stage 1A and filling in Stage 1C
- Intermediate cover over southern portion of Stage 1B
- Construction of the third lined cell to the south including excavation and grading of southern slope

5.2 Phase 2

Phase 2 contains three stages, 2A, 2B, 2C as presented on Drawings C-08. The total estimated airspace is 165,700 m^3. The major construction activities during this phase are as follows:

- Filling in Stage 2A
- Final cover over northern most side slopes
- Intermediate cover over a portion of Stage 1C
- Removal of intermediate cover as required and filling in Stage 2B

- Application of intermediate cover over southern portion of Stage 2A
- Filling in Stage 2C

5.3 Phase 3

Phase 3 contains three stages, 3A, 3B, 3C as presented on Drawings C-09. The total estimated airspace is 138,700 m^3. The major construction activities during this phase are as follows:

- Extension of liner up the southern slope
- Filling in Stage 3A
- Finale cover over side slopes extended
- Filling in Stage 3B
- Filling in Stage 3 C
- Complete final cover application over entire Landfill

6. Site Operations

6.1 Authorized Wastes

The waste authorized to be accepted at the Site and discharged into the Landfill is:

- Construction and demolition waste, excluding clean wood and other separated recyclables
- Land clearing debris
- Non-hazardous contaminated soil, as defined by the HWR
- Waste asbestos containing materials (ACM) managed according to Section 40 of the HWR
- Burn ash (from previous operations) and future burn operations if authorized

The waste not authorized to be accepted at the Site and discharged into the Landfill is:

- Hazardous waste according to HWR, except waste asbestos
- Domestic Solid Waste
- Sludge and Liquid Waste
- Controlled Wastes as defined by the Landfill Criteria
- Gypsum drywall, unless asbestos containing
- Organic waste

6.2 Material Recovery

Materials recovered from the incoming waste streams for re-use/recycling include:

- Yard waste

- Clean wood
- Concrete
- Asphalt
- Gypsum drywall

6.3 Waste Acceptance Policy

6.3.1 Soil

Prior to the acceptance of soil at the Site, Upland will require the completion of the Waste Profile Sheet (WPS) and representative soil quality data, in accordance with CSR and HWR. Waste Profile Sheets require signature of a Qualified Professional (QP) confirming the samples collected and analyzed are representative of the soil in question. The submitted data will be compared by Upland to the Site acceptance criteria to ensure compliance with the OC.

6.3.2 Construction and Demolition Waste

Prior to the acceptance of construction and demolition (C&D) waste, the C&D waste will be subject to a waste screening process. Material from deconstructed houses or renovations must be accompanied with record Hazard Assessment, as per WorkSafeBC's requirement to confirm the presence of asbestos or other hazardous materials. Additional testing to confirm the C&D waste is non-hazardous may be required as per the requirements of the HWR and MOE Technical Guidance. The submitted data will be compared by Upland to the Site acceptance criteria to ensure compliance with the OC. Construction debris from new construction will not require a hazard assessment.

6.4 Landfilling of Wastes

All waste will be placed within the Landfill footprint in accordance with the recommended fill methods described in the Landfill Criteria for a landfill receiving 20,000 to 50,000 tonnes of waste per year. The recommendations include the following:

- The active face will be kept to a minimum, while maintaining sufficient area for safe unloading of waste and traffic operations. The Landfill Criteria recommended maximum area of 243 square metres will be maintained when possible.
- The lift height will be kept to the Landfill Criteria recommended maximum of 2.5 metres.
- The waste will be compacted to achieve the most efficient compaction density.

6.4.1 Landfilling of Waste Asbestos Containing Materials

Asbestos containing materials (ACM), as defined by the HWR, will be transported in compliance with the Transportation of Dangerous Good (TDG) Act and Regulations.

The disposal of ACM will be completed in accordance with Part 6, Section 40 of the HWR.

6.5 Cover Placement

Cover is required to control vectors, wildlife, fire, litter, odour, infiltration, landfill gas, scavenging, etc.

6.5.1 Daily Cover

Daily cover will be placed on the active face at the end of each operating day. Daily cover will consist of either 150 mm of non-hazardous level soil, as defined by the HWR or approved alternative cover. Soil used for daily cover may be removed from the active face immediately prior to landfilling in the same area. Soil used for daily cover will have minimal fines to prevent perched leachate layers within the waste and to prevent dust migration from the Landfill.

Surface water contact with the daily cover will be contained and treated as leachate and will be conveyed to the leachate management system discussed in Section 9.

6.5.2 Intermediate Cover

Intermediate Cover will be placed on areas of the Landfill that are not scheduled to receive the placement of additional waste for 30 days or more. Intermediate cover will consist of 300 mm of virgin soil and will meet Industrial soil quality standards as defined by the CSR or approved alternative cover. The thickness may include daily cover if daily cover is present in the area and the daily cover meets the Industrial soil quality standards. Soil used for intermediate cover may be removed from the active face immediately prior to landfilling in the same area.

The surface water runoff from the intermediate cover will be treated as clean surface water and will be conveyed through the surface water management system, as discussed in Section 8.

6.5.3 Final Cover

Final Cover will be placed within 365 days on any part of the Landfill footprint within that has reached final contours and is large enough to warrant final cover application. The final cover barrier layer will consist of the following layers from top to bottom:

- 150 millimeters of topsoil with suitable vegetation
- 600 millimeters of sand as a protective cover
- Geosynthetic clay liner
- 150 millimeters sand cushion layer over the waste

The final cover system is shown in Drawing C-10. A water balance model, as discussed in Section 9.6.1, was used to determine the resulting infiltration through the final cover system. The results forecast this final cover system to exceed the performance of the minimum final cover specified in the Landfill Criteria (600 millimetres of low permeable soil).

The surface water runoff from the final cover will be treated as clean surface water and will be conveyed through the surface water management system, as discussed in Section 8.

The soil used for final cover will meet the applicable CSR industrial land use standards.

6.6 Hours of Operation

The hours of operations of the overall site are Monday to Friday 7:30 am to 4:00 pm. The Landfill hours will generally be restricted to the overall site hours. Special arrangements may be made to receive waste outside of these hours from time to time. The Landfill will not be open for receiving waste unless otherwise scheduled in advance, and waste characterization procedures have been completed to ensure the waste is suitable for disposal at the Site. When required, the Landfill will be open on Saturday and Sunday to receive incoming waste from approved sources.

6.7 Neighbour Relations Plan

Upland recognizes the need to maintain positive relations with landowners adjacent to and nearby the Site. Ongoing efforts to mitigate the impacts of nuisance factors such as dust, litter and odour will be carried out in accordance with the protocols discussed in the following Sections.

All operational complaints received by Landfill personnel will be recorded and directed to the Site Manager. The Landfill personnel will undertake corrective action(s) as soon as possible after identification of need. A complaint response procedure, including an email address and phone number, will be provided at the Site entrance for the submission of nuisance complaints from the public. The complaint, nature of complaint, time received, and corrective action taken resolution will be documented. The records must be kept in accordance with the record keeping procedures described in Section 6.17 and 14.9, and included in the next annual operations report, as discussed in Section 14.10.

6.8 Nuisance Controls

The Landfill will comply with all local government nuisance bylaws.

6.8.1 Dust Control

Dust generation occurs at landfill sites due to the handling of soils, dry waste such as demolition waste, plaster, and concrete, as well as the movement of vehicles along gravel and dirt access roads. Dust mitigation measure will be employed at the Site on an as-needed basis and may include the following:

- Use of granular daily cover daily with minimal fines content (i.e. silts and clays)
- Reduction of allowable vehicular speeds
- Use of water to control dust
- Seeding programs
- Proper placement of stockpiles and covers to minimize dispersion
- Vegetative buffer zones around the Site to provide shelter to the landfill
- The topographical changes and Pit walls to provide shelter to the landfill

Soil stockpiles not used for more than one year are to be seeded.

6.8.2 Noise Control

Potential noise impacts from the Site may result from the operation of the landfill equipment. The operation of this equipment will comply with the noise emission standards as outlined in the Society of Automotive Engineers (S.A.E.) J88 – Latest Edition "Sound Measurement – Earth moving Machinery". Noise mitigation will also be provided by the following Site features:

- Vegetative buffer zones
- Distance of Landfill operations from Site boundary and neighbouring properties
- The topographical changes and Pit walls

6.8.3 Litter Control

Preventative litter control measures are steps taken to minimize the blowing of litter from the active area of the Landfill and from incoming waste loads. Litter must not migrate beyond the Landfill property boundary. The following measures will be used at the Site to control and minimize windblown litter:

- All loads must be tarped to prevent litter from blowing out of the vehicle. Upland reserves the right to not accept loads that are not tarped.
- The active face will be selected based on the direction and intensity of the wind to provide maximum shelter for the active area. The aerial extend of the working face will be kept to a minimum on windy days.
- Litter will be collected within the Site and along the Site boundaries when necessary.
- Appropriate use of cover soil
- Installation of litter fences and use of operational berms within the Landfill, as necessary
- The topographical changes and Pit walls

6.8.4 Odour Control

The waste streams that will be discharge at the Landfill are generally not a source of odour due to low organic content. The Landfill operations will, however, be carried out in a manner that prevents generation of nuisance odours from all activities having the potential to cause nuisance odours. The following measures will be used at the Site to control and minimize nuisance odours:

- Daily and intermediate cover will be applied as outlined in Section 6.5.1 and 6.5.2
- Leachate management systems will include adequate odour controls such as aeration to prevent unpleasant odours
- Odour control systems must be in place when odorous waste is anticipated

6.8.5 Sight Lines

The sight lines from the Gold River Highway to the active face of Landfill will be minimized. To minimize the sight lines, the following measures will be in place:

- Vegetated perimeter buffer zone
- Landfill footprint location within the base of the Pit
- Final contours will be below the adjacent tree lines
- Berms within the Landfill to minimize sightlines to exposed waste, when necessary
- Application of daily and intermediate cover
- Application of final cover on the northern edge of the Landfill include vegetative cover as soon as reasonably possible

6.9 Vector and Wildlife Management

The Landfill is not expected to attract vectors or wildlife due to the lack of municipal solid waste, such as curbside garbage or other organic matter to be disposed of in the Landfill. Furthermore, the Landfill will comply with the daily, intermediate, and final cover requirements stated in Section 6.5. If vector and wildlife become problematic at the Site, these measures will be revised to ensure the protection of the wildlife and the environment.

The leachate treatment pond is not expected to attract wildlife or waterfowl, due to the aerators that will operate intermittently and will prohibit access to the pond at that time. Should waterfowl become an issue in the aeration pond during the passive filling or decanting portions of the treatment cycle, bird abatement strategies will be employed, such as the use of a falconer.

6.10 Burning

The Permit allows open burning of non-treated wood material including stumps, trees and similar material. During the proposed operations a technical assessment report for burning will be prepared and submitted to the MOE, if burning is proposed in a manner consistent with the existing Permit or the Landfill Criteria. Burn operations will not commence until approval is granted by the MOE.

6.11 Landfill Fire Management

The Landfill will be operated in a manner that reduces the risk of landfill fires. The following measures will be in place:

- Appropriate placement, thickness, and compaction of inert daily and intermediate cover and compaction as outlined in Section 6.5 to minimize oxygen intrusion.
- Fire breaks will be maintained surrounding the Landfill footprint with a minimum width of 15 m. The Fire breaks will be free of trees, brush, tall grass, and other combustible materials.
- The Landfill has year-round and immediate access to a water supply from the wash plant ponds.
- Fire safety measures in place in accordance with the fire safety plan discussed in Section 15.

6.12 Scavenging

Scavenging is defined in the Landfill Criteria as the informal and unauthorized recovery and removal of waste. Scavenging of waste from the active face and within the Site is will be prohibited due to health and safety concerns. Recovery of items from the incoming waste that has potential re-use value will occur as discussed in Section 6.2.

6.13 Site Health and Safety Plan

A Site Health and Safety Plan (HASP) will be prepared and kept on Site at all times. The Site operations will meet the requirements of WorkSafeBC.

6.14 Site Security and Signage

Access to the Site will continue to be via the existing Site entrance off Gold River Highway, which enters the Site from the north, as shown on Drawing C-01. The Site entrance gate is locked outside of normal operating hours to prohibit vehicle entrance and uncontrolled disposal when the Site is closed. A chain link fence is present along the northern property boundaries along Gold River Highway and Argonaut Road.

Signage will be erected and maintained at the Site entrance and will include the following information:

- Name of owner and contact information
- Hours of operation
- Emergency contact information
- Accepted and restricted wastes

The existing signage will be maintained for continued operation of the Site. The signs will be reviewed from time to time by Landfill staff for adequacy and additional signs implemented as required.

6.15 Weigh Scale

A weigh scale is currently located at the Site entrance. This weigh scale will continue to be used for the Landfill operations.

The weigh scale will be maintained in proper working order and meet the requirements of the federal Weights and Measures Act.

6.16 Traffic Volumes

Traffic volumes will be dependent on the amount of waste and non-hazardous soils destined for the Site during any given time period. The waste may be received at specific times of the year and be distributed unequally throughout the year. In general, the traffic flow volume is expected to see a marginal increase from the existing traffic volumes to the Site.

6.17 Records

All relevant records will be maintained by the Site owner for the entire operating life of the Landfill and for the duration of the contaminating lifespan, as estimated in Section 13. Relevant records will be maintained on-site for a minimum of 7 years, and all records will be submitted to the Director within 14 days of a request from the MOE. Records will include the following:

- The Permit or the Operations Certificate
- All plans and reports prepared in support of the development for the Site
- Inspection records conducted by regulatory agencies
- A complaint log system providing source of complaint, nature of complaint, time received and actions taken
- Waste tonnages and volumes disposed of in the Landfill for each category of waste received
- Waste sources, characterization and approvals

6.18 Operational Personnel

The Landfill will employ a Site Manager/Operator who oversees all daily Landfill operations.

The Site Manager or Operator will be present at all times that the facility is open for business and will inspect every load of incoming waste to ensure it matches the waste characterization, and complies with the requirements of the OC.

The Site Manager, Operator, or other staff members are responsible for accepting and recording waste loads, as discussed above, and also for collecting tipping fees, stockpiling, placement of waste, and placement of daily cover, as required. An equipment operator is responsible for the operation of the front-end loader, bulldozer, hydraulic excavator, and compactor.

Additional staff will be utilized at the Site as the work load demands to meet environmental control requirements including dust, litter, and odour control measures.

6.19 Operator Training

At least one supervisor shall successfully complete the Solid Waste Association of North America's (SWANA) Manager of Landfill Operations (MOLO) course. At least one of the operations staff working regularly at the Landfill active face will successfully complete SWANA BC's Qualified Landfill Operator's course. These certifications will be kept current as per by SWANA's requirements.

Under the Environmental Management Act, Municipal Wastewater Regulations, Part 4, Division 1, Section 47, the aeration pond must be operated by a person certified by, and in accordance with, the Environmental Operators Certification Program.

6.20 Equipment Requirements

Adequate equipment will be maintained at the Site to ensure that operational requirements will be met. The equipment to be used on-site will include:

- Front-end loader
- Dozer
- Waste Compactor
- Excavator

6.21 Winter and Wet Weather Operation

Winter operations require advanced planning for Site preparation, snow removal, and the stockpiling and storage of cover material. Winter operations for the Landfill will be coordinated with the active aggregate extraction activities.

Many operational problems can occur as a direct result of failure to prepare an adequate disposal area in advance of winter weather. An area sufficient to hold more than the expected volume of waste will be prepared in advance of the onset of winter. In addition, stockpiles of cover material, areas for stockpiling snow, and snow fences to minimize and control drifting on an as needed basis, will be provided and placed prior to the onset of winter.

During the winter months the active disposal area will be located in such a manner so as to be free draining, sheltered from the prevailing winds and if possible located with a southern exposure. Up to twice the estimated required area for disposal through the winter months, will be prepared to minimize problems due to heavy snow and equipment failure. During winter conditions, flatter grades may be required at the daily working face to facilitate equipment travel.

Snow plowing and a snow storage area will be considered in advance of winter conditions. A snow storage area will be created adjacent to the active disposal area to permit storage of snow removed from the tipping face, such that it does not interfere with daily Landfill operations. The snow storage area will be located such that during snow melt events, the runoff will be treated as storm water and not flow into the active disposal area. Snow which has contacted waste will be managed as leachate. In the event of extreme weather conditions, or at the discretion of the operator, the Site may stop receiving waste material.

Snow maintenance and wet weather operation will be conducted in such a manner as to minimize infiltration and operate the Landfill in a dewatered condition.

During wet weather operations surface water will be directed away from the active disposal area by means of temporary soil berms constructed upgradient of the active area, as required. Under extremely wet weather conditions the waste disposal operations may be moved to drier working areas to facilitate vehicle travel at the working face.

On-site equipment used for continued Landfill operations during rainfall events, will be provided with closed cabs.

Site roadways will be maintained in a passable condition during wet weather conditions. Secondary haul roads to the active Landfill area will be located so as to ensure continuous access to the active face during wet weather conditions. Should washouts of the Site roadways occur due to rainfall events, the roadways will be reconstructed in a timely fashion.

7. Seismic Assessment

7.1 Geotechnical Overview

The Site consists of deep layers of sand and gravel, sandy, and gravelly sand deposits turning into fine sand layers at increasing depths overlying bedrock. The sandy overburden is generally in dense to very dense conditions, with SPT 'N' values in the ranges of 30 blows per 0.3 m of penetration. Bedrock is confirmed to have a west to east slope. The bedrock outcrops in the western portions of the Site, and dips steeply to the east. Bedrock outcrops were observed near the western boundary of the Site.

A bedrock ridge is present west and northwest of the Site. Bedrock was encountered at depths ranging from 16 to 24 metres below ground surface in the central portion of the Pit, and was found to be deeper than 45 metres below ground surface in the eastern portion of the Pit.

7.2 Landfill Settlement

The Landfill area was analyzed for three types of potential settlement (total or differential). The results will be considered during detailed design to ensure the design provides allowance for forecasted settlement.

7.2.1 Short-term Settlement

Short-term settlement, or elastic settlement, may occur almost immediately after changes in loading occurs. Immediate settlements in the order of 100 mm to 200 mm are expected during the vertical expansion of the Landfill.

7.2.2 Long-term Settlements

Long Term settlements, or primary consolidation settlements, occurs due to the expulsion of pore water from the waste material. Depending of the loading, saturation degree, and the drainage path within the Landfill, this settlement may take years to complete and can be differential in nature. Due to the compaction of the waste and the duration of the construction, these settlements are expected to be tolerable.

7.2.3 Creep Settlement

Creep settlement, or secondary consolidation, occurs under nearly constant effective stresses and is associated with plastic adjustment of the material. Theoretically, this type of settlement will never end, but will slow down with time. Due to the compaction of the material and the staged construction approach, these settlements are expected to be tolerable.

7.3 Seismic Evaluation

A seismic evaluation was carried out based on hazard values recommended by the National Building Code of Canada (NBCC 2010), as discussed in GHD's 2016 Geotechnical Investigation Report, Considering the low consequence of failure at the Site, seismic hazard values with 2 percent and 5 percent probability in 50 years (return period of 2475 and 1000 years, respectively) were used in the seismic evaluations. The evaluation concluded that the historical data does not show the potential for liquefaction within the waste material, and the liquefaction potential in the existing native soils is very low to low during extreme seismic events with return periods of 2475 years or less.

7.4 Slope Stability

Slope stability analysis was carried out, as discussed in GHD's 2016 Geotechnical Investigation Report. Limit equilibrium method was utilized to evaluate the stability of the slopes across the Landfill under different material, water level, and loading conditions.

Considering the low consequences of failure of the Landfill, as further discussed in the GHD's 2016 Geotechnical Investigation Report, a target Factor of Safety (FOS) of 1.2 to 1.3 is considered adequate for short term (during construction) stability of the slopes under static loading. For long term (post construction) conditions, a target FOS of 1.5 is considered adequate. For seismic events with a return period of 2475 years, FOS of 1.1 is considered adequate. The slope stability study concluded that the target FOS are obtained along the studies cross sections and that the FOS will increase with time due to the nature of the material.

8. Surface Water Management Plan (SWMP)

8.1 SWMP Objectives

Completion of the Landfill closure design will result in changes in landform and surface water runoff patterns within the lower Pit area of the Site. The SWMP will ensure the following objectives are met:

- The runoff from the Landfill is conveyed in a manner that does not cause erosion or possible damage to the Landfill
- The runoff from the watershed around the Landfill is conveyed and directed away from the Landfill to minimize surface water contact with waste, and minimize leachate generation
- Minimize potential for on-site erosion and sediment loading in the base of the Pit (there are no downstream water courses that will be impacted by sediment loading)

This SWMP has been developed for the Landfill only and does not consider the overall Property storm water management system.

8.2 SWMP Design Criteria

8.2.1 SWMP Design Criteria – Landfill Criteria

Section 5.6 of the Landfill Criteria requires hydrologic modeling to assess the performance of the surface water management works under minor and major storm events, and is to be completed for 5-, 10-, and 100-year design storm events.

Based upon these objectives, the SWMP design criteria is as follow:

- The storm water channels shall be designed to convey the discharge of a 1:100-year, 24-hour storm event.
- Maintain a positive grade to prevent sedimentation and maintain hydraulic design capacity. Ditches shall be designed to accommodate localized settlement (no grade reversals).
- The channels must be armored (rip rap, erosion control matting, or vegetative cover) to prevent erosion of ditch bottom and side slopes.
- Make allowances for additional water that may result from snowmelt
- Consideration for the effects of multi-day precipitation events

8.2.2 Additional SWMP Design Criteria Considered

The following design criteria were used as guidance documents for the design of the SWMP:

1. In accordance with the BC Supplement to TAC (Transportation Association of Canada) Geometric Design Guide 2007 Edition (Tab 10-1000 Hydraulics Chapter) (BCMOT, 2007) the channels shall have the following characteristics:
    - The maximum allowable depth of flow is 0.6 m
    - The recommended minimum freeboard is 0.3 m for small drainage channels
    - Typical channel side slopes range between 1.5:1 (H: V) to 4:1
2. In accordance with the Best Management Practices Guide Prepared for Greater Vancouver Sewerage and Drainage District (Gibb, Kelly & Schueler, 1999), the infiltration pond should meet the following criteria:
    - The maximum draining time is 48 hours
    - Recommended maximum water ponding depth is 0.3 m
    - Minimum infiltration capacity is 13 mm/hr
    - Maximum infiltration capacity is 61 mm/hr
    - Minimum 600 mm free board
3. In accordance with the Best Management Practices Guide for Stormwater, prepared for Greater Vancouver Sewerage and Drainage District (Gibb, Kelly & Schueler, 1999), the sediment forebay should meet the following criteria:
    - Sediment forebay should provide 10% volume of permanent pool storage for wet pond

- Sediment forebay should provide 10% volume of total design storage volume for dry pond

4. In accordance with the Storm Water Management Planning and Design Manual (MOE Ontario, 2003), the infiltration areas should meet the following criteria:
    - Minimum length to width ratio is 3:1
    - Maximum ponding depth is 0.6 m
    - Minimum 1 m depth for sediment forebay
    - Minimum 2:1 length to width ratio for sediment forebay
5. In addition, the storm water management system will be designed to meet the following criteria:
    - The storm water management system will be designed using the 24-hour, 25-year and 100-year synthetic design storm with a Type 1A distribution
    - The storm water infiltration area will have the capacity to accommodate the runoff volume generated from the 100-year storm event with 0.6 metres (m) of freeboard
    - To account for frozen or saturated ground conditions and the Landfill cap liner design, the sub-catchment parameters for depression storage and infiltration will be adjusted to be lower than would be typically considered for this type of soil and vegetative cover
    - Make allowances for additional precipitation and greater storm events due to the possibility of climate change in the region
    - Make allowances for additional precipitation over multi-day precipitation events

8.3 SWMP Overview

The SWMP will include the following elements:

- Perimeter berm to ensure the impact water from the landfill sides slopes (i.e. with daily cover or exposed waste) will remain within the landfill and separate the surface water system
- Mid-slope swales approximately half way up the side slopes of the final closure to shorten the drainage path and help prevent erosion
- Drop-down channels where the southern edge of the Landfill final contours intercepts the excavated slope of the Pit
- Energy dissipation pools at the base of the drop-down channels along the southern edge of the Landfill
- Ditches on the east and west sides of the Landfill to convey surface water to the north of the Landfill into the infiltration areas located in the base of the Pit
- A surface water diversion berm south of the Landfill on the upper portion of the Site to convey water from the upper portion of the Site around the Landfill to the base of the Pit or to other areas of the Site. The purpose of this diversion is to ensure the upper portion of the Site is not part of the Landfill surface water catchment.

- Energy dissipaters and infiltration area sediment forebays located at the ditch outlets north of the Landfill will also act as a sediment trap to minimize larger sediment migration into the infiltration areas.
- Infiltration area in the base of the Pit to match the pre-Landfill surface water flow

8.4 Hydrologic Assessment

8.4.1 Model Overview

A hydrologic assessment of the Site watershed was completed to provide estimates of the peak discharge that is expected within the proposed channels. The hydrologic assessment was completed by developing a hydrologic model of the Site to estimate the runoff volume and discharge rate for post-development condition. Storm water modeling for the Site was conducted using the software program PCSWMM 2015 developed by Computational Hydraulics International (CHI). PCSWMM uses the USEPA SWMM5 engine (currently version 5.1.010), and is a spatial decision support system for the USEPA SWMM5 program. The USEPA Storm Water Management Model (SWMM) is a dynamic rainfall-runoff simulation model that can be used for either single event or long-term (continuous) simulation of runoff quantity and quality.

PCSWMM allows modelling of runoff and conceptual design of drainage works such as piping network, open channel (rivers, creeks and ditches), weirs, dams, orifices, and storage/detention units. The computer model uses hydrologic and hydraulic methods to calculate and route hydrographs. The model requires input of a hyetograph, topographical features (catchment area, width, slope and hydraulic roughness), soil parameters, ground cover conditions (land use and vegetation cover) and drainage paths (rivers, pipes and storage units).

8.4.2 Design Storms

There are three Environment Canada weather stations in relatively close vicinity of the Site which generate Intensity-Duration-Frequency (IDF) reports, which are used to develop the synthetic design storms. They are Strathcona Dam (ID 1027775), Campbell River Airport weather station (Station No. 1021261), and Campbell River STP (ID 1021265). The location of these three weather stations is presented on Figure 8.1.

The Campbell River Airport station IDF report was selected based on the proximity to the project site, length of record and physiographic characteristics. The elevation for Campbell River Airport is 108 m, which is lower than the minimum elevation of the site (approximately 167 m). The Campbell River Airport IDF report is provided in Appendix C.

The design of the storm water management system is based upon the return-period rainfall depths derived from the Campbell River Airport Intensity-Duration-Frequency (IDF) reports developed by Environment Canada. The total rainfall depths were increased by 10% to compensate for the change in elevation between the Campbell River Airport and Site elevation. Synthetic design storms were developed to assess the performance of the proposed storm water management features which are based upon the IDF total rainfall depths.

To account for the potential increase in rainfall depths as a result of climate change, as discussed in Section 2.4, GHD increased the synthetic design storm rainfall depths by 6%, which represents a total increase of 16% over the IDF reported values.

Synthetic design storms were created for the 5-year, 10-year, and 100-year, 24-hour storm event using the Soil Conservation Service's Type 1A distribution which is appropriate for this geographic area. Rainfall parameters representing design storms are listed in Table 8.1.

Multi-day precipitation events were also considered. The probability of a multi-day precipitation events with the same intensity as the 100-year, 24-hour storm event for all days within the multi-day event is low. It is more likely that a multi-day precipitation event would result in a lower intensity that the design storm utilized. (100-year, 24-hour storm) For this reason, the 100-year storm event was used as the design storm parameter of the surface water channels and sediment forebays. The infiltration areas were sized to accommodate the 100-year, 24-hour storm with allowance for additional water from snowmelt and multi-day precipitation events, as discussed in Section 8.4.4.

8.4.3 Hydrologic Model

The SWMP was developed for the full Landfill closure condition. The Landfill cover will be fully vegetated and consist of 150 mm of top soil over 600 mm sand over a GCL, as described in Section 6.5.3. The design of the SWMP features has assumed that there will be little to no storage capacity within the Landfill cover system and the majority of rainfall will result in runoff from the Landfill cover. This assumption would account for frozen ground conditions or antecedent wet moisture conditions, such as during a multi-day precipitation event. Therefore, the sub-catchment parameters for depression storage and infiltration will be adjusted to be lower than would be typically considered for this type of soil and vegetative cover which would have a greater infiltration capacity.

The Landfill cover system is divided into a series of catchments. The catchment boundary delineation is presented on Figure 8.2. Corresponding catchment model input parameters are summarized in Table 8.2. A surface water diversion berm will be required to route surface runoff away from the Landfill area that is not considered within the overall catchment boundary.

Runoff generated from each catchment is routed to a series of channels which will convey it away from the Landfill cover. A flow schematic, describing the SWM conveyance features (i.e. channels, ponds) and flow direction is presented in Figure 8.3.

8.4.4 Infiltration Area Configuration

Two infiltration areas proposed for the stormwater runoff from the Landfill. A west infiltration area will be used to store and infiltrate the surface runoff from west part of the Landfill and an east infiltration area will be used to store and infiltrate the surface runoff from east part of the Landfill. The bottom elevation of both areas will be approximately is 167.3 m which is approximately 10 meters higher than the groundwater table. The infiltration areas may be delineated by berms and existing ground features, and may be shaped to allow for the continued use of the Site during storm events.

The required bottom surface area for each of the infiltration area is estimated at 2,682 m^2, while the top surface area of both of the infiltration areas will be 4,320 m^2 excluding sediment forebay area. The total available storage volume from each of the infiltration areas is approximately 3,500 m^3.

A stage-area table for pond configuration is included in Appendix C.

The infiltration capacity of the overburden soils on the floor of the Pit is relatively high (Section 2.4 HHCR). The existing surface of the base of the Pit may be used as the infiltration areas. The designated infiltration area will contain an overflow route that will convey excess surface water to other portions of the Pit for infiltration, in the event of a large multi-day precipitation event temporarily overwhelming the infiltration areas.

8.4.5 Infiltration Rate

The area to the adjacent north of the Landfill is proposed as an infiltration area. Stratigraphic and single well response tests were completed for this area.

A copy of test results in included in Section 2.4 of the HHCR.

The borehole log for this area indicates:

1. Groundwater elevation is greater than 1.5 m below the ground surface.
2. Gravel and sand are the predominant soil types.

According to the Best Management Practices Guide Prepared for Greater Vancouver Sewerage and Drainage District, an infiltration rate of 60 mm/hr was conservatively assumed to represent the infiltration rate. Actual infiltration rates should be confirmed in the field as part of the detailed design stage.

8.4.6 Infiltration Discharge Estimation

Using the stage area table provided in Appendix C, the infiltration area at an elevation of 167.3 m was interpolated as 2,682 m^2. Infiltration discharge was calculated as the product of infiltration rate and the infiltration area bottom area. This infiltration discharge was applied in the PCSWMM model as outflow from the infiltration areas.

8.4.7 Sediment Forebay

A sediment forebay will be installed at the inlet of the stormwater infiltration areas to preferentially settle large particulates in the sediment load within an area that can be conveniently accessed for maintenance. The sediment forebay for the infiltration areas were sized according to the design guidelines given in Section 8.2.2. Detailed calculations for the length and width for sediment forebay is provided in Appendix C.

An energy dissipation structure at the outlet of the steep channels is required to prevent erosion of base of the Pit. A basin approximately 1 m deep that is 5 m wide and 10 m in length will be required to transition the discharge from super-critical to sub-critical flow. The basin will be lined with the concrete block lining similar to the channel lining.

8.4.8 Modelling Results

All hydrologic models were analyzed using synthetic design storms with return periods of 5-year, 10-year and 100-year design storms.

Table 8.3 provides a summary of the estimated peak discharge rates from each catchment.

Table 8.4 provides a summary of the estimated runoff volume from each catchment. The model results indicate during the 100-year design storm that in excess of 90% of the rainfall results in runoff.

Hydrologic model outputs files are provided in Appendix C.

The model also calculates the peak discharge within the channels. The channels were designed to convey the peak discharge from the 100-year design storm event with at least 0.3 m of freeboard. A summary of the channel characteristics and performance is provided in Table 8.5. Table 8.5 also provides recommendations for the addition of erosion protection (i.e. turf reinforcement matting or ditch lining) for ditches with excessive grades resulting in a higher shear stress. Ditch lining is recommended for any ditch that would have an estimated shear stress in excess of 50 Pascal's (U.S. Soil Conservation Service Channel Design Handbook for Retardance Class C Vegetation) during the 100-Year event.

Table 8.6 provides a summary of the ponding depths and storage volumes for the infiltration areas. The infiltration areas will provide sufficient volume to store the 100-year design storm event and have a sufficient surface area to drain in less than the maximum limit for all storms (48-hours). As discussed in Section 8.4.4, overflow infiltration areas will be designated as a contingency.

9. Leachate Management Plan

9.1 Leachate Management Objectives

The objective of the leachate management plan is to achieve water quality compliance at the Site by minimizing leachate generation, collecting and treating all leachate, discharge all treated leachate through on-Site infiltration and provide on-Site attenuation for further polishing.

The leachate generation will be minimized by:

- Maintaining a small active face
- Applying appropriate intermediate and final cover at the earliest opportunity
- Promoting clean surface water diversion away from the Landfill
- Pursuing progressive closure of the Landfill

9.2 Typical Construction and Demolition (C&D), Land Clearing, and Contaminated Soil Leachate General Overview

Principle factors affecting the composition of leachate include (McBean et al., 1995):

- Waste composition
- Age of refuse
- Landfill operations
- Climatic conditions
- Hydrogeological conditions
- Conditions within the landfill (e.g. chemical and biological activities, temperature, pH, and redox conditions)

The mass of refuse stored in a landfill represents a finite source of pollutants. Typical construction and demolition (C&D), land clearing, and contaminated soil waste leachate is a mixture of organic and inorganic compounds produced from refuse materials by a combination of physical, chemical and biochemical processes. Physical processes, related to leachate generation, involve the flushing and dissolution of pollutants as water percolates through the refuse material. Chemical processes, including ion exchange, sorption/desorption, and change in pH, contribute to leachate production by enhancing the mobilization of various pollutants (leachate constituents). Biological processes contribute to leachate production via the degradation of organic constituents into simpler and more mobile compounds.

The mass of pollutants available for leaching is largely a function of the physio-chemical nature of the waste, the extent of waste stabilization, and the volume of infiltration into the landfill (Lu et al., 1984). As a result, the leachate composition may be significantly impacted by not only the above-stated factors, but also key elements of the landfill design and operations.

Leachate produced from typical Demolition, Land Clearing and Construction (DLC) waste landfills is generally considered to be less threatening to human health and the environment compared to leachate from other types of disposal facilities, such as municipal solid waste (MSW) landfills (Townsend, 2000) that contain large quantities of putrescible waste. Unlike MSW, DLC waste consists largely of inorganic components and organic matter with a low degree of biodegradability. Preliminary investigation results of DLC lysimetric testing show concentrations of Chemical Oxygen Demand (COD) in the range of 44 to 1,700 mg/L (Townsend, 2000) which is significantly lower than the typical COD concentration range of 3,000 to 45,000 mg/L in MSW (SWANA, 1991).

Typically, the most potentially prominent contaminants in the leachate from C&D landfills are sulphate, arsenic, iron, manganese, and Total Dissolved Solids (TDS).

A major source of sulphate can be attributed to the presence of gypsum drywall in typical C&D landfills. Gypsum drywall has widely been used as interior walls in construction due to its high fire resistance (Townsend, 2000). When gypsum drywall is landfilled and comes in contact with infiltrating water, calcium and sulphate are released into solution.

In the 1970's to 1980's, wood was preserved with chromated copper arsenate (CCA-treated wood) and used in the construction of decks, patios, gazebos, and other wooden structures. CCA-treated wood in typical C&D waste landfills contributes to arsenic, chromium, and copper levels in typical C&D waste leachate. It is anticipated the technological advancements of wood treatment will eventually lead to a phase-out of CCA-treated wood products. CCA-disposal rates at typical C&D waste landfills will peak and then eventually level-off (Jambeck, 2004).

Manganese is found in alloys, paints, and naturally in plant tissue. In a study of demolition waste leachate, high concentrations of manganese (17 mg/L) were found from wood-based laboratory landfill experiments. Therefore, wood waste is likely the prominent source of manganese present in C&D waste leachate.

High TDS concentrations in C&D leachate are mostly likely attributed to calcium, sulphate and alkalinity ions from the dissolution of gypsum drywall and the leaching of calcium carbonate and calcium hydroxide from concrete.

Non-hazardous contaminated soil may contain a large variety of contaminants depending on the source of the waste material. Common soil contaminants include metals, polycyclic aromatic hydrocarbons (PAHs), volatile organic compounds (VOCs) and petroleum hydrocarbons (PHCs). Some metal-contaminated soils may increase metals concentrations in the leachate but this is dependent on the form of the metal in the soil, the metal solubility and the conditions in the landfill. Contaminated soil could increase the concentrations of PAHs, VOCs, and PHCs in leachate but these compounds are readily biodegradable within the leachate. Contaminated soil must be considered non-hazardous for acceptance at the Site, as defined by the HWR. The leachability of the pollutants in non-hazardous contaminated soil will be low compared to hazardous waste and free-product concentrations.

ACM does not affect the quality of the leachate in terms of impacts from the asbestos material, as asbestos does not have the leachability characteristic that distinguished hazardous chemicals, identified in the HWR. ACM is only hazardous when the potential for asbestos fibres to become airborne prior to and during landfilling. Once landfilled ACM is an inert material.

9.3 Typical C&D Leachate Generation Lifecycle

The composition of typical C&D leachate will vary over time as conditions within the waste material change. Biological activity is a major influence affecting leachate chemistry. An awareness of the microbial activity degrading the refuse throughout landfill development is central to understanding the resultant leachate chemistry. Biological degradation generally involves aerobic and anaerobic phases, which can occur simultaneously and have varying impacts on leachate chemistry.

When refuse is landfilled in an active cell, the initial biodegradation phase occurs under aerobic conditions resulting in the partial degradation of organic components in the refuse material. The aerobic decomposition typically results in high carbon dioxide (CO_2) concentrations, a lowering of pH and an increase in temperature, COD, biochemical oxygen demand (BOD) and specific conductance levels in leachate.

As the availability of oxygen is limited, the organic material will undergo anaerobic decomposition. In the beginning of this anaerobic phase, generally elevated levels of organic acids, ammonia, hydrogen and carbon dioxide are produced. The production of organic acids and carbon dioxide can lower the pH in the leachate, enhancing the dissolution of inorganic constituents including iron (Fe), magnesium (Mg), zinc (Zn) and calcium (Ca). This phase is also characterized by elevated levels of BOD, COD, and specific conductance. As the degradation of organics into simpler and more mobile compounds continues, lower BOD levels will be reached and the pH will stabilize. Inorganic elements such as sulphate, chloride, iron, sodium and potassium, however, can continue to leach and dissolve for a prolonged period of time.

In anaerobic conditions, the three most important bacteria capable of degrading organics include Iron(III)-reducing (Fe(III)-reducing bacteria), sulphate-reducing and methanogenic bacteria. The Fe(III)-reducing bacteria oxidate organic matter with the reduction of Fe(III), sulphate-reducing bacteria oxidize organic matter by reducing sulphate and producing hydrogen sulphide, while methanogenic bacteria convert organic matter to carbon dioxide and methane. Typically, these bacteria are not active simultaneously, thus no hydrogen sulphide or methane production will occur until the Fe(III) reduction is complete and no methane production until sulphate is depleted (Lovley, 1987). In other words, Fe(III)-reducing bacteria can out-compete both sulphate-reducing and methanogenic bacteria for fermentable substrates until Fe(III) becomes depleted, then sulphate-reducing bacteria can out-compete methanogenic bacteria for organics until sulphate is depleted.

Based on the above, typical C&D landfills will likely not reach methanogenic anaerobic degradation due to the ability of sulphate-reducing bacteria to out compete methanogenic bacteria for fermentable substrates in the presence of sulphate, which is plentiful in C&D leachate (Eun, 2004). Conditions in typical C&D landfills favour sulphate-reducing bacteria, therefore unlike in municipal solid waste landfills, little methane gas is produced and hydrogen sulphide gas is generated instead.

Anaerobic conditions can occur within the refuse during landfilling, but are generally more ideal after closure. Over time, generated leachate typically decreases in "strength" or chemical concentration as a result of "washout" (i.e., tendency of contaminants to be transported away from the Site by infiltrating water) (Reinhart, 1995). This does not present a problem to the surrounding environment so long as careful monitoring of both the leachate quantity and quality are carried out, and leachate is collected and treated in an appropriate manner.

9.4 Leachate Indicator Parameters

A number of leachate parameters can be utilized as indicators of leachate derived impacts. As chemicals are transported in landfill leachate, their concentrations can be reduced or attenuated by a variety of processes including dilution, dispersion, sorption, ion exchange and biological degradation. An indicator parameter of landfill derived impacts should be a chemical which is subject to minimal attenuation so that it can signal the early movement of a leachate plume.

Chloride is one of the preferred indicator parameters as it is usually present in landfill leachate at elevated concentrations and is attenuated only by dilution and dispersion. Chloride, which is commonly found in MSW leachate at elevated concentrations, is found in C&D landfill leachate but at lower levels. Typical MSW landfill leachate contains chloride concentrations in the range of 100 to 3,000 mg/L (SWANA, 1991) whereas C&D landfill leachate chloride concentrations are reported to typically range from 5 to 62 mg/L (Townsend, 2000). The use of chloride as an indicator parameter must be evaluated further based on the observed leachate quality for the Site.

The major contaminants of concern with respect to C&D, land clearing and contaminated soil landfills are metals and hydrocarbons. Hydrocarbons do not make good indicator parameters as there are many processes that degrade these parameters within the landfill. Metals can make good indicator parameters depending on the type, quantity, solubility and other variables; however, in many cases metals are not sufficiently mobile due to their ability to adsorb to soil particles.

Site specific leachate indicator parameters will be finalized during the commissioning phase of the leachate collection and treatment system during the first year of the landfill operation. These leachate indicator parameters will be selected based on the actual leachate chemistry observed. The leachate indicator parameters will be reviewed annually as part of the annual operations and monitoring report discussed in Section 14.10.

At this time, the forecasted leachate indicator parameters include the following, consistent with the HHCR.

- Hardness
- Total Dissolved Solids (TDS) (lab)
- Conductivity (lab)
- Chloride
- Alkalinity (total)
- Hydrogen Sulphide
- Sulphate
- Ammonia
- Boron
- Iron
- Manganese

9.5 Site Specific Leachate Quality Forecast

This section presents the conceptual leachate quality forecast. It is recommended that a leachate treatment design basis report be completed as part of the detailed design of the leachate treatment facility. As the nature of the waste may vary throughout the Landfill lifespan, it is anticipated that the contaminants of concern may require modifications or additions. The leachate characterization updated annually, and documented as part of the annual operations and monitoring report discussed in Section 14.

For the purpose of this DOCP, a forecasted leachate profile has been developed using leachate quality data from other similar landfills in BC, and compared with similar landfills in other parts of Canada for verification purposes. The forecasted leachate profile contained in this report serves as an estimated baseline for the leachate quality but will be revised based on Site specific conditions and incoming waste types to continue to assess the level of treatment required.

Table 9.1 provides a range of leachate concentrations from four similar landfills that are used to forecast the leachate quality profile for the Site. As shown in Table 9.1, parameters that are forecasted to potentially exceed the CSR Schedule 6 DW Standards within the untreated leachate include:

- Chloride
- Sulphate
- Sulphide
- Arsenic
- Copper
- Boron
- Iron
- Magnesium
- Manganese
- Sodium
- Zinc

As noted in Section 9.4, typical C&D waste leachate chloride concentrations are reported to range from 5 to 62 mg/L (Townsend, 2000). However, the observed leachate chloride concentrations from C&D landfills evaluated herein vary significantly. Sodium concentrations are also likely linked to the concentration of chloride in the leachate. As shown in Table 9.1, the maximum concentrations of chloride and sodium observed in leachate from the Mayer Waste Disposal Site were 98.9 mg/L and 256 mg/L, respectively. When compared to the maximum concentrations of chloride and sodium observed in leachate from the Highwest Waste Management Facility (4,300 mg/L, each), it is clear that chloride and sodium concentrations in leachate at C&D landfills is highly site specific and dependent on the waste accepted at the Site.

Similarly, sulphate concentrations in leachate are highly variable from one landfill to the next as shown in Table 9.1. The variation in sulphate concentrations is likely related to the relative proportion of gypsum waste present at the Site. Therefore, the sulphate concentrations forecasted for the Site assume that gypsum drywall will be disposed of on Site and therefore the sulphate concentrations will be elevated. If gypsum is not disposed of on Site in significant quantities, the actual sulphate concentrations may by lower.

9.6 Leachate Quantity

The principal factors governing the quantity of leachate generated at a landfill include:

- Moisture addition
- Thickness of refuse layer
- Compaction and permeability of refuse mass
- Slope, thickness and permeability of intermediate and final cover

Moisture addition to a landfill can arise from a number of possible sources (McBean et al., 1995):

- Water present in waste mass when landfilled
- Percolation of water (precipitation) through the landfill surface
- Horizontal flow through sides (not applicable to Upland due to lined slope and berms)
- Upgradient flow from the bottom (not applicable to Upland due to lined base)

Water entering the landfill is retained within the waste by surface tension and capillary pressure until the waste reaches field capacity, which is defined as the point at which the force of gravity on the leachate overcomes the forces retaining the leachate (El-Fadel et. al., 2002). In general, waste is placed at a water content below field capacity, hence percolation and inflow are considered to be the principle sources of water infiltration for leachate generation. The specific moisture content of the waste at field capacity varies with the waste composition, density, and porosity. The heterogeneous nature of the waste and channeling of leachate through paths of low hydraulic resistance causes leachate generation prior to the waste mass reaching field capacity, however, it can be expected that leachate flow rates will increase once field capacity has been reached.

Horizontal flow into the Landfill through the sides will not occur at this Site. The north, west, and east sides of the Landfill are not connected to adjacent land mass, and therefore horizontal flow into the Landfill could only be possible through the buried portion of the landfill. The buried portion of the landfill on the southern side of the Landfill will not be subjected to horizontal flow into the Landfill due to the base liner system extended up the southern side slope and over the perimeter berm. A vadose zone exists between the groundwater and the base liner system. The high hydraulic conductivity of the underlying soils will provide a preferential pathway for groundwater flow through the soils and not through the liner system.

9.6.1 Estimating Leachate Quantities

It is assumed that all precipitation, which infiltrates through the Landfill cover will become leachate once the Site has reached field saturation capacity. A tool commonly used to estimate the amount of water in a landfill is the Water Balance Method (WBM). This method is based on the principle of conservation of mass and accounts for the total amount of precipitation falling onto a landfill. It utilizes the following equation to estimate the total amount of water infiltrating the landfill (McBean et al., 1995):

Infiltrate = Precipitation – Surface Runoff – Soil Moisture Storage – Evapotranspiration.

In addition to the WBM, The Hydrologic Evaluation of Landfill Performance (HELP) Model is a quasi-two-dimensional hydrologic model for conducting water balance analysis of landfills, cover systems, and other solid waste containment facilities. It is a long-accepted standard model for landfill cover performance developed by the US Army Corp of Engineers.

For the purpose of this report, the HELP Model will be used to estimate leachate generation. The WBM will be used to verify HELP Model results. HELP Model outputs are presented in Appendix D. The infiltration through daily cover will be calculated with the HELP model, however, the surface runoff rate will be added to the infiltration rate, as it will be intercepted by the perimeter containment berms and managed as leachate.

9.6.2 Conceptual Leachate Generation Model

The generation of leachate is dependent on a number of factors including the precipitation rates, landfill cover systems, landfill development, and the duration of each stage of landfill development.

Precipitation data for the Campbell River Airport (Station 1021262) from 1981 to 2010 is summarized in Table 2.1. The precipitation data is provided by month and used to calculate average daily precipitation rates. It is noted that November, December and January account for

45% of the annual precipitation. As discussed in Section 8, climate change models forecast an increase of up to 6 percent during the life of the Landfill.

The cover systems are discussed in Section 6.5. A summary of the HELP results, or the annual leachate generation for each cover system is provided in Table 9.2.

The Landfill development is described in Section 5. During each of the nine stages, the estimated area that will be covered with daily, intermediate and final cover varies. The estimated area of each type of cover during each stage is presented in Table 9.3.

The development plan includes a Landfill footprint of 34,145 square metres. The Landfill will have varying combinations of daily, intermediate, and final cover throughout the life of the Landfill that will affect the leachate generation, as presented in Table 9.3. Annual leachate volumes were calculated by multiplying the corresponding leachate generation rate of each cover system, presented in Table 9.2, by the respective areas during each stage of development. The approximate annual collected leachate volumes will range from 14,268 m^3 (39 m^3/day) in Stage 1A to 24,633 m^3 (67 m^3/day) in Stage 1C to 580 m^3 (less than 2 m^3/day) post-closure, as shown in Table 9.4.

The waste in the landfill will provide a significant amount of detention capacity that will prevent instantaneous surcharges in leachate volumes in the Landfill leachate collection system as a result of a large precipitation event.

9.7 Leachate Collection

The Landfill leachate will be collected by a series of perforated collection pipes installed at the bottom of each cell, as shown in Drawing C-03. The collection pipes will discharge to a sump to be constructed at the low point of the Landfill in the center (east-west) of the northern most end of the Landfill, as shown on Drawing C-03 and C-11. The leachate will be pumped from the sump on an as-needed basis via a manually operated leachate pump housed in one of the two sump riser pipes. The leachate will be conveyed to the aeration pond for treatment, after which it will be decanted to the infiltration pond. The location of the treatment ponds is shown on Drawing C-03 and C-04.

9.8 Leachate Treatment

9.8.1 Treatment Objectives

The leachate treatment system will be designed to treat the leachate to meet the applicable CSR water quality standards (Schedule 6 DW) prior to discharge to the Infiltration Pond. The CSR standards are published by the BC MOE and are designed to be protective of human health and the environment. The DW standards protect the potential for future drinking water use of the overburden, sand and gravel aquifer downgradient of the Site.

As noted in Section 13.1.1 the groundwater flow in the shallow aquifer beneath the Pit is 706 m^3/day one order of magnitude above the average annual daily leachate generation rate. As such the available on-Site attenuation capacity within the overburden, sand and gravel aquifer provides for contingent reduction of treated leachate concentrations further protecting the off-Site receiving environment.

9.8.2 Treatment Capacity

As discussed in Section 9.6, the leachate volume was estimated using the HELP model and the development Stages of the Landfill. For the purposes of designing a leachate treatment system, it is assumed that all leachate generated will be collected and treated as any losses that occur from Landfill saturation and Landfill base liner leakage are negligible.

Based on the leachate generation rates during the individual stages of the Landfill development plan, the maximum annual average leachate generation will occur in Stage 1C. During Stage 1C, the annual leachate generation rate is estimated to be 24,633 cubic metres (67 m^3/day).

The leachate treatment pond has been designed to manage the maximum annual average leachate generated with 100% redundancy. The treatment pond capacity was also verified to ensure sufficient capacity is available to treat the maximum monthly average of leachate generated through the winter months (highest precipitation months) during Stage 1C. Table 9.5 provides a summary of the monthly average forecasted Stage 1C leachate generation rates. As shown in Table 9.5 the maximum forecasted monthly average leachate generation is 128 m^3/day during November. The maximum monthly average leachate generation with a potential six percent increase due to climate change will not exceed the design treatment capacity, as shown in Table 9.5.

As an additional measure of redundancy, the Landfill storage capacity was evaluated. Because the Landfill is lined, leachate can be temporarily stored within the Landfill. It is noted that the design criteria for the leachate collection system and landfill liner indicates that the leachate head should not exceed 0.3 metres. Therefore, the storage capacity of the Landfill is limited to 0.3 metres over the base area available during Stage 1C. Accounting for an assumed leachate collection system porosity of 0.3, this results in a maximum capacity of the leachate collection system is 1,910 cubic metres.

If the leachate volumes are found to differ during detailed design, commissioning, or at any point in the landfill lifespan, modifications to the treatment system capacity may be required.

9.8.3 Conceptual Treatment Process

9.8.3.1 Process Components

Lined Cells

All Phases of the Landfill will be lined with a geomembrane and GCL base liner system to collect leachate, as described in Section 3.6. The lined Landfill allows for containment of leachate prior to treatment and also mitigates the need to design the system for peak daily precipitation. As discussed above, several processes occur within the Landfill to reduce concentrations of contaminants and these processes vary over time with the development of the Landfill. The details of the liner system are shown in Drawing C-10.

Leachate Collection

All Phases of the Landfill will include the installation of leachate collection pipes (Drawing C-03) and drain rock layer (Drawing C-04), as described in Section 3.7. The details of the leachate collection system are shown on Drawing C-10 and C-11. Leachate will be conveyed via the leachate collection system to the north of the cell, where a leachate sump will be installed. The sump details are provided on Drawings C-11 and C-12. A single manually operated pump will be installed in one of the sump risers. The second sump riser provides redundancy to allow for maintenance and cleaning and the use of a second pump.

Aeration Pond

The conceptual design features of the aeration pond include:

- 2.5H:1V side walls lined with 60-mil HDPE liner overlying a GCL
- Side slopes protected with poorly graded round drainage stone
- A submerged coarse bubble aeration system
- Positive displacement blowers, including variable frequency drives, sized to provide the required air demand
- Floating decant pump
- Decant outlet pipes located at the bottom of the pond and at a height of approximately 1.2 metres from the bottom of the pond
- Approximate bottom dimensions of the aeration pond will be 25 metres by 30 metres. The approximate top dimensions of the aeration pond will be 39 metres by 46 metres.

Treated leachate will be allowed to settle prior to decantation to the infiltration pond. The settling period will facilitate the removal of suspended solids. Periodic removal of sludge accumulated in the aeration lagoon will be required. Sludge can be removed by vacuum truck and conveyed to an excavated infiltration area in the Landfill's active face.

Infiltration Pond

The infiltration pond will be used to infiltrate treated leachate and some of the collected storm water into the groundwater system. The design and construction of the infiltration pond is supported by the results of the hydrogeologic characterization of the Site, as provided in the HHCR.

The location of the infiltration pond has been selected to allow for natural attenuation to occur while allowing for continued Site operations. The Site is underlain by a vadose zone of varying thickness, and will be used to attenuate, via sorption, diffusion, dilution, dispersion, and biodegradation, the treated leachate to further reduce the concentrations of the leachate constituents prior to reaching the sand and gravel aquifer and the downgradient property line.

If a treatment capacity increase is required, as discussed in Section 9.8.2, a settling pond will be considered to provide the additional volume required. The addition of a settling pond would allow the aeration pond to work full time as an aeration system, and the leachate would be decanted into the settling pond for the settling portion of the treatment cycle. Once settling had occurred the leachate would be decanted to the infiltration pond. In this scenario, an infiltration pond would be constructed to the north of the two ponds currently included in the design, as shown on Drawings C-02A. The configuration of the pond should allow for gravity drainage between the ponds. If this is not feasible at detailed design, a pump station will be required.

9.8.3.2 General Operation

Leachate will be stored temporarily in the Landfill. When leachate levels in the Landfill warrant removal and the previous leachate treatment cycle is complete, the pump system will be activated to pump leachate collected in the sump into the adjacent aeration pond. The aeration pond will operate as a batch reactor in three distinct cycles: fill/aeration, settle, and decant, controlled by process times and the aeration pond water level.

An aeration pond will provide the necessary biological and physical-chemical treatment processes when operated. The batch treatment will be completed in a 7-day cycle as follows:

- Fill – 1 day
- Aerate – 2 days
- Settle – 1 day
- Decant – 1 day
- Idle – 2 days (for operator weekends)

The aeration pond will be designed to ensure a minimum freeboard of one metre under maximum leachate generation scenarios. This freeboard will ensure that even under the peak 7-day rainfall event and peak leachate generation scenarios that suitable freeboard will remain. The leachate volume within the aeration pond will be divided into three categories:

- Residual Volume (1,090 m3) – This volume of leachate will remain in the aeration pond at all times to ensure the treatment bacteria and chemical processes remain active
- Maximum Annual Average 7-day leachate flow volume (475 m3) – This is the anticipated average volume that will be treated in each cycle.
- Maximum leachate flow volume (475 m3) – This is the anticipated redundant volume available for treatment during higher leachate generating months without utilizing the freeboard volume.

A schematic illustrating the aeration pond operating levels is provided as Figure 9.1.

9.8.3.3 Treatment Process

Aeration oxidizes dissolved metals such as iron and manganese to less soluble forms and produces flocs that settle into a sludge for periodic removal. Concentrations of other metals present in the leachate that are not readily oxidized in an aeration lagoon will also be reduced when the suspended (not dissolved) components of these metals settle out into the sludge.

Hydrocarbons and volatile organic compounds will be readily volatized in an aeration lagoon thereby reducing the concentration.

The dissolved metals will be removed if required by chemical precipitation, by adding a volume of chemical that will cause an increase or decrease of pH of the leachate to facilitate the formation of an insoluble salt.

An aeration lagoon will also biologically treat ammonia by converting it to nitrite and subsequently nitrate in a process called nitrification. Nitrification also reduces BOD should it be a concern for the leachate. The biological process requires a balance of nitrogen (in the form of ammonia), carbon (naturally present in leachate in the form of alkalinity) and phosphorus. The forecasted leachate quality estimates low concentrations of phosphorus, which may be limiting to the biological process. Should process modeling indicate that biological processes will be phosphorus limited, manual addition of phosphoric acid will provide the required nutrient balance. Similarly, if in the future the process becomes carbon limited due to a reduction in alkalinity, an alternate carbon source such as sodium bicarbonate can be added manually to maintain the nutrient balance. The biological processes are impeded at lower temperatures. Process modeling during the preparation of a leachate treatment design basis will indicate whether additional steps are required to ensure adequate temperature is maintained during the colder months of the year. Sulphate, chloride, and sodium treatment are dependent on the form that each is present in the leachate and the forecasted concentration of each is highly dependent on the composition of incoming waste. Treatment of arsenic, boron, magnesium, and zinc treatment is dependent on the form that each is present in the leachate.

The forecasted treated leachate quality is presented in Table 9.1. Further studies will be performed on the actual leachate during the preparation of the leachate treatment detailed design basis to ensure adequate level treatment is attained. The leachate treatment process may be modified throughout the life of the Landfill to ensure the performance and compliance criteria are met.

9.8.4 Treatment Sampling Program

During the commissioning of the aeration pond and during the operation in Stage 1A, the leachate treatment system will not be at maximum capacity, a program will be implemented to determine the leachate treatment sampling program. The untreated leachate and treated leachate will be sampled regularly during the commissioning to develop a relationship between the parameters of concern within the leachate and the batch treatment sampling program. Because the treatment system will not be operating at full capacity the batches may held while the commission program is underway to ensure only leachate meeting the treatment objectives is infiltrated. The finalized leachate treatment sampling program will outline the parameters sampled in every batch to indicate the effectiveness of the treatment process and the confirmatory sampling required at the quarterly environmental monitoring events. Additional confirmatory sampling may be conducted.

Subsequent to commissioning, samples will be collected at a minimum on a quarterly basis to analyze for the parameter list below. The collection of the samples sent to for laboratory analysis may be collected more frequently to verify the batch sampling program, and to assist in the operation and maintenance of the leachate treatment facility.

- BOD
- COD
- Alkalinity
- Phosphorus
- TKN
- Ammonia
- pH
- Iron
- Manganese
- Sulphate

10. Landfill Gas (LFG) Management Plan

10.1 LFG Production

LFG is primarily generated as a result of biological decomposition of organic waste material. The processes involved in biological decomposition of solid waste are highly variable. In the early stages of decomposition (typically less than 2 years after initial placement), microbial activity is oxygen consuming (aerobic). This results in relatively high in-situ temperatures, production of gases composed primarily of carbon dioxide (CO_2) with other trace compounds, and production of acidic leachate.

As the oxygen in the solid waste mass is consumed, activity of anaerobic microbes increases and eventually results in production of LFG that is predominantly methane (CH_4) and CO_2, and in some cases hydrogen sulphide gas (H_2S). In this phase of the decomposition, the in-situ temperatures are typically in the range of 30 to 40°C and the leachate has a more basic pH. This methanogenic phase of decomposition will reach an equilibrium level, which will continue for some length of time. The equilibrium condition and the duration of methanogenic decomposition are the primary determinants of the LFG production over time. Within a few years, this anaerobic stage typically becomes and remains dominant until all organic matter in the Landfill has been fully decomposed. The typical LFG production stages are illustrated in Figure 10.1.

Conditions in typical C&D landfills favour sulphate-reducing bacteria, therefore unlike in municipal solid waste landfills, little CH_4 is produced and H_2S is generated instead.

These processes are dependent upon the following primary parameters:

- Age of solid waste
- Quantity of solid waste
- Solid waste composition
- Moisture content
- Density and filling practices
- Climate (i.e., precipitation and temperatures)
- Landfill chemistry

This list is not considered comprehensive but serves to illustrate the complexity of the processes involved in the production of LFG. The solid waste age, quantity, and composition, along with site moisture content are considered the primary influences on the rate and duration of LFG production.

The composition and quantity of the solid waste placed in a landfill will determine the amount of material available for decomposition. Materials with a higher organic content are more readily decomposable than those wastes with a low or no organic content. For example, food and agricultural wastes contribute more readily to LFG production than construction rubble. In general, waste that is derived from residential sources contains a higher decomposable fraction than those derived from other sources.

Collected LFG may contain varying amounts of nitrogen (N_2) and oxygen (O_2) due to intrusion of outside ambient air into the landfill. The typical composition of the gas may be in the following range depending on the operation of the LFG collection system:

- Methane – 35 to 60 % by volume
- Carbon dioxide – 35 to 60 % by volume
- Oxygen – 0 to 5 % by volume
- Nitrogen – 0 to 15 % by volume

For modelling and design purposes, the composition of LFG produced and collected is assumed to be 50% CH_4 and 50% CO_2, each by volume.

The optimal range of moisture content in refuse for methane production is reported to be 40 to 70% by weight (Reinhart & Townsend, 1998). Actual LFG production is sensitive to moisture; however, the degree of moisture distribution and saturation within the landfill are difficult to determine. Furthermore, there are various technical difficulties in ensuring adequate leachate distribution and collection within a landfill.

Due to the complexity of the processes involved in LFG production, the methods available to predict variations in production over the life of a site provide only estimates to permit the design of control systems. Flexibility to address changes in the LFG production should always be a primary design consideration in any LFG management program.

The use of predictive models provides the best method of defining a particular site's LFG generation potential. The following subsections present the results of estimated LFG production at the Site with mathematical models.

10.2 Regulatory Criteria

The BCMOE Landfill Gas Management Regulation requires the following:

- Landfills receiving over 10,000 tonnes of waste per year, or landfills that have over 100,000 tonnes of waste in place, complete a LFG generations assessment every five years
- The assessment of the forecasted LFG generation rate in the year of the assessment and for the next 5 years be prepared by a qualified professional and submitted to the MOE
- If the landfill is currently generating over 1,000 tonnes of methane per year, according to the LFG generation assessment, then a LFG design plan must be submitted to the MOE within one year
- Once the LFG design plan is accepted, an active landfill gas collection system is required to be installed within four years of the LFG design plan acceptance

The production of hydrogen sulphide gas is related to health and safety concerns, as well as nuisance impacts, and is regulated under WorkSafeBC, as discussed in Section 10.5.

10.3 LFG Generation Model

There are numerous models available for estimating rates of production of LFG. Accepted industry standard models are generally first order kinetic models that rely on a number of basic assumptions. These models are used to predict the variation of LFG generation rates with time for a typical unit mass of solid waste. This generation rate curve is then applied to records (or projections) of solid waste filling at a site to produce an estimate of the landfill's LFG production rate over time.

The Scholl Canyon model, a first-order kinetic function, is the accepted industry standard model to evaluate LFG production and emission rates for the purpose of assessing potential LFG impacts. The Scholl Canyon model is used to estimate LFG production over time as a function of the LFG generation constant (k), the methane generation potential (L), historic filling records, and future projections for waste filling rates. Typical values of k range from 0.006 per year for dry sites to 0.07 per year for wet sites. Depending upon the regional precipitation and waste composition, production of LFG may continue for more than 50 years after closure and can result in total yields ranging from approximately 10 to 350 cubic metres of methane per tonne of waste.

The formula for the Scholl Canyon model can be expressed as follows:

$$Q_T = \sum_{t=1}^{n} 2\, L_0 k M_t e^{-kt}$$

Where:

Q_T = total LFG emissions (50 % CH_4 and 50 % CO_2 by volume)

K = LFG generation constant ($year^{-1}$)

L_o = methane generation potential (m^3 CH_4/tonne of waste)

M = mass of waste (tonnes) placed in year t

T = time in years

10.4 LFG Generation Assessment

10.4.1 Landfill Gas Generation Assessment Requirements

As required by Section 4(5) of the Regulation, this Section relates to the tonnage thresholds that determine the regulatory requirement to prepare a landfill gas (LFG) generation assessment. The Regulation applies to landfills that accept MSW on or after January 1, 2009. A landfill is termed a regulated landfill site under the Regulation if it has 100,000 tonnes or more of MSW in place or receives 10,000 or more tonnes of MSW in any calendar year after 2008.

Based on the estimated annual tonnages, the Landfill will be considered a 'regulated landfill site' as per Section 4(5) of the Regulation and a landfill gas (LFG) generation assessment report will need to be submitted to the MOE following the first year of landfill operations as required in Section 4(5) of the Regulation.

10.4.2 Waste Characterization

This Section summarizes characteristics at the Site, anticipated waste tonnage, and waste characterization, as required by Sections 4(2)(a), 4(2)(b), 4(2)(c), 4(3)(a), and 4(3)(d) of the Regulation and described in Section 5.1 of the Guidelines.

For this assessment, waste landfilled was segregated into the following three categories by mass:

- Relatively inert (waste includes waste materials with low or no degradable organic carbon, such as metal, glass, plastic, soil, contaminated soils, and water treatment plant screened fines).
- Moderately decomposable (includes materials with a degradable organic carbon fraction that will decompose at a moderate or slower rate such as paper, wood, wooden furniture, rubber, textiles, and construction and demolition material).
- Decomposable (includes materials with a high degradable organic carbon fraction that will decompose relatively quickly such as food waste, yard waste, and slaughterhouse waste).

As per Section 4(3)(d) of the Regulation and described in Section 5.1 of the Guidelines, waste characterization information is required as part of the generation assessment. This information should include the historical, where possible, and projected annual waste mass categorized into mass of relatively inert, moderately decomposable, and decomposable wastes, and historical and projected waste mass.

The site specific waste characterization is presented in Table 10.1. As shown, the waste will be categorized into 75 percent relatively inert, 25 percent moderately decomposable, and zero percent decomposable.

10.4.2.1 Climate

The moisture content within a landfill is one of the most important parameters affecting the gas generation rate. Moisture provides an aqueous environment necessary for anaerobic processes responsible for LFG production, and serves as a medium for transporting nutrients and bacteria that play a major role in the decomposition process. The precipitation data, as discussed in Section 2.4 was used to determine appropriate values for model input parameters. The potential effects of climate change on the annual precipitation rate were evaluated. It was found that the model inputs do not change for annual increase of up to than 25 percent, which exceeds the forecasted precipitation rate change due to climate change, as discussed in Section 2.4 and 8.4.2.

10.4.2.2 Model Input Parameters Used and Justification

The following Section presents the information required by Section 4(3)(d) of the Regulation and described in Sections 5.2 (Methane Generation Rate Selection Matrix) and 5.3 (Water Addition Factor) of the Guidelines.

The methane generation potential, L_o, represents the total potential yield of methane from a mass of waste (m^3 of methane per tonne of waste). The L_o value is dependent on the composition of waste, and in particular the fraction of organic matter present. The methane generation rate, k, represents the first-order biodegradation rate at which methane is generated following waste placement. This constant is influenced by moisture content, the availability of nutrients, pH, and temperature.

Moisture content is influenced primarily by the infiltration of precipitation through the Landfill cover and the nature and composition of the waste. For this assessment, a water addition factor of 1.0 was selected. The water addition factor may increase or decrease the LFG generation rate by 10 percent. The potential Landfill leachate storage in the Landfill during the winter months will not significantly increase the moisture within the Landfill, as the leachate will be stored primarily within the leachate collection system, and not within the waste.

10.4.2.3 Landfill Gas Generation Model Results

The Regulation Sections 4(2)(d), 4(2)(e), and 4(3)(a)] requires that a LFG generation assessment include the following:

- The annual tonnage of waste received for disposal at the Site in the calendar year immediately preceding the year in which the assessment is conducted.
- An estimate of the quantity of methane generated at the Landfill in the calendar year immediately preceding the calendar year in which the assessment is conducted.
- Projections for methane anticipated to be generated annually at the Site in the calendar year of the assessment and in each of the four calendar years following the calendar year of the assessment.

For this assessment, the anticipated average annual waste tonnages throughout the life of the Landfill (32,890 tonnes per year) were used. When an actual LFG assessment is produced for submission to the MOE, the recorded waste tonnages will need to be used for the assessment.

This assessment projects the methane generated annually at the Landfill for each calendar year that the Landfill is anticipated to be operational.

Table 10.2 presents a summary of the above information. As noted on the table, the peak methane generation occurs in the year after closure. The maximum annual methane generation is estimated to be approximately 560 tonnes per year in the year following closure. The methane generation rate will steadily decline in post-closure years.

Table 10.3 presents the input values for the Scholl Canyon Model and LFG generation results. Figure 10.2 shows a graphical representation of the annual LFG generation estimate commencing at the 2017 (assumed Landfill start date) to 2066 (end of the 30 post-closure monitoring period).

10.4.2.4 Future Considerations

The estimated 2036 (Landfill closure year) methane generation for the Site is approximately 544 tonnes. As the regulatory threshold is 1,000 tonnes of methane per year, the Landfill is not expected to surpass the threshold during the Landfill lifespan. If the methane generation rate surpasses the threshold due to higher annual tonnages, more decomposable waste, the Landfill continuing for a longer timeframe than originally plan, or due to a regulatory revision, a LFG Management Facility Design Plan will be submitted to the MOE director. Within 4 years of submitting the LFG Management Facility Design Plan, a LFG Management system designed to target a landfill gas collection efficiency of 75 percent must be commissioned and operational. The LFG regulation may change between now and the closure of the Site.

The LFG Management Facility Design Plan must be prepared by a qualified professional in accordance with the Landfill Gas Management Regulation.

10.5 LFG and Safety

As indicated in Section 10.1, LFG is produced primarily due to biological decomposition, generating CO_2 and CH_4. Predominantly due to pressure gradients, LFG migrates through either the landfill cover or adjacent soil and enters the atmosphere, contributing greenhouse gas (GHG) emissions, creating health and toxicity issues, and creating nuisance odours. These impacts are largely dependent upon the pathway by which humans and the environment are exposed.

Sub-surface migration of LFG is influenced by pressure differentials within the waste mass, LFG migration from areas of high pressure to areas of low pressure, diffusion of LFG through from areas of high concentrations to low concentrations, and the permeability of the waste, liner, and cover systems.

Sub-surface migration of LFG poses two primary concerns related to the accumulation of gases within or below structures near the Landfill. First, accumulation of LFG in a subsurface structure (i.e., basement, buried manhole, etc.) may expose those required to enter the structure to an oxygen deficient environment. Second, accumulation of LFG introduces the risk of an explosion if a source of ignition is present. The risk of explosion occurs when the concentration of methane in air exceeds its Lower Explosive Limit (LEL). Due to the fact that the LEL of methane is approximately 5% by volume in air, only a small proportion of LFG (containing approximately 50% methane by volume) is necessary to create explosive conditions.

Visual observation of the sub-surface migration of LFG is possible through identification of areas impacted by vegetative stress. Vegetative stress occurs due to the displacement of oxygen in the soil and the resultant oxygen deprivation of the plant roots. Deterioration of vegetation on or near landfills may be both an aesthetic and a practical issue. In areas where vegetative cover is diminished, erosion of the cover may occur. This may result in a "cascade" effect resulting in increased LFG emissions.

H_2S, if present, presents immediate danger to the health and safety of workers. WorkSafeBC regulations and guidelines must be followed. At a minimum, the following procedures are recommended, if the potential for H_2S becomes an issue.

- No persons shall traverse or operate equipment within the limit of waste or in the vicinity of the leachate management infrastructure without wearing a 4-gas meter.
- All leachate collection system cleanout and sump riser pipes blind flanges should be completely sealed, bolted, locked, and identified with appropriate signage.
- Appropriate measures should be taken to prevent persons untrained in H2S safety and without the appropriate personal protective equipment from entering the site. Appropriate signage should be installed around the limit of waste.

- Appropriate chain link fencing and signage should be installed around leachate sumps, leachate manhole, and toe drains.
- All workers and contractors working in designated Site "Hot Zones" (fenced areas) should be required to have completed the H2S Alive course.
- All workers and contractors working on-site should be required to have reviewed and acknowledged the Site health and safety plan which discusses the H2S safety plan and restricts smoking anywhere onsite.

10.6 LFG as a Greenhouse Gas

As discussed in Section 10.1, LFG consists of varying levels of CH_4, CO_2, oxygen, and nitrogen. For modelling and design purposes, the composition of LFG produced and collected is often assumed to be 50% CH_4 and 50% CO_2, each by volume. These two gases are two of the recognized greenhouse gases that contribute to climate change. CH_4 has a global warming potential approximately 25 times that of CO_2.

10.7 LFG Control

The Landfill expansion will utilize a geosynthetic liner system, which will limit subsurface migration of LFG. As such, sub-surface migration of LFG will likely occur through the final cover, resulting in degradation of the final cover and vegetative stress. The LFG Management Plan shall be limited to the installation of a passive gas venting system as part of the final cover design.

The use of passive bio-filters will be evaluated as part of the detailed design of the final cover and passive gas venting system. Methane from the Landfill would be directed to a biofilter(s) via the passive venting system. Biofilters are typically a mix of sand and wood chips that facilitate the growth of aerobic bacteria that oxidizes methane to carbon dioxide, reducing the greenhouse gas emissions from the landfill. Passive biolfilters will be considered at the detailed design of the final cover system, when it is possible to assess the actual methane generation rates based on actual waste characteristics in the landfill.

The guidance document entitled "Technologies and Best Management Practices for Reducing GHG Emissions from Landfills Guidelines" provides guidance for the selection of technologies and best management practices for reducing GHG emissions from landfills.

10.8 LFG Monitoring and Assessment

The highly permeable overburden unit at the Site may allow the LFG to migrate away from the Landfill if there is a leak within the Landfill cells. It is therefore recommended that the potential off-Site LFG migration be monitored at the periphery of the Site, and into the existing buildings currently occupied by the operational personnel. The soil gas concentrations at the Landfill boundary must not exceed the lower explosive limit of methane (five percent by volume). The soil gas concentrations in on-Site buildings must not exceed 20 percent of the lower explosive limit of methane (one percent by volume) at any time.

In accordance with the above noted recommendation, two soil vapour monitoring locations will be installed at site as part of the construction of the cells.

1. Near the Site office.
2. At the northern property boundary along the Gold River Highway to monitor migration of LFG off-site.

The monitoring requirements are further discussed in Section 14.

11. Closure Plan

The following sections outline site-specific closure activities and post-development care requirements in accordance with the Landfill Criteria.

11.1 Total Site Capacity

The estimated total and remaining Site capacity is estimated to be 506,000 m^3.

11.2 Landfill Site Life

The estimated Landfill Site life is approximately 20 years, and is assumed to start in 2017.

11.3 Final Closure Design

The final contours for the Landfill area are based on the construction of a 0.90-metre-thick final cover (0.15 millimetres of sand overlain by a GCL, 0.6 metres of protective sand layer, 150 millimetres of topsoil) constructed over top of the final waste grades presented on Drawing C-05. In accordance with the Landfill Criteria, the final cover slopes will be a maximum of 3H:1V (33 percent) on all side slopes and a minimum of 10H:1V (10 percent) on the top slopes of the Site.

Details concerning final cover design and construction, including final cover soils, topsoil, and cover vegetation are discussed in Section 3.12. When a section of the Landfill reaches final contour elevation final cover will be installed by an experienced contractor and inspected by a qualified professional engineer to ensure that construction has been completed in accordance with detailed design.

11.4 Progressive Closure Strategy

In keeping with a progressive closure strategy at the Site, areas of the Landfill that reach final waste contours in accordance with the Landfill Development plan presented on Drawings C-07 through to C-09 will be closed once sufficient area to warrant construction of final cover is available.

The Site life will be updated in the annual operations and monitoring report based on the final waste contours and the average annual fill rates.

11.5 End Use

There is presently no end use plan formulated for the Site. It is anticipated that the Site will remain industrial land use and continue the gravel extraction activities.

A detailed End Use Plan will be developed for the Site within one to two years prior to closure. The end use plan will comply with the requirements of the CSR and a new declaration under Part 8 of the CSR may be submitted to the MOE Director. The End Use Plan will be submitted to the City and the Regional Waste Manager for review and approval prior to implementation.

11.6 Post-Closure Requirements

11.6.1 Site Monitoring

The long-term environmental monitoring program for the Site will include hydraulic monitoring and chemical analysis of surface water and groundwater at the Site in accordance with the Environmental Monitoring Plan (EMP) discussed in Section 14. The EMP will be maintained during and after Site closure and will be evaluated on an annual basis. In accordance with the Landfill Criteria, the long-term monitoring program will be maintained for a minimum post-closure period of 30 years. Any proposed amendments to the long-term monitoring program will be submitted to the Director for review and approval prior to implementation.

11.6.2 Vector, Vermin and Animal Control

After closure, the Site will continue to be monitored for the presence of vectors, vermin, and wildlife and should problems become evident, the appropriate steps will be taken to address the issue.

11.6.3 Surface Water Control

The strategy outlined in the SWMP (Section 8) will be implemented into the post closure surface water control measures. The mid-slope swales, surface water diversion berm, ditches, sediment forebays, and infiltration areas will be completed and maintained around the landfill. Channels with steep slopes will require reinforcement to prevent erosion, as discussed in the SWMP. The ditches and ditch outlets will require reassessment upon closure to ensure that they are functioning satisfactorily. Vegetation will be maintained on the Landfill surface and in the channels to ensure channels flow freely and are not overloaded at peak rainfall events. Monitoring of the Landfill surface conditions will be required, and if damage due to erosion, settlement, or other factors are found, maintenance will be required.

11.6.4 Post-Closure Infiltration Areas

The post-closure conditions of the Landfill will require the designation of infiltration areas within the base of the Pit to manage the surface water in large rainfall events. The conceptual design of the infiltration areas is discussed in Section 8.4.

11.6.5 Post Closure Maintenance and Monitoring Requirements

The EMP, discussed in Section 14, should be maintained for a minimum period of 30 years post-closure. This will be to assess the need to implement a contingency measure to further reduce the environmental risk. If monitoring results are as expected, the frequency of the monitoring events may be decreased to annually. The parameters should be analyzed annually until they completely stabilize at which time a monitoring program every 5 years is appropriate. It is important to continue monitoring to ensure conditions do not change.

11.6.6 Site Facilities

The Landfill facilities for storm water and leachate management will remain intact and operational post-closure of the Landfill. A closure plan shall be submitted to the Director for approval at least 6 months prior to the closure of the Landfill.

12. Contaminating Lifespan Assessment

The purpose of this assessment is to evaluate the contaminating lifespan (CLS) of the Landfill. The CLS is the time period after the final closure of the Landfill until which the Landfill leachate no longer poses a risk to the environment because the concentrations of leachate contaminants have decayed sufficiently that the leachate constituent concentrations meet the applicable CSR standards for regulatory compliance.

During the CLS, the Landfill will require treatment, monitoring, and maintenance of the leachate management system to manage the post-closure Landfill conditions. These measures can be terminated at the end of the CLS.

The CLS of the Site was estimated based on the available data, and relevant models acquired through a literature review. In this case, GHD has utilized a first order decay function to estimate the CLS of the Site. The contaminants modeled to estimate the CLS include chloride and sulphate. These contaminants were selected as conservative parameters, as they decay only through dissolution and are not subject to biological degradation. GHD also investigated chromium, copper, and cadmium, however, forecasted leachate concentrations are below applicable environmental protection guidelines. GHD utilized the Rowe (1995, 2004) CLS model to confirm/evaluate the first order decay results for chloride.

The potential effects of climate change on the annual precipitation rate were evaluated. It was found that forecasted precipitation rate change of 6% due to climate change, as discussed in Section 2.4. However, for the CLS it is more conservative to not include the potential increase in precipitation due to climate change as this will have a negligible effect on the infiltration into the Landfill through the final cover system but will increase the rate of decay resulting in a shorter contaminating lifespan.

The CLS assessment should be updated regularly and include amendments to the list of parameters, where required, based on the actual parameters within the Landfill leachate. The CLS assessment updates should form part of the updates to the Design, Operation, and Closure Plan, as required by the Landfill Criteria.

12.1 First Order Decay Model

Contaminant transport was simulated utilizing the 1DTRANSEN model. The leachate source concentration in the one-dimensional transport model is governed by the time function.

$$C_0 = \begin{cases} (t/t_1)C_B + C_A & 0 < t < t_1 \\ C_B & t_1 \le t < t_2 \\ C_B e^{-\mu t} & t \ge t_2 \end{cases}$$

For the purpose of this assessment the time period where t is greater than or equal to t_2, was used representing Landfill closure. When the simulation time is greater than t_2, the source concentration is assumed to decay exponentially at a rate of μ, the first order decay constant. The initial concentration, C_B, was estimated for each contaminant of concern (COC), based on data from existing C&D landfills that accept a similar waste stream as the Landfill.

12.1.1 Constituents of Concern

Based on the nature of waste normally found in C&D, land clearing, and contaminated soil landfills the quality of leachate is generally much weaker in comparison to leachate from municipal landfills and also tends to have a lower organic content. The landfill leachate strength at any given time depends primarily on waste composition. Concentrations of the leachate constituents of concern were estimated based on data from existing similar landfills. The data was compiled from several similar landfills and utilized the maximum concentrations forecasted for the Landfill.

The forecasted constituents of concern concentrations in leachate are provided in Table 9.1.

12.1.2 Results

The CLS as estimated by the First Order Decay method, in years for the constituents of concern identified for the Site are as shown in the table below. The supporting calculations are provided in Appendix E.

Parameter	Years to Meet CSR DW Criteria
Chloride	28.0
Sulphate	9.0

12.2 Rowe Model

12.2.1 Model Based On Rowe (1995, 2004)

Rowe (1991) examined the issue of leachate strength decrease for conservative contaminant species (e.g., chloride) where the decrease in strength is essentially due to dilution (i.e., no biological breakdown or precipitation) as water infiltrated through the waste with time. Assuming that the decrease is due to dilution, the variation in concentration at any time t is given by:

$$C_{(t)} = C_0^{-q_0 t / H_r}$$

Where:

$$H_r = \frac{M_a}{A_0 * C_0}$$

Source: Rowe, 1994

$$M_a = H_w * \rho_{dw} * P$$

Where:

M_a	=	mass of contaminant per unit area (kg)
H_r	=	reference height of leachate (kg)
A_o	=	area (m^2)
H_w	=	maximum waste thickness (m)
ρ_{dw}	=	dry density of waste (kg/m^3)
p	=	proportion of the total mass of waste that is contributed by chloride
C_o	=	peak or average chloride concentration (mg/L)
q_o	=	average rate of infiltration (m/yr)
$C_{(t)}$	=	target concentration [i.e., ODWS] (kg/m^3)
T	=	time required (yr)

This model was used to validate the results of the First Order Decay Model. Note that this model was utilized for two scenarios, as follows:

- Scenario 1: maximum chloride concentration, average proportion of chloride in waste
- Scenario 2: maximum chloride concentration, maximum proportion of chloride in waste

Scenario 2 represents the worst case conditions.

12.2.2 Site Parameters

Concentrations of Leachate Constituents of Concern

As described in Section 12.1.1.

Dry Density of Waste

The estimated dry density of waste, based on expected waste stream, is 1,300 kg/m^3.

Volume of Waste

The total volume of waste is 506,000 m^3 within an area of 36,000 m^2.

Chloride Percentage in Waste

The mass of contaminant can be characterized in terms of the mass of waste and proportion of that mass which is the chemical of interest. Rowe (1995) reports that the data on the mass of contaminants in waste are relatively sparse and published data of chloride representative of municipal waste are in the range of 0.07 percent and 0.21 percent of the in-situ mass of refuse. Laner et al. (2011) reported a range of 0.003 to 0.09 percent of chloride in the dry mass of waste. Fellner et al. (2009) reported that chloride in the dry mass of waste is 0.05 percent.

As noted above, based on the nature of waste normally found in C&D, land clearing, and contaminated soil landfills, the chloride concentration in waste are generally less than in municipal solid waste landfills. An investigation at another landfill included advancement of three boreholes into waste to characterize the chloride contribution. Chloride was found to be 0.064 percent, 0.042 percent, and 0.014 percent of the total waste in the three boreholes (Genivar, 2012a). The average measured chloride in the waste is 0.04 percent. This parameter is of paramount importance since it determines the mass of chloride present in the landfill, which has to be carried out by the infiltration water.

Target Concentration

The target concentration is defined by the CSR standards required to achieve compliance in the groundwater. The Drinking Water standard is 250 mg/L. For the purpose of the CLS assessment, a resulting concentration above this threshold would be defined as an "unacceptable impact" at the Site boundary.

12.2.3 Results

The CLS for chloride was evaluated using the Rowe Model to confirm the result of the First Order Decay Method for estimated CLS. The estimated CLS, in years, for each scenario modelled is presented in the table below. The supporting calculations are provided in Appendix E.

Scenario	Years to Meet CSR DW Criteria
Maximum chloride concentration, average proportion of chloride in waste	26
Maximum chloride concentration, maximum proportion of chloride in waste	27

12.3 Summary

The CLS of the Landfill was estimated using the First Order Decay Method to determine the time period required after the closure of the Landfill for the concentration of select leachate constituents to reach the compliance criteria. The governing leachate constituent was determined to be chloride as it had the longest CLS of the modelled parameters. The First Order Decay Method determined that the time period for chloride to decay to meet the CSR DW standards was 28 years. The Rowe Model was used to verify the CLS of chloride from the Landfill. The result of the Rowe Model was a

CLS of 26 to 27 years, which confirms the results of the First Order Decay Method. Based on these results, the CLS of the Landfill is 28 years.

13. Groundwater and Surface Water Impact Assessment

In order to estimate groundwater quality at the downgradient Site boundary, a generalized water balance and mass balance approach has been used. The following sections provide discussion of the calculations and assumptions used to assess future groundwater quality compliance at the Site as well as the predicted groundwater quality under 'worst-case' conditions.

13.1 Water Balance

A generalized water balance has been developed for the Site to quantify and characterize the basic hydrogeologic functioning in the vicinity of the Landfill. The water balance considers the primary inputs, and movement of water within and across the Site using both empirically derived data and theoretical calculations where data is unavailable (e.g., leachate leakage from the Landfill). These inputs are then used in combination with forecasted contaminant mass inputs to derive the predicted future groundwater concentrations at the downgradient Site boundary.

The inputs to the water balance are as follows:

- Groundwater flow into the Landfill area, below the liner, from upgradient sources
- Precipitation over the Landfill area that results in:
  - Leachate generation, which, in turn, results in:
    - Leakage into the underlying aquifer
    - Leachate that is collected for treatment
  - Runoff infiltrating into overburden soils
- Infiltration of the treated leachate effluent
- Infiltration of precipitation falling downgradient of the Landfill footprint and effluent infiltration pond

As discussed in Section 2.4, the forecasted rate of change for annual precipitation was found to be an increase of 6% due to climate change. However, for the impact assessment it is more conservative to not include this potential increase in precipitation as this will have a negligible effect on the rate of leakage through the liner system but will increase the rate of dilution downstream of the Landfill due to increased infiltration.

13.1.1 Groundwater Flow Beneath Landfill

Groundwater flow beneath the Landfill footprint was estimated using aquifer properties as measured using the on-Site monitoring well network. The groundwater flow direction and gradient were calculated using the most recent and comprehensive groundwater monitoring data from April 2017. The April 2017 groundwater elevations and stratigraphic details from the Pit area monitoring wells were used to determine aquifer characteristics (MW1-14, MW2-14, MW2A-15, MW3-14, MW4A/B-15, MW8-17, and MW9-17). The locations of the monitoring wells are discussed in Section 14.

The pre-landfilling concentrations were calculated using the average concentration of each sample collected from the overburden, sand and gravel aquifer between 2015 and 2017, as discussed in the HHCR. For the purposes of predicting the mass inputs, a concentration of 0 mg/L has been used where a parameter concentration was not reported above the detection limit.

Groundwater flow beneath the Landfill is directed to the southeast. To determine the cross-sectional area through which groundwater flow occurs beneath the Landfill perpendicular to the direction of groundwater flow, the northeast to southwest diagonal of the Landfill footprint, approximately 250 m in length, is multiplied by the expected mixing zone depth within the saturated thickness of the sand and gravel aquifer beneath the Landfill.

Infiltrating leachate through the Landfill base will mix with groundwater over a mixing zone within the saturated portion of the sand and gravel aquifer. The leachate must firstly travel through the unsaturated zone ranging in thickness of approximately 1 to 12 m below the proposed Landfill liner (in the northwest and southeast corners of the Landfill respectively). Based on the infiltration rate into the unsaturated zone, it is estimated that it will take over several decades for leachate to reach the saturated portion of the sand and gravel aquifer.

The maximum depth of the mixing zone can be estimated following the United States Environmental Protection Agency's (USEPA's) Soil Screening Guidance: User's Guide (USEPA, 1996; Equation 12), as follows:

$$d = \sqrt{0.0112 \times L^2} + d_a \times \left(1 - e^{\frac{-LI}{Kid_a}}\right)$$

Where:

d	=	zone depth (m)
L	=	length parallel to groundwater flow (250 m based on the northwest to southeast diagonal of the Landfill footprint parallel to the southeastern groundwater flow direction)
d_a	=	saturated thickness of groundwater-bearing unit (5.46 m based on historical average saturated thicknesses measured at monitoring well MW3-14 beneath the Landfill)
I	=	infiltration rate through the Landfill (1.6×10^{-8} m/day based on the 'worst-case' leakage through the Landfill under a daily cover condition described in Section 13.1.2)
K	=	hydraulic conductivity (2×10^{-2} cm/s)[1]

[1] The results from the single well response tests completed on September 18, 2015 for the sand and gravel aquifer were used to estimate the overburden aquifer hydraulic conductivity (i.e., 2.0×10^{-2} cm/sec).

i = horizontal hydraulic gradient in the direction of groundwater flow (0.03 m/m based on the change in groundwater elevations across the Site measured in April 2017)

The calculated mixing zone depth based on the parameters provided above is 26.5 m. This theoretical mixing zone depth would extend into the shallow fractured bedrock beneath the sand and gravel aquifer; however, groundwater elevation measurements at MW4A/B-15 have consistently shown upward vertical hydraulic gradients ranging from 0.04 to 0.06 m/m. Groundwater in the sand and gravel aquifer cannot flow against the upward vertical hydraulic gradients from the shallow bedrock. Thus, flow is consistently directed upwards from the shallow fractured bedrock into the sand and gravel aquifer and not vice-versa. Thus, the mixing zone for potential infiltrating leachate is limited to the saturated portions of the sand and gravel aquifer. The average saturated thickness measured at MW3-14 beneath the proposed Landfill is 5.46 m, and the mixing zone depth is specified as this value. This is considered very conservative as the thickness of the saturated portion of the sand and gravel aquifer quickly increases in a downgradient direction and is over 40 m thick at the downgradient Site boundary (MW10-17).

The groundwater flow passing through the cross-sectional area can be calculated using Darcy's Law and is expressed with the following equation:

$$Q = KiA$$

Where:

Q = groundwater flow rate passing through the cross-sectional area

A = cross-sectional area through which groundwater is flowing

The cross-sectional area for groundwater flow is calculated as follows:

$$A = L_x \times d$$

Where:

L_x = source length perpendicular to groundwater flow (250 m based on the northeast to southwest diagonal of the Landfill footprint perpendicular to the direction of groundwater flow)

The calculated cross-sectional area for groundwater flux is 365 m^2. The corresponding groundwater flow rate is 706 m^3/day (i.e., 258,000 m^3/yr). This groundwater flow rate corresponds to a groundwater velocity of 1.7 m/day. Using the flow direction measured in April 2017, a travel time of 165 days is estimated for groundwater to travel from the treated infiltration pond to the Site boundary located approximately 270 m downgradient.

13.1.2 Potential Leachate Leakage

Leachate generation rates were estimated using the Hydrologic Evaluation Landfill Performance (HELP) model, as discussed in Section 9. Three separate HELP models were created to simulate differing stages of Landfill development. As a conservative estimate, the Landfill development stage with the highest leachate generation rates (Stage 1C) has been used for the purposes of assessing downgradient water quality. An additional HELP model was conducted to determine the maximum potential leachate leakage through the Landfill base liner. The maximum potential leachate leakage occurs during minimum runoff and at maximum leachate generation rates. Applying the results from this 'worst-case' scenario provides the most conservative estimate of the potential impacts to groundwater quality (i.e. the maximum contaminant mass loading with the least un-impacted runoff entering the groundwater mixing zone).

The following HELP model results were used in estimating the annual leachate leakage and un-impacted runoff rates. These rates were estimated using daily, intermediate, and final cover conditions:

- Total precipitation – 1,489 millimetres per year (mm/yr) (0.004 m/day)
- Runoff
    - Daily Cover – 64 mm/yr (1.7×10^{-4} m/day) (collected by the perimeter berm and treated as leachate)
    - Intermediate Cover – 64 mm/yr (1.8×10^{-4} m/day)
    - Final Cover – 19 mm/yr (5.2×10^{-5} m/day) (direct runoff) and 1,057 mm/yr (0.003 m/day) (runoff from the sand drainage layer)
- Leachate Generation
    - Daily Cover – 1,138 mm/yr (0.003 m/day)
    - Intermediate Cover – 1,052 mm/yr (0.003 m/day)
    - Final Cover – 17 mm/yr (4.7×10^{-5} m/day)
- Leakage Through the Landfill
    - Daily Cover – 0.00581 mm/yr (1.6×10^{-8} m/day)
    - Intermediate Cover – 0.00534 mm/yr (1.5×10^{-8} m/day)
    - Final Cover – 0.00011 mm/yr (3×10^{-10} m/day)

In the 'worst-case' Landfill development scenario, Stage 1C, the approximate area that will be completed with daily, intermediate, and final cover will be 15,466 m^2, 5,744 m^2, and 0 m^2, respectively.

By multiplying the generation rates provided through HELP modeling by the anticipated area of the respective development type (daily, intermediate, or final), volumetric generation rates can be calculated for leachate generation, runoff, and leakage through the Landfill.

The total maximum volume of leachate generation is estimated to be 24,633 m^3/year (67 m^3/day). Of the total maximum annual leachate generated 0.121 m^3/year (0.00033 m^3/day) may potentially leak through the Landfill base and enter the mixing zone beneath the Landfill footprint. This leakage rate conservatively assumes no clogging of the pore space within the individual liner system materials will occur. The leachate collection system will intercept the vast majority of leachate for treatment. Treated leachate then will be discharged to an infiltration pond.

Of the total precipitation predicted to fall on the Landfill footprint, approximately 3.5 m^3/day will runoff of the Landfill during Stage 1C development as clean storm water. This runoff will be conveyed via drainage ditches to the northeastern and northwestern corners of the Landfill footprint where it will infiltrate through the floor of the Pit and ultimately enter the mixing zone in the sand and gravel overburden aquifer.

13.1.3 Infiltration from Treated Effluent

Based on the anticipated maximum leachate generation rates, it is expected that the maximum annual average daily leachate collection and treatment rate resulting from 1,489 mm of precipitation per year will be approximately 67 m^3/day. As discussed earlier this which occurs during Stage 1C which will be active for less than 3 years under the modelled Landfill fill rate of 32,890 m^3/year. This treated leachate infiltration rate represents a long-term estimate of leachate that will be removed from the Landfill and treated on a daily basis based on the ‘worst-case’ development scenario described above.

13.1.4 Downgradient Precipitation

Precipitation that falls downgradient of the Landfill footprint and infiltration pond will provide an additional source of un-impacted water entering the mixing zone within the upper 4.46 m of saturated shallow, sand and gravel, overburden aquifer.

Using the precipitation data from the Campbell River Airport Station (summarized in Table 2.1) precipitation near the Site falls annually at an average rate of 1,489 mm annually. The downgradient area between the Landfill footprint and the southern Site boundary is approximately 78,400 m^2.

In order to estimate the percentage of precipitation that will infiltrate into the mixing zone, an additional HELP model was created to simulate the undeveloped portion of the Site. This HELP model, included in Appendix F, shows that downgradient of the Landfill footprint, approximately 24 mm will result in runoff, 370 mm will be removed from the water balance through evapotranspiration, 24 mm will be stored in in the soil, and the remaining 1,068 mm, or 71.9%, will infiltrate directly into the shallow overburden.

Thus, at a conservative infiltration rate of 71.9%, an additional 229 m^3/day will enter the mixing zone.

13.2 Contaminant Mass Balance

To assess the future potential groundwater quality and identify any potential compliance issues at the Site boundary, future contaminant concentrations need to be calculated to compare against applicable regulatory standards (BC CSR DW). In order to predict future groundwater contaminant concentrations, a generalized mass balance approach has been utilized to estimate the contaminant inputs across the Site. Combining the water balance components calculated above with pre-landfilling groundwater quality, forecasted leachate characteristics, and treated leachate effluent characteristics, the total mass of key landfill contaminants can be estimated at various stages of groundwater flow across the Site. These contaminant mass inputs can then be divided over the total water inputs to derive future groundwater concentrations at the downgradient Site boundary. The Interstate Technology & Regulatory Council provides guidance for using mass discharge to evaluate contaminant mass balance (ITRC, 2010), and the contaminant mass balance approach presented below follows this guidance.

Pre-landfilling groundwater quality was determined using the average concentrations from groundwater samples collected from each of the sand and gravel overburden monitoring wells during September and October, 2015. Multiplying the average concentrations by the existing groundwater flux provides a mass of each parameter. For example:

$$M_d^{UP} = \bar{C} \times Q \times \frac{1{,}000\ L}{m^3}$$

Where:

M_d^{UP} = Chloride mass discharge from upgradient locations (mg/day)

$\bar{C}$ = Average 2015 measured contaminant concentration (mg/L)

Similarly, the mass discharges resulting from surface water runoff from the Landfill footprint (i.e., M_d^{R-O}) precipitation infiltration downgradient of the Landfill footprint (i.e., M_d^{DG-I}) are calculated as follows:

$$M_d^{R-O} = \bar{C} \times Q_{R-O} \times \frac{1{,}000\ L}{m^3}$$

and

$$M_d^{DG-I} = \bar{C} \times Q_{DG-I} \times \frac{1{,}000\ L}{m^3}$$

Where:

M_d^{R-O} = Chloride mass discharge from Landfill run-off (mg/day)

M_d^{DG-I} = Chloride mass discharge from downgradient precipitation infiltration (mg/day)

Q_{R-O} = Total run-off vertical flow rate from Landfill footprint (m^3/day)

Q_{DG-I} = Infiltration vertical flow rate over downgradient locations (m^3/day)

Using the forecasted leachate profile, discussed in Section 9, and the leakage rates calculated with the HELP model, forecasted effluent characteristics, and maximum daily flow into the infiltration pond of 67 m^3/day total contaminant mass loading can be calculated for the leachate and treated effluent inputs into the mixing zone. The treated effluent concentration used as inputs were the CSR Schedule 6 DW standards as a conservative input to this assessment.

Table 13.1 provides a summary of the calculated contaminant mass for each input as well as the pre-landfilling groundwater quality, anticipated leachate concentrations, and forecasted treated leachate effluent concentrations.

13.3 Compliance Assessment

Adding the mass discharge from each of the groundwater flow inputs (existing groundwater, surface water runoff, leachate, treated leachate effluent, and downgradient precipitation) and dividing by the total volume (i.e., the sum of each input in the water balance) provides an estimate of the final concentration of each parameter. For example:

$$C_{PRED} = \frac{M_d^{UP} + M_d^{R-O} + M_d^{DG-I} + M_d^{LL} + M_d^{EFF}}{Q + Q_{R-O} + Q_{DG-I} + Q_{LL} + Q_{EFF}} \times \frac{1\ m^3}{1{,}000\ L}$$

Where:

C_{PRED}	=	Predicted contaminant concentration in groundwater at the downgradient property boundary (mg/L)
M_d^{LL}	=	Contaminant mass discharge from leachate[1] (mg/day)
M_d^{EFF}	=	Contaminant mass discharge from treated leachate effluent[2] (mg/day)
Q_{LL}	=	Landfill leachate vertical flow rate (m^3/day)
Q_{EFF}	=	Landfill leachate treated effluent vertical flow rate (m^3/day)

Table 13.1 provides a summary of the forecasted final contaminant concentrations at the downgradient Site boundary.

As shown in Table 13.1 the predicted concentration of each of the contaminant parameters is below the compliance criteria (CSR Schedule 6 DW).

13.4 Confirmatory Comparison

The water balance method, discussed above was used to confirm that groundwater containing parameters with concentrations above the CSR Schedule 6 Fresh Water Aquatic Life (FWAL) will not migrate beyond 500 m from the property boundary. To complete this comparison, the downgradient infiltration area, discussed in Section 13.1.4, was extended to include the area on-Site and 500 m from the Site boundary. Table 13.1 compares the forecasted groundwater quality 500 m downgradient from the property boundary to the CSR Schedule FWAL standards. As shown in Table 13.1 the predicted concentrations of each of the parameters is below the CSR Schedule FWAL standard.

14. Environmental Monitoring Program

The EMP for the Site has been developed to monitor the performance of the Landfill design within its environmental setting. The EMP will ensure performance and compliance criteria are met

1 The mass discharge from landfill leachate was estimated based on the forecasted leachate concentrations and the leachate vertical flux rate.

2 The mass discharge from treated leachate effluent was estimated based on the forecasted leachate effluent quality and the effluent vertical flux rate.

throughout the lifespan of the Landfill through to post-closure. The EMP has been developed in accordance with the following documents:

- Guidelines for Environmental Monitoring at Municipal Solid Waste Landfills
- Landfill Criteria

The EMP includes leachate, groundwater, surface water, soil gas, geotechnical, and refuse/soil volume monitoring. The EMP includes a quality assurance/quality control (QA/QC) plan to ensure representative data is collected. The EMP must be reviewed annually, and may be modified in the future if findings during routine inspections, monitoring events and any other information related to the effect of discharge on the receiving environment.

14.1 Compliance Criteria

The compliance criteria for the water quality comparison for the on-site groundwater was determined in the HHCR. The compliance criteria are the CSR Schedule 6 and 10 DW standards. These standards will form the basis of the EMP.

14.2 Leachate Monitoring

The objective of the leachate monitoring program is to provide the following data:

- Leachate Quality to confirm leachate indicator parameters, leachate treatment requirements and efficiencies, and assess the potential impacts to the receiving environment
- Leachate quantity – to assess the suitability of leachate treatment system components
- Leachate level in the Landfill – to ensure a maximum depth of 0.3 m within the Landfill to ensure geotechnical stability and minimize pore pressure over the base liner system.

Leachate monitoring will be conducted at the leachate sump located at the north end of the Landfill, and from the leachate treatment pond. Leachate samples will be collected and analyzed quarterly. The leachate will be analyzed for field parameters, general chemistry, nutrients, LEPH/HEPH, and CSR metals. Once annually, the samples collected may be analyzed for a comprehensive set of parameters to determine if additional parameters should be included in the EMP.

The sample collected from the leachate treatment pond will be used to assess the leachate treatment system performance, and determine if changes to the treatment process are required.

The leachate monitoring as part of the EMP is in addition to the requirements of the LMP, discussed in Section 9, to assess the treatment effectiveness prior to discharge of treated leachate to the infiltration pond.

14.3 Groundwater

The objective of the groundwater monitoring program is to detect at the earliest opportunity the potential for impacts to groundwater associated with landfilling activities. The groundwater monitoring will provide information regarding the extent and magnitude of potential impacts, identify the need to mitigate potential environmental risk, and ensure regulatory compliance.

The groundwater monitoring program also includes the assessment of upgradient groundwater quality for comparison to the down-gradient and cross-gradient groundwater quality.

Groundwater samples will be collected and analyzed quarterly. The groundwater samples will be analyzed for field parameters, general chemistry, nutrients, LEPH/HEPH, and CSR metals. The monitoring locations are shown on Figure 14.1. The existing monitoring wells that will be included in the EMP are shown in yellow. The well completion details are presented in Table 14.1. The proposed monitoring wells that will be included in the EMP are shown in magenta. The groundwater monitoring program will include the following monitoring wells:

- Up-gradient – MW6-17, MW9-17, MW1-14, MW4A-15, MW4B-15
- Cross-gradient – MW2-14, MW2A-16
- Immediate Downgradient – MW13-17 (proposed)
- Downgradient Compliance wells: MW-10-17, MW11-17 (proposed), MW12-17 (proposed),

The existing upgradient monitoring wells, MW7-17 and MW8-17, were installed to characterize the groundwater regime in the vicinity of the Site and are not included in the EMP. MW3-14 may be included as supplemental information in the EMP early in the Landfill lifespan, however, the monitoring well will be decommissioned to allow for the construction of the Landfill cells during Phase 2. The existing monitoring wells MW5A-15 and MW5B-15 are not included in the EMP as they are hydraulically upgradient and disconnected from the overburden, sand and gravel aquifer.

Hydraulic monitoring of groundwater levels will be conducted at each groundwater monitoring event for included in the Annual Operation and Monitoring Report discussed in Section 14.10. Pre-landfilling water levels were measured during the baseline monitoring events in September 2015, October 2015, January 2016, February 2016, and April 2017. The hydraulic monitoring results are presented in Table 14.2.

14.4 Surface Water

The objective of the surface water monitoring program is to continue to obtain supplementary information from nearby lakes to characterize background water quality. The two lakes, McIvor Lake and Rico Lake, will be included in the EMP for this purpose. Surface water samples from the Lakes will be collected annually.

There are no permanent surface water features on the Site or downgradient of the Site to include as part of the compliance monitoring.

The location of the lakes and the monitoring locations are shown on Figure 14.1.

The water level in the lakes will be recorded as part of the EMP to be included in the Annual Operations and Monitoring Report discussed in Section 14.10. The Rico lake level will be recorded using the Rico Lake gauge established, as shown on Figure 14.1. The McIvor Lake level will be obtained from the BC Hydro reservoir level records.

Additional surface water sampling location may be conducted within the surface water ditches on the east and west side of the Landfill, when water is present.

14.5 Quality Assurance/Quality Control

In order to ensure adequate quality control for water quality samples, the following quality assurance/quality control (QA/QC) measures will be used as a minimum:

- Activities performed by qualified and trained personnel
- Field QA/QC including field duplicate and field blank analysis
- Use of charge balance calculations
- Analytical testing by an accredited laboratory

14.6 LFG Monitoring

LFG monitoring is required to ensure the health and safety of the Upland staff, users of the Site and the public. The LFG monitoring will be conducted annually using subsurface soil vapour probes, consistent with the BC Landfill Gas Management Facilities Design Guidelines, Section 6 of the Guidelines for Environmental Monitoring at Municipal Solid Waste Landfills, and Sections 4.2 and 9.3 of the Landfill Criteria. The soil gas concentration limits are discussed in Section 10.8.

The proposed locations of the soil vapour probes are shown on Figure 14.1 and will include one location near the Site office, and one location at the northern property boundary along Gold River Highway.

14.7 Geotechnical

The geotechnical condition of the landfill will be monitored as part of the EMP. Monitoring staff will record the condition of the Landfill including observations of evidence of the following conditions:

- Distress (i.e., berms, cover, vegetation, ditches, etc.)
- Slope stability
- Settlement
- Potential for leachate breakout/pore pressure building up
- Erosion on side slopes, ditches, or sediment forebays (once constructed during progressive final closure)

All notable observations will be reported to Landfill Staff and included in the Annual Operations and Monitoring Report discussed in Section 14.10. If appropriate, a qualified professional will be engaged to complete a supplemental Site inspection.

14.8 Refuse/Soil Volume Monitoring

A survey of the active Landfill area will be conducted on a regular basis (i.e., every 1 to 2 years) during Landfill operations. The survey data will be used to calculate the volume of airspace consumed, an estimate of the apparent waste density obtained, and the remaining airspace available. From this data, predictions of remaining Site life will be updated and included in the Annual Operations and Monitoring Report discussed in Section 14.10.

14.9 Inspection and Record Keeping

Regular Landfill inspections will be conducted by Landfill personnel and include inspections of the following:

- Nuisance factors associated with the Landfill
- Regular housekeeping procedures such as dust, litter, and odour, are under control
- Locations of distress (i.e., berms, cover, vegetation, ditches, etc.)

The Landfill staff will maintain a checklist of housekeeping items that need to be implemented on a regular basis. Records of observations made during the Landfill inspections and all regular housekeeping activities carried out will also be maintained.

14.10 Annual Operations and Monitoring Report

An annual operations and monitoring report will be submitted to the Director by March 31 of each year. The annual report will include the following information as per Section 3.2 of the OC:

- An executive summary
- Tonnage and disposition of each type of waste received at the facilities for the year including tonnage received, sorted and processed at the material recovery facility, stored on-Site, and discharged to the selected waste Landfill
- Remaining selected waste Landfill life and capacity
- Recommendations to improve operational efficiencies, if applicable
- Leachate management including leachate quantities and qualities
- Landfill gas monitoring results
- Review of the preceding year of operation, plans for the next year and a summary of any new information or changes to the facilities and plans, programs, assessments, surveys and reports
- In the event of any non-compliance with the conditions of this operational certificate, an action plan and schedule to achieve compliance
- Updated groundwater contours and discussion of seasonal fluctuations
- Comparison of the monitoring data with the performance criteria in Section 4 of the Updated Landfill and the Guidelines for Environmental Monitoring at Municipal Solid Waste Landfills, interpretation of the monitoring data, identification and interpretation of irregularities and trends, recommendations, and any proposed changes to the monitoring program

The annual reports will be made available to the City of Campbell River staff and the Regional Districts Waste Management Board.

15. Fire Safety and Emergency Response Plan

15.1 Overview

The introduction of ambient air (i.e., oxygen) into a landfill can potentially lead to landfill fires. The prevention and control of landfill fires is an important operational consideration. While the occurrence of landfill fires is still relatively infrequent, it is critical to understand landfill fires, their prevention, and control.

Effective fire management can be achieved by understanding the causes of landfill fires as part of a preventative strategy and by understanding the means of addressing a landfill fire if one occurs.

15.2 Background

A landfill fire will only occur if the following conditions are present:

- A fuel is provided (e.g., waste and/or the methane component of LFG is a combustible fuel source)
- Oxygen is present (oxygen can be present in the voids of uncompacted waste)
- An ignition source is provided

Fires can occur for a variety of different reasons or combinations of conditions including:

- Introduction of an ignition source to the landfill
- Deposition of hot loads in the landfill
- Chemical reactions occurring within the landfill

Landfill fires can be surficial, subterranean, or both, depending on the transmission and migration pathways within the waste matrix. Surficial fires typically occur along the working surface of the landfill and are easily observable.

Subterranean fires occur under the cover of the landfill and may not be visually observable by site personnel. Subterranean fires typically start out small and in a localized area, spreading beneath the landfill cover as conditions permit. Landfill operations can also affect the spread of landfill fires, with landfill fires following preferential flow paths along waste lift lines or in areas of low waste densities (i.e., upper levels of waste, new and uncompacted waste), where the mixture of oxygen and methane is optimal as a fuel.

Signs that a subterranean fire may be occurring or has occurred include:

- High oxygen and carbon monoxide (1,000 ppm) concentrations
- High LFG temperatures (> 60 degrees Celsius indicates aerobic conditions; > 75 degrees Celsius indicates that combustion is likely occurring at some location within the waste)
- Accelerated landfill settlement in localized areas
- Impacted infrastructure (e.g., melted piping)

- Smoke, odour, or residue

A landfill fire can be confirmed through monitoring for incomplete combustion compounds (e.g., carbon monoxide) using field-monitoring equipment or for more accurate results, laboratory analysis. Field samples collected from installed LFG probes for laboratory analysis should be collected in tedlar bags or in evacuated canisters.

15.3 Implications of Landfill Fires

Implications of a landfill fire include:

- Risks to health and safety which include release of toxic gases, site hazards, sink holes on the landfill surface, and equipment interaction
- Impacts to the surrounding environment including surface water impacts, leachate generation, and air emissions
- Damage to site infrastructure including landfill liner damage and leachate collection system impacts
- Potential damage to equipment

Landfill fires pose a health and safety risk to humans due to the unsafe conditions that the fires create. The burning waste can emit toxic gases. Sink-holes and waste settlement may occur as a result of waste combustion, posing additional hazards to site personnel and equipment.

Landfill fires also pose a great risk to environmental conditions of the landfill and the surrounding area. As previously stated, fires can generate toxic air emissions; uncontrolled combustion of halogenated compounds often results in emission of dioxins and furans.

15.4 Fire Prevention

There are several obvious means of preventing fires at landfills, including rules and plans that prevent smoking, welding, or equipment repair on or near the Landfill. If work is absolutely necessary within the Landfill, permit requirements should be developed for performing hot work in areas of potential LFG generation.

Recognition of changing Site conditions will provide site personnel with the necessary information and time to take preventative measures. Conditions that may be observed prior to a subterranean fire include problems at the surface of the Landfill that may be indicative of high oxygen infiltration potential (e.g., poor final cover quality, final cover erosion, vegetative stress). Particular note should be made of any protrusions through the interim and/or final cover system such as vertical extraction wells, gas vents, monitoring points, etc., as these are potentially weak points in a final cover system

The above conditions should be closely monitored and a fire control strategy implemented if it is determined that a landfill fire is occurring. The following Landfill operations can be instrumental in preventing and controlling landfill fires:

- Placement of intermediate cover material
- Adequate stockpile of soil material for intermediate cover and fire control

- Availability and maintenance of appropriate equipment for fire control

It is recommended that all intermediate cover material be removed subsequent to additional waste placement to aid in maintaining the interconnectivity of waste lifts for the improved LFG collection efficiencies. Leaving intermediate cover material in place as a permanent fire control measure (i.e., fire breaks) is an incorrect approach and is not recommended.

15.5 Fire Control and Extinguishment

The methods used to control and terminate a landfill fire are dependent on several Site-specific factors including:

- The location of the landfill fire (i.e., active disposal areas, passive LFG venting areas)
- Waste composition (i.e., C&D)

A single solution for managing landfill fires does not exist. Therefore, a multifaceted approach to preventing and controlling landfill fires is necessary. The following approaches need to be considered individually or in combination to most effectively determine if there is a fire and to control and extinguish a landfill fire:

- Supplemental soil cover material to cut off the supply of oxygen to a fire, returning the waste to anaerobic conditions
- Availability of water to hydrate low permeability soil cover material
- Fire suppressant foams to assist in sealing the surface where there may be air infiltration to the waste mass
- Fire breaks and containment berms can be possible augments for very specific applications and locations, but should not be considered as primary control mechanisms
- Injection systems such as steam, carbon dioxide, or nitrogen are possible if they are necessary to cut off air supply to the fire
- Operational considerations including the use of cover material, stockpiling of soil material on Site, availability of information on historic waste placement, as-recorded drawings, and equipment availability
- Confirmatory/field investigations including thermographic imaging, intrusive investigations (i.e. boreholes), and thermistors

An operator needs to be aware of the type of landfill fire (i.e., waste or LFG). If it is a waste fire within the waste mass and not simply at the surface, it may not be possible to physically cut off the source of fuel and/or air. The operator must also be aware of the many different approaches associated with extinguishing landfill fires.

The primary mechanism for extinguishing a landfill fire is its fuel source (i.e., methane). By allowing methane concentrations to increase within the waste matrix, conditions will reach a point whereby the oxygen-methane fuel mixture will be too methane rich for combustion and the fire will no longer be self-sustaining. In short, the subterranean fire will be extinguished through an abundance of methane and a deficiency of oxygen (i.e., creating an environment that cannot support continued combustion). Creating this environment can be enhanced through the use of a low permeability cover material. The low permeability cover material will provide a layer that will minimize the venting of LFG and the intrusion of atmospheric air (i.e., oxygen). The use of low permeability cover material in combination with the application of water will be effective in helping to seal the surface and remove the air infiltration pathway that allows oxygen to feed and support the fire (i.e., to decrease the hydraulic conductivity of low permeability material).

While this type of response may be counter intuitive to typical fire management programs, more common approaches such as excavation of the landfill cover in the vicinity of a suspected fire to expose the source should never be undertaken; it merely serves to introduce additional air, and thus oxygen, into the waste, thereby potentially propagating/feeding the fire. Excavation of suspected fires also puts equipment and equipment operators at risk. The operation of heavy equipment in the vicinity of should be undertaken with care, and only to develop access to the area in question or to spread soil cover material.

15.6 Fire Safety and Emergency Contingency Plan

A Fire Safety and Emergency Contingency Plan has been developed for the Site operating in accordance with the BC Occupational Health and Safety Regulation 296/97 Part 4, S.4.13 - 4.18 (Emergency Preparedness and Response) and Part 5, s.5.97 - 5.102 (Emergency Procedures), as well as Section 2.8 of the BC Fire Code. The Fire Safety and Emergency Contingency Plan has been submitted to the appropriate fire authority(ies), the responding fire department(s), the Director, and the City.

A copy of the draft Fire Safety and Emergency Contingency Plan is provided in Appendix G. This plan will be reviewed and updated at least once annually.

All of which is Respectfully Submitted,

GHD

Shauna Sturgeon, P. Eng.

Gregory D. Ferraro, P. Eng.

16. References

Blackmun, G.J., B.V. Lukyn, W.E. McLean and D. Ewart, 1983. Quinsam Watershed Study, Canadian Manuscript Report of Fisheries and Aquatic Sciences No, 183.

British Columbia Ministry of Environment (MOE), 2016. Second Edition Landfill Criteria for Municipal Solid Waste.

British Columbia Ministry of Environment (MOE), 1996. Guidelines for Environmental Monitoring at Municipal Solid Waste Landfills.

British Columbia Ministry of Environment (MOE) and RH Guthrie, 2005. Geomorphology of Vancouver Island: Extended Legends to Nine Thematic Maps.

British Columbia Ministry of Transportation (BCMOT), 2007. Supplement to TAC (Transportation Association of Canada) Geometric Design Guide 2007 Edition

CCME, 2006. National Guidelines, CCME, National Guidelines for Hazardous Waste Landfills PN 1365

Computational Hydraulics Inc. (CHI), (n.d.). User's Guide to SWMM5, Guelph, Ontario, Canada

Computational Hydraulics Inc. (CHI), 2011. PCSWMM User's Manual, Guelph, Ontario, Canada

CRA, 2002. Hydrologic Performance Assessment – Updated Design, Edwards Landfill Site, Haldimand- Norfolk Sanitary Landfill Inc., Haldimand County, October 2002.

CRA, 2012. Chloride Concentration in the Waste Cores, E-mail, Edwards Landfill, 2012

CRA, 2012. Leachate Concentration, E-mail, Edwards Landfill, 2012

El-Fadel, M., E. Bou-Zeid, W. Chahine, and B. Alayli, 2002. Temporal variation of leachate quality from pre-sorted and baled municipal solid waste with high organic and moisture content. Waste Management.

Environment Canada, April 2005. Canada's Greenhouse Gas Inventory, 1990 - 2003, Greenhouse Gas Division, Environment Canada.

Eun, S., 2000. Hydrogen Sulphide Flux Measurements and Dispersion Modeling from Construction and Demolition (C&D) Debris Landfills. Thesis (Masters). University of Central Florida.

Fellner et al, 2009, Comparing field investigations with laboratory models to predict landfill leachate emissions, Fellner J., Döberl G., Allgaier G., Brunner P. H., Waste Management 29 (2009) 1844–1851.

Genivar, 2012.Leach quality, Brooks Road Landfill, 2012

Gibb, A., H. Kelly and T. Schueler, 1999. Best Management Practices Guide Prepared for Greater Vancouver Sewerage and Drainage District.

Golder Associates, 2014. Static Testing Results for Acid Rock Draining (ARD) and Metal Leaching (ML) Potential, Upland Contracting Pit #1, Campbell River, BC.

Government of Canada – Environment and Natural Resources, 2016, Canadian Climate Normals 1981-2010 Station Data – Campbell River A, Climate ID 1021261.

Greene, A.R., J.S. Scoates and D. Weis, 2005. Wrangellia Terrane on Vancouver Island, British Columbia: Distribution of Flood Basalts with Implications for Potential Ni-Cu-PGE Mineralization in Southwestern British Columbia.

ITRC, 2010. Use and Measurement of Mass Flux and Mass Discharge, August.

Jambeck, J., T. Townsend, H. Solo-Gabriele, 2004. Leachate Quality from Simulated Landfills Containing CCA-Treated Wood. *Environmental Impacts of Preservative-Treated Wood Conference,* February 8-11 Orlando, FL.

Laner et al, 2011, Environmental compatibility of closed landfills – assessing future pollution hazards, Laner D., Fellner J., and Brunner P. H., Waste Management & Research, 29(1) 89–98

Levelton, B.H., 1991, Inventory of Methane Emissions from Landfills in Canada, Unpublished report prepared for Environment Canada by Levelton & Associates.

Lovely, D., E. Phillips, 1987. Competitive Mechanisms for Inhibition of Sulphate Reduction and Methane Production in the Zone of Ferric Iron Reduction Sediments. *Applied and Environmental Microbiology* Vol. 53, No. 11, pp 2636-2641.

Lu, J.C.S., B. Eichenberger, B. and R.J. Stearns, 1984. Leachate Production and Management from Municipal Landfills: Summary and Assessment. U.S Environmental Protection Agency EPA-600/2-84-092, May.

Lu, J.C.S., R.D. Morrison and R.J. Stearns, 1981. Leachate Production and Management from Municipal Landfill: Summary and Assessment, Land Disposal: Municipal Solid Waste – Proceedings of the Seventh Annual Research Symposium, EPA-600/9-81, pp. 1-17, 1981

McBean, E., F. Rovers, and G. Farquhar, 1995. Solid Waste Landfill Engineering and Design. Prentice-Hall Publishing Co., New Jersey.

McCammon, J.W., 1977. Bulletin 65: Surficial Geology and Sand and Gravel Deposits of Sunshine Coast, Powell River, and Campbell River Areas. http://www.empr.gov.bc.ca/Mining/Geoscience/PublicationsCatalogue/BulletinInformation/BulletinsAfter1940/Pages/Bulletin65.aspx

Pacific Climate Impacts Consortium. "Plan2Adapt." 2013. https://www.pacificclimate.org/analysis-tools/plan2adapt (Accessed April 25, 2016)

Reinhart, D.R., 1995. The Impact of Leachate Recirculation on Municipal Solid Waste Landfill Operating Characteristics. Waste Management & Research (1996).

Reinhart, D.R.and T.G. Townsend, 1998. Landfill Bioreactor Design & Operation. Lewis Publishers, Boca Raton, FL.

Rowe, 1991. Contaminant impact assessment and the contaminating lifespan of landfills, R. Kerry Rowe*, Canadian Journal of Civil Engineering*18, 244-253.

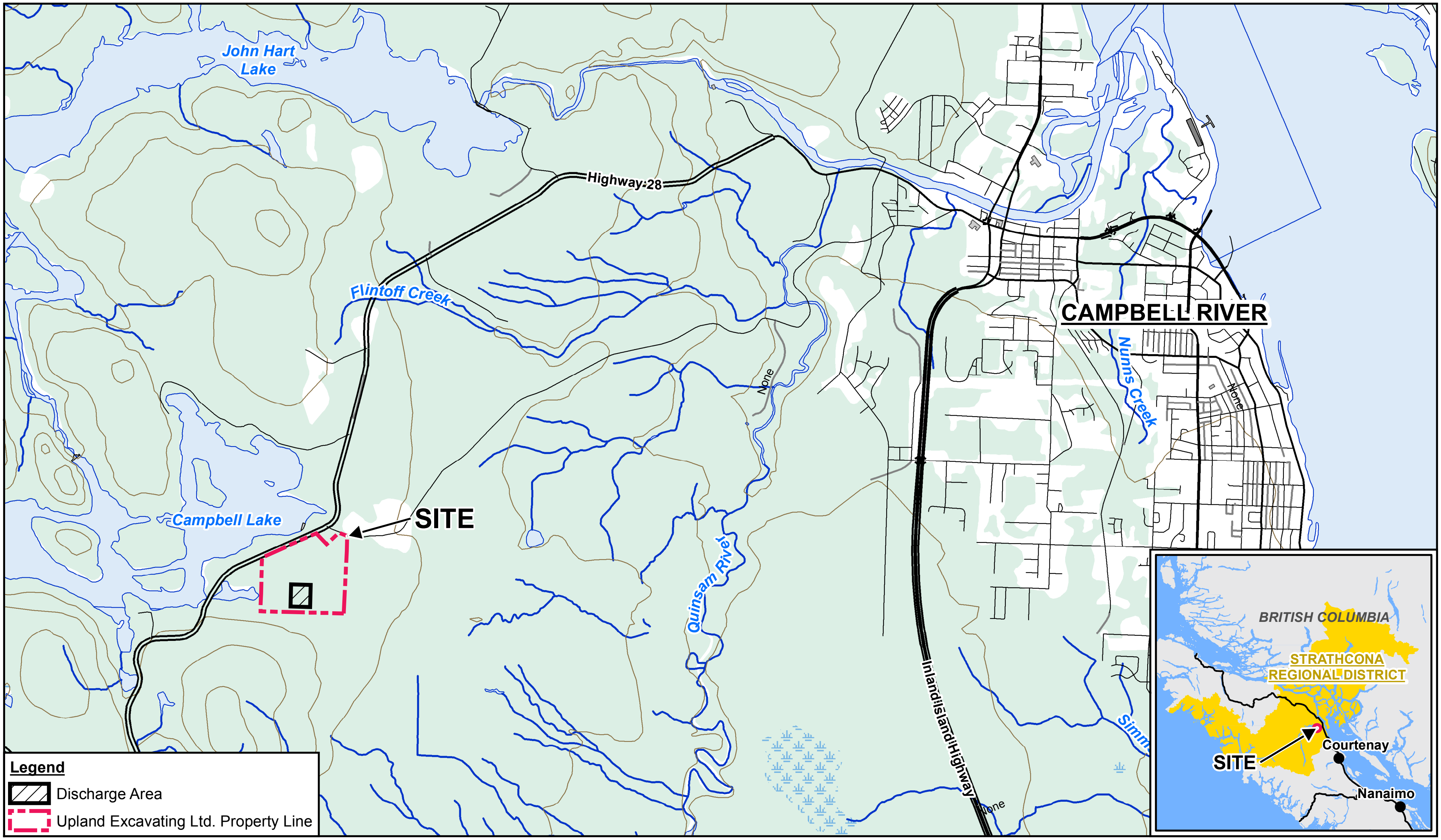
Rowe, 1995. Leachate characteristics for MSW landfills, R.K. Rowe, Geotechnical Research Centre Report, GEOT-8-95

Rowe, 2004.Comments on the Barrier System, Proposed Ashcroft Ranch Landfill, R. Kerry Rowe, 31 October 2004

Solid Waste Association of North America (SWANA), 1991. Manager of Landfill Operations Training Course. Course Manual. Publication # MSW-D 2360 GMISC 0005.

Townsend, G., Y. Jang, W. Weber, 2000. *Continued Research into the Characteristics of Leachate from Construction and Demolition Waste Landfills*. Report 00-04. Florida Center for Solid and Hazardous Waste Management, Gainesville, Florida.

USEPA, 1996. Soil Screening Guidance: User's Guide. EPA/540/R-96/018, July.



Source: CanVec Edition 1.1 © Department of Natural Resources Canada, all rights reserved. National Road Network 2.0 GeoBase. ESRI Base Data, 2008.

0 500 1,000 1,500
Meters

Coordinate System:
NAD 1983 UTM Zone 10N

N

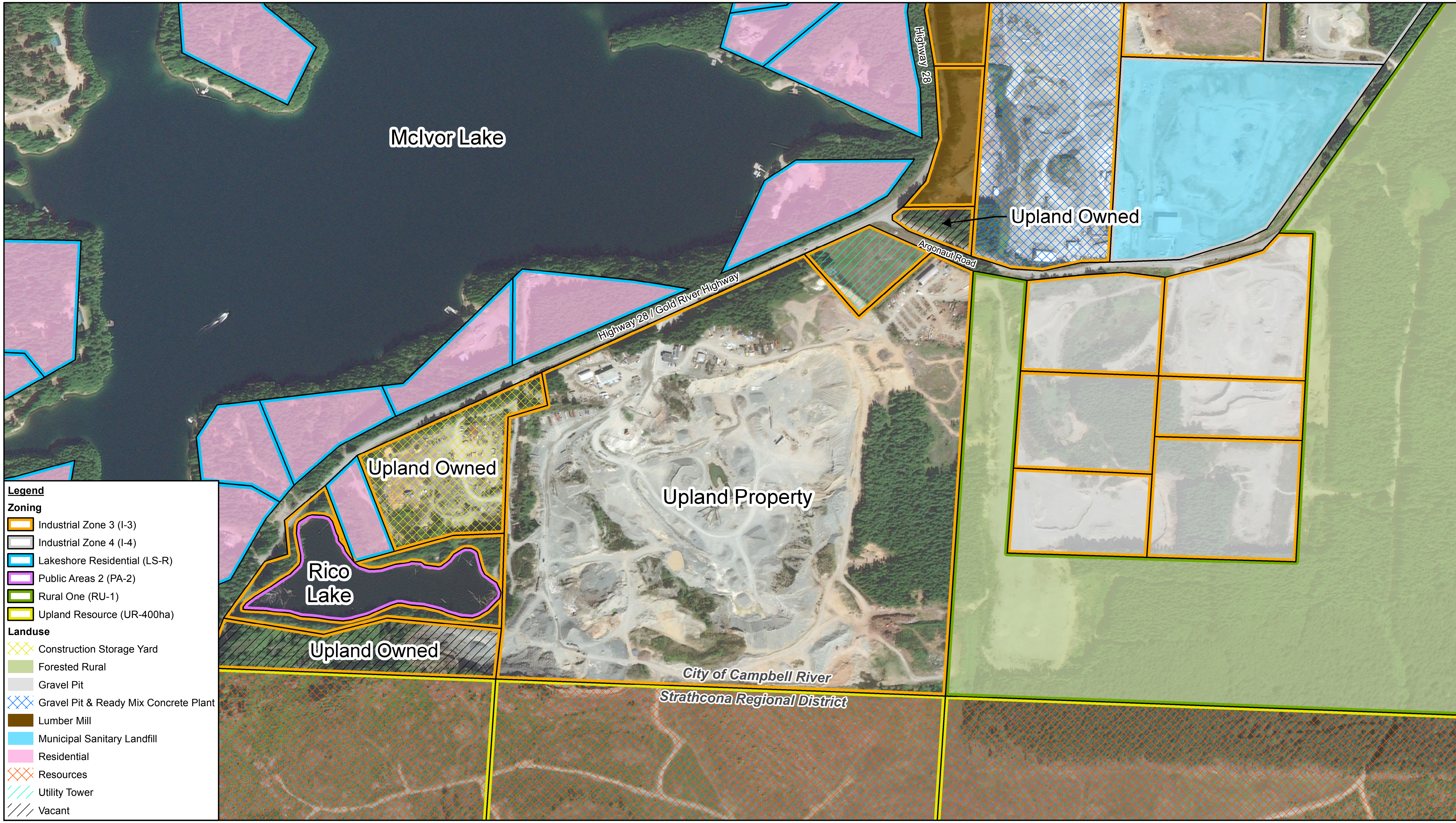
UPLAND EXCAVATING LTD.
UPLAND LANDFILL, CAMPBELL RIVER, BRITISH COLUMBIA
2017 DESIGN, OPERATIONS, AND CLOSURE PLAN

088877-03
Jun 1, 2017

SITE LOCATION MAP

FIGURE 1.1

GIS File: Q:\GIS\PROJECTS\88000s\88877\Layouts\010\88877-03(010)GIS-OT001.mxd



Sources: CanVec Edition 1.1 © Department of Natural Resources Canada, all rights reserved; National Road Network 2.0 GeoBase; Property Parcels - City of Campbel River; Microsoft product screen shot(s) reprinted with permission from Microsoft Corporation.

0 60 120 180
Meters

Coordinate System:
NAD 1983 UTM Zone 10N

N

GHD

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2017 DESIGN, OPERATIONS, AND CLOSURE PLAN

ADJACENT LAND USES AND ZONING

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May 30, 2017

FIGURE 1.2

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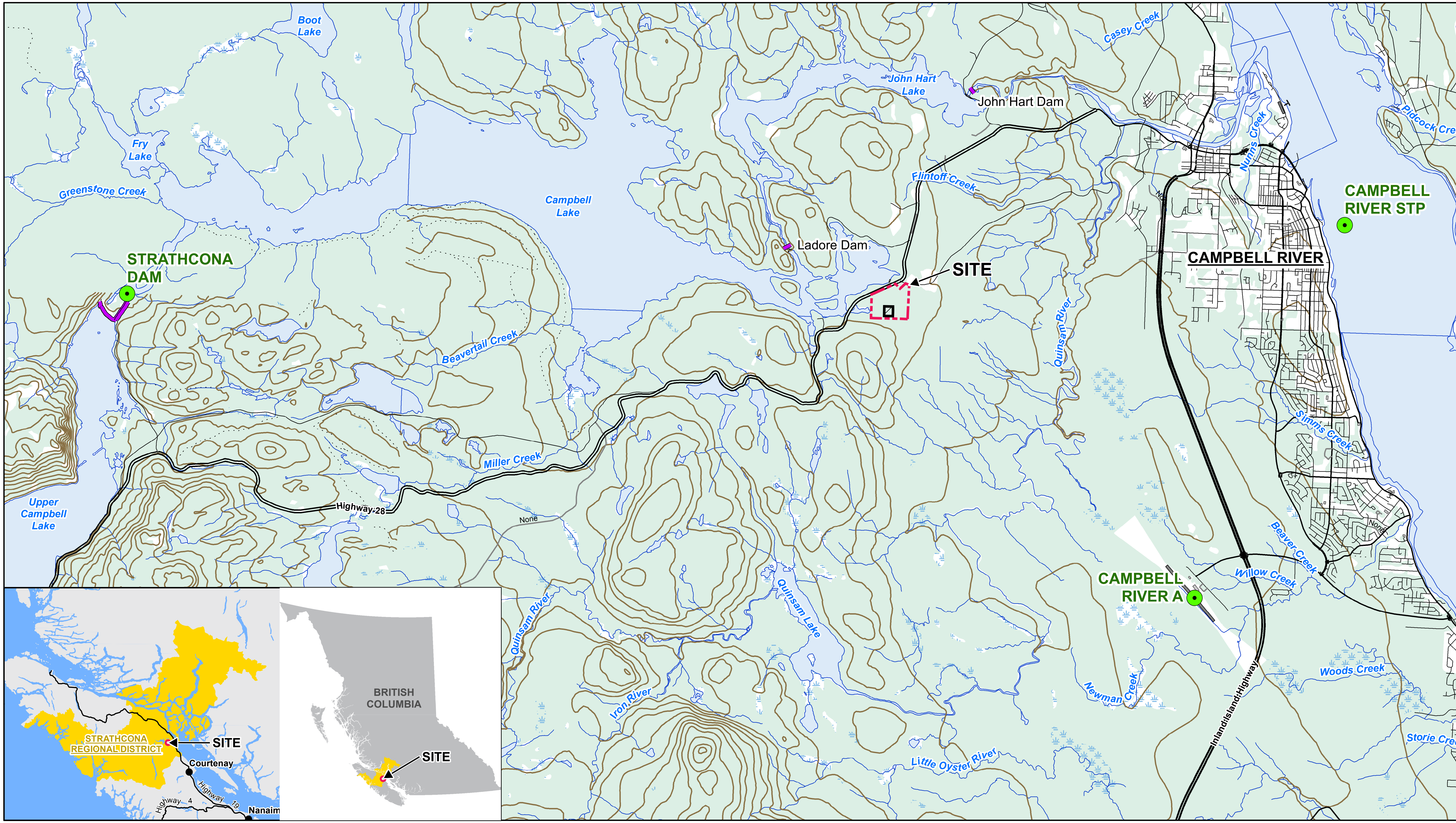

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0 750 1,500 2,250
Meters

Coordinate System:
NAD 1983 UTM Zone 10N

N

Legend

- IDF Station
- Manmade Hydrographic Entity (Dam)
- Discharge Area
- Upland Excavating Ltd. Property Line

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UPLAND LANDFILL, CAMPBELL RIVER, BRITISH COLUMBIA
2017 DESIGN, OPERATIONS, AND CLOSURE PLAN

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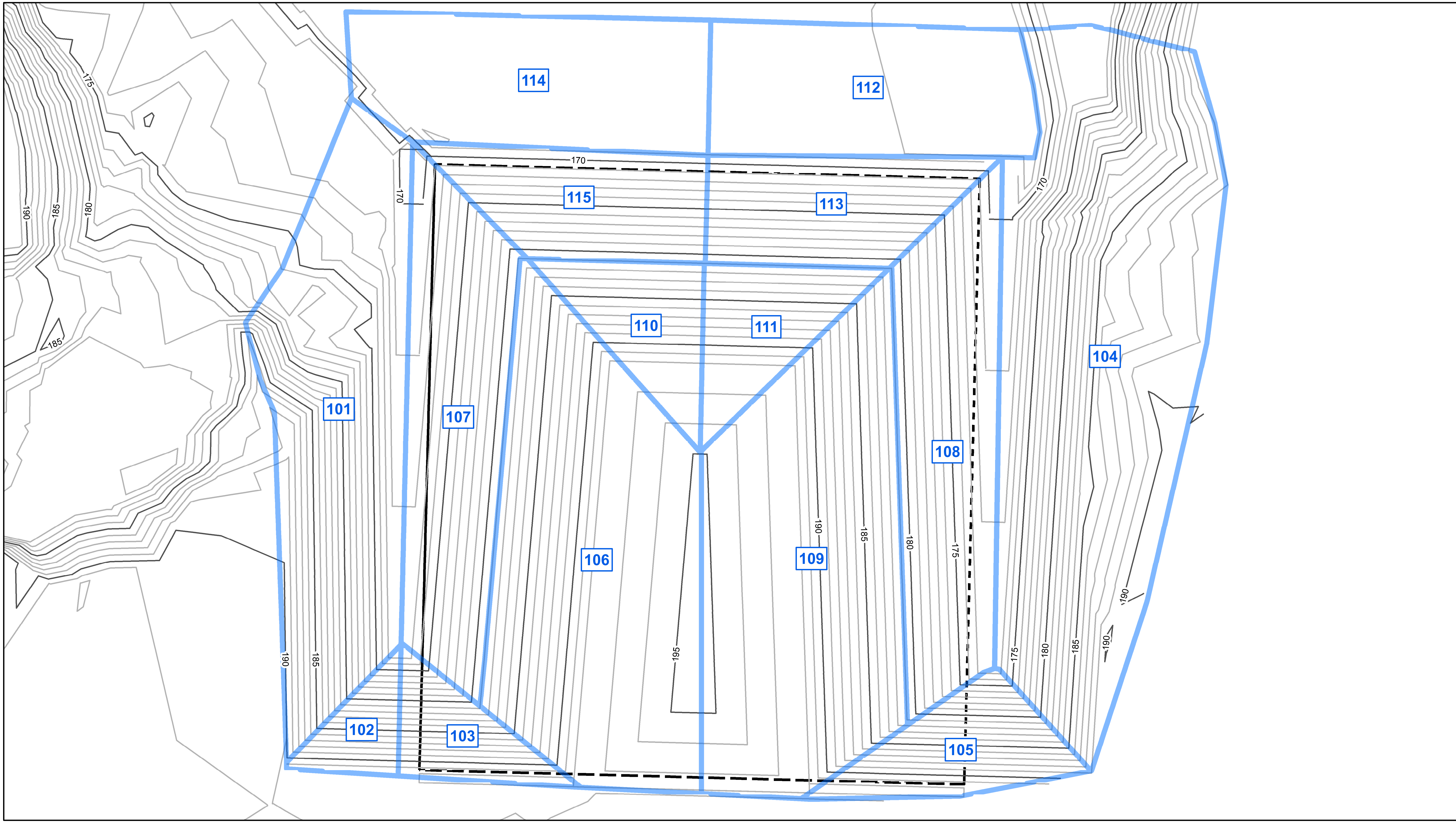
SITE LOCATION & IDF STATION LOCATIONS

FIGURE 8.1

GIS File: Q:\GIS\PROJECTS\88000s\88877\Layouts\010\88877-03(010)GIS-OT005.mxd



Source: CanVec Edition 1.1 © Department of Natural Resources Canada, all rights reserved. National Road Network 2.0 GeoBase. ESRI Base Data, 2008.

0 12 24 36
Meters

Coordinate System:
NAD 1983 UTM Zone 10N

N

Legend

- Limit of Waste
- Major Contour (5 m)
- Minor Contour (1 m)
- Subcatchment Boundary
- 100 Subcatchment Number

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2017 DESIGN, OPERATIONS, AND CLOSURE PLAN

SURFACE WATER CATCHMENT BOUNDARIES

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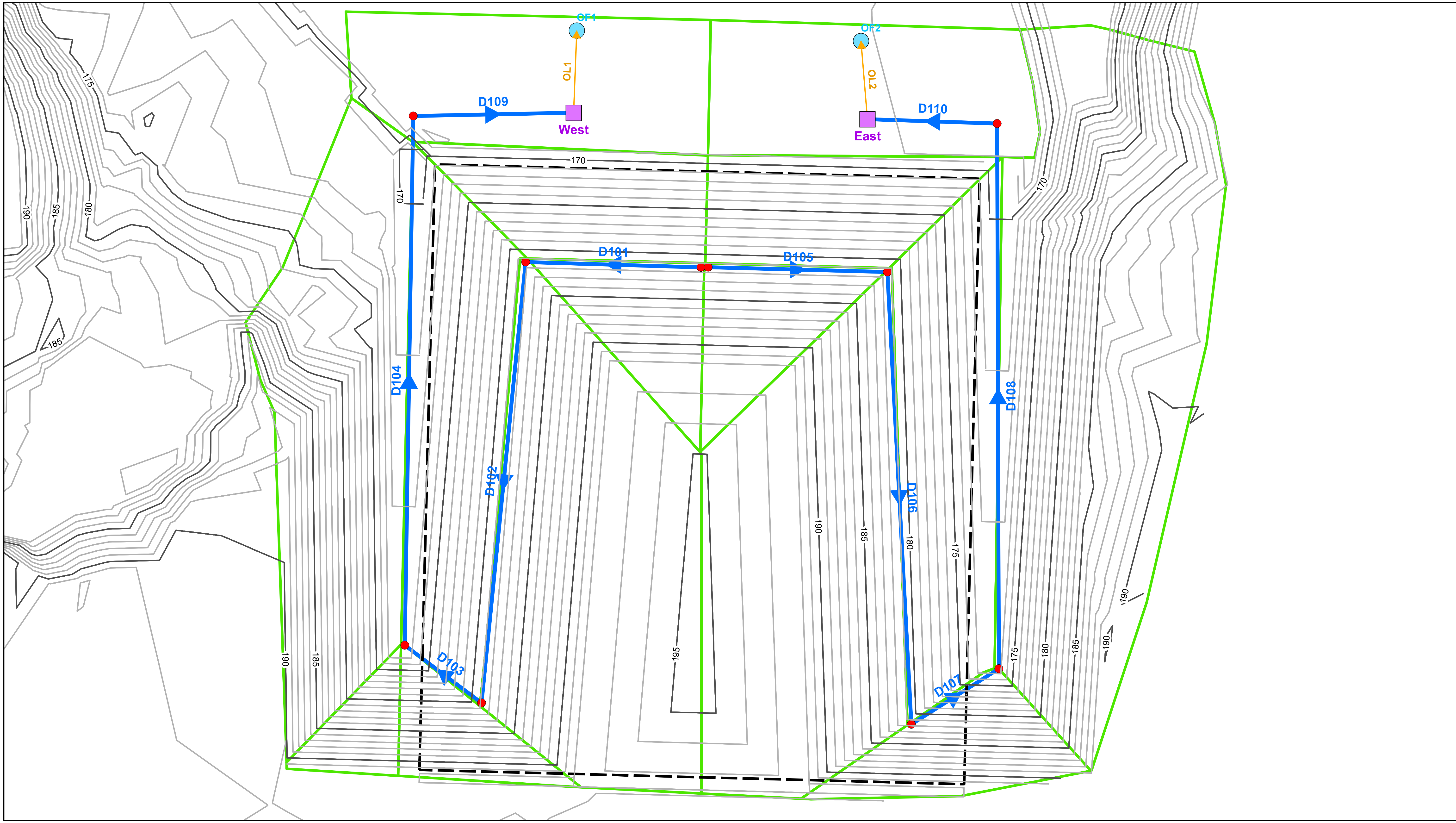
FIGURE 8.2

GIS File: Q:\GIS\PROJECTS\88000s\88877\Layouts\010\88877-03(010)GIS-OT002.mxd



0 12 24 36
Meters
Coordinate System:
NAD 1983 UTM Zone 10N

N

Legend

- Limit of Waste
- Major Contour (5 m)
- Minor Contour (1 m)
- Conduits
- Outlets
- Sediment Forebay
- Junctions
- Infiltration Area

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2017 DESIGN, OPERATIONS, AND CLOSURE PLAN

SURFACE WATER FLOW SCHEMATIC

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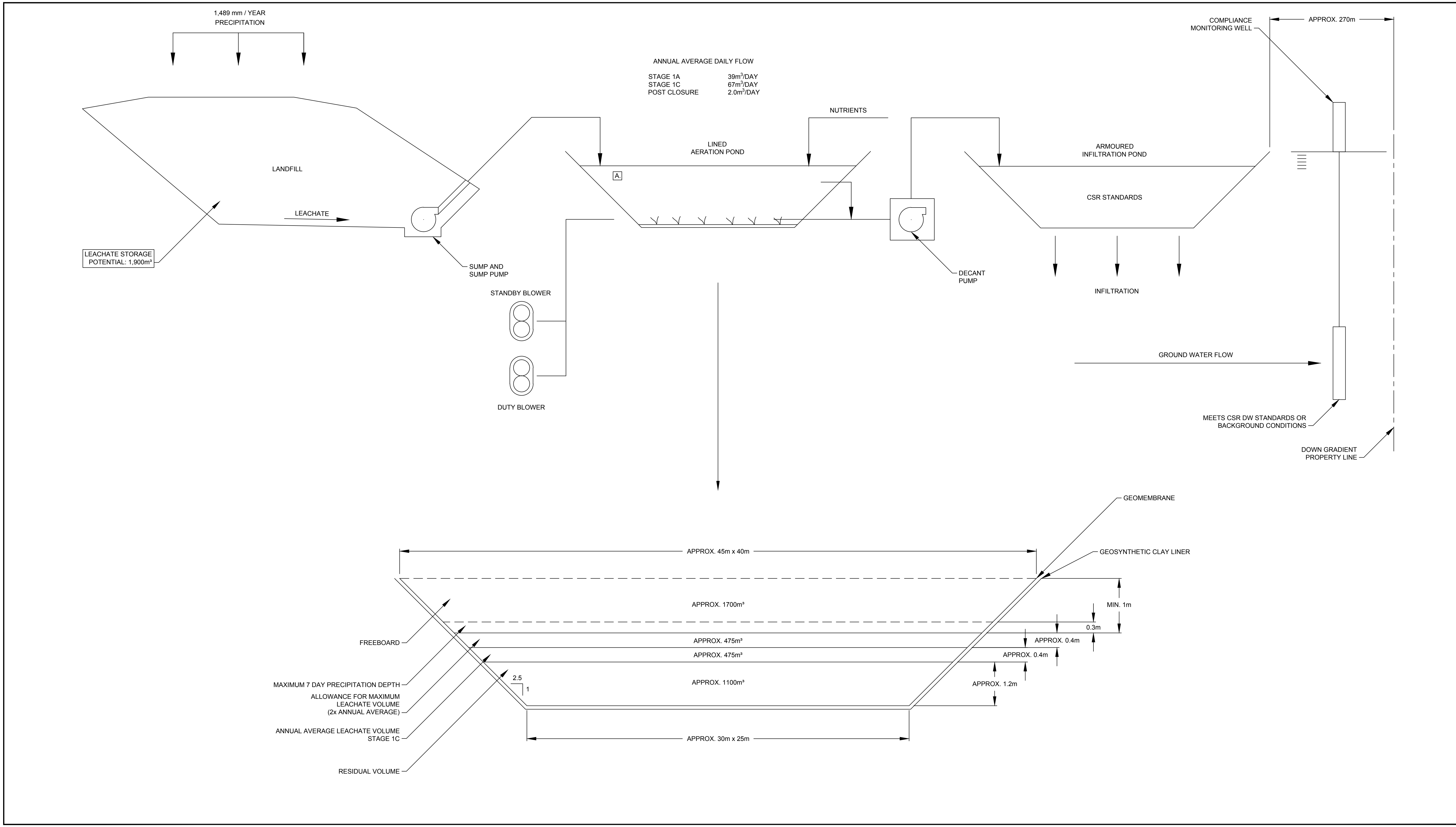
FIGURE 8.3

GIS File: Q:\GIS\PROJECTS\88000s\88877\Layouts\010\88877-03(010)GIS-OT003.mxd



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PROPOSED UPLAND LANDFILL
2017 DESIGN, OPERATIONS AND CLOSURE PLAN

LEACHATE TREATMENT FLOW SCHEMATIC
CONCEPTUAL LEACHATE TREATMENT FACILITY

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May 30, 2017

FIGURE 9.1

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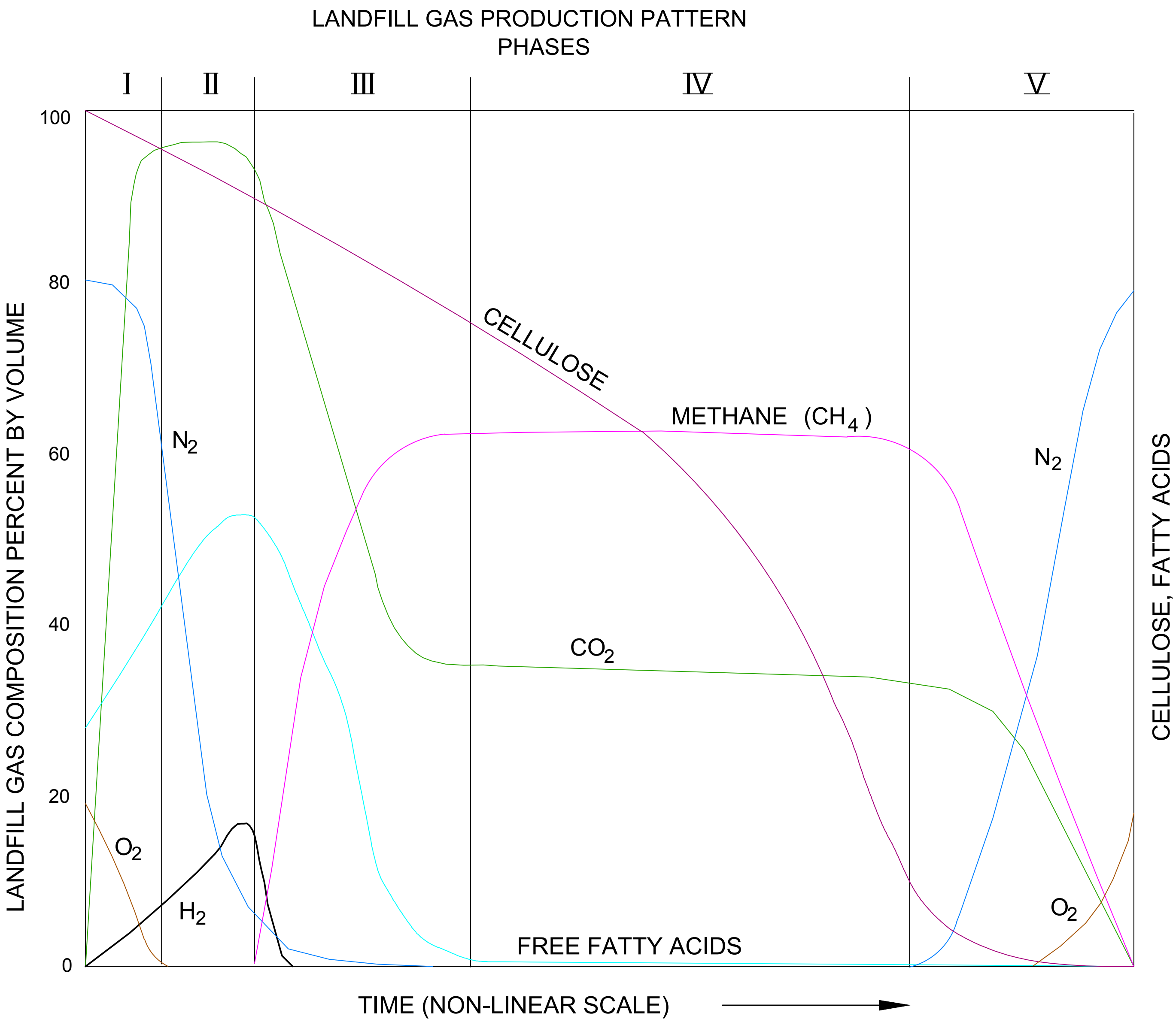


PHASES	CONDITION	TIME FRAME - TYPICAL
I	AEROBIC	HOURS TO 1 WEEK
II	ANOXIC	1 TO 6 MONTHS
III	ANAEROBIC, METHANOGENIC, UNSTEADY	3 MONTHS TO 3 YEARS
IV	ANAEROBIC, METHANOGENIC, STEADY	8 TO 40 YEARS
V	ANAEROBIC, METHANOGENIC, DECLINING	1 TO 40+ YEARS
TOTAL		10 TO 80+ YEARS

SOURCE:

FARQUHAR AND ROVERS, 1973,
AS MODIFIED BY REES, 1980,
AND AUGENSTEIN & PACEY, 1991.

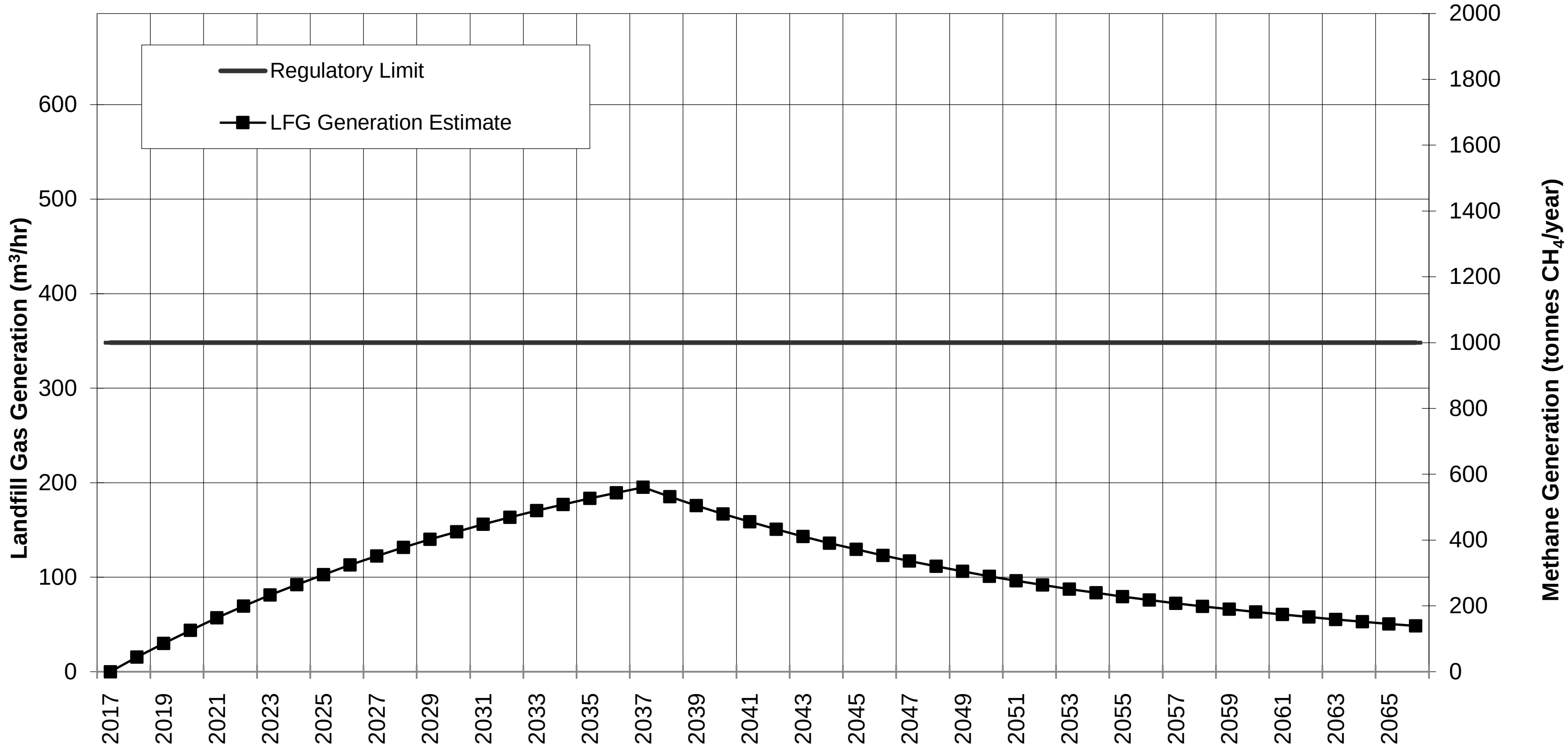
UPLAND EXCAVATING LTD.
PROPOSED UPLAND LANDFILL
2017 DESIGN, OPERATIONS AND CLOSURE PLAN

88877-03
May 31, 2017

TYPICAL LANDFILL GAS PRODUCTION STAGES

FIG. 10.1

CAD File: P:\drawings\88000s\88877\88877 - REPORTS\88877-03(010)\88877-03(010)GN\88877-03(010)GN-WA003.dwg



k values (year^{-1})	0.02, 0.06, 0.11	<u>Waste Composition</u>	
L_o (weighted) (m^3 CH4/tonne)	20, 120, 160	Relatively Inert (%)	75.0%
Precipitation (mm/year)	1,489	Moderately Decomposable (%)	25.0%
Volumetric LFG Composition (percent methane)	50%	Decomposable (%)	0.0%

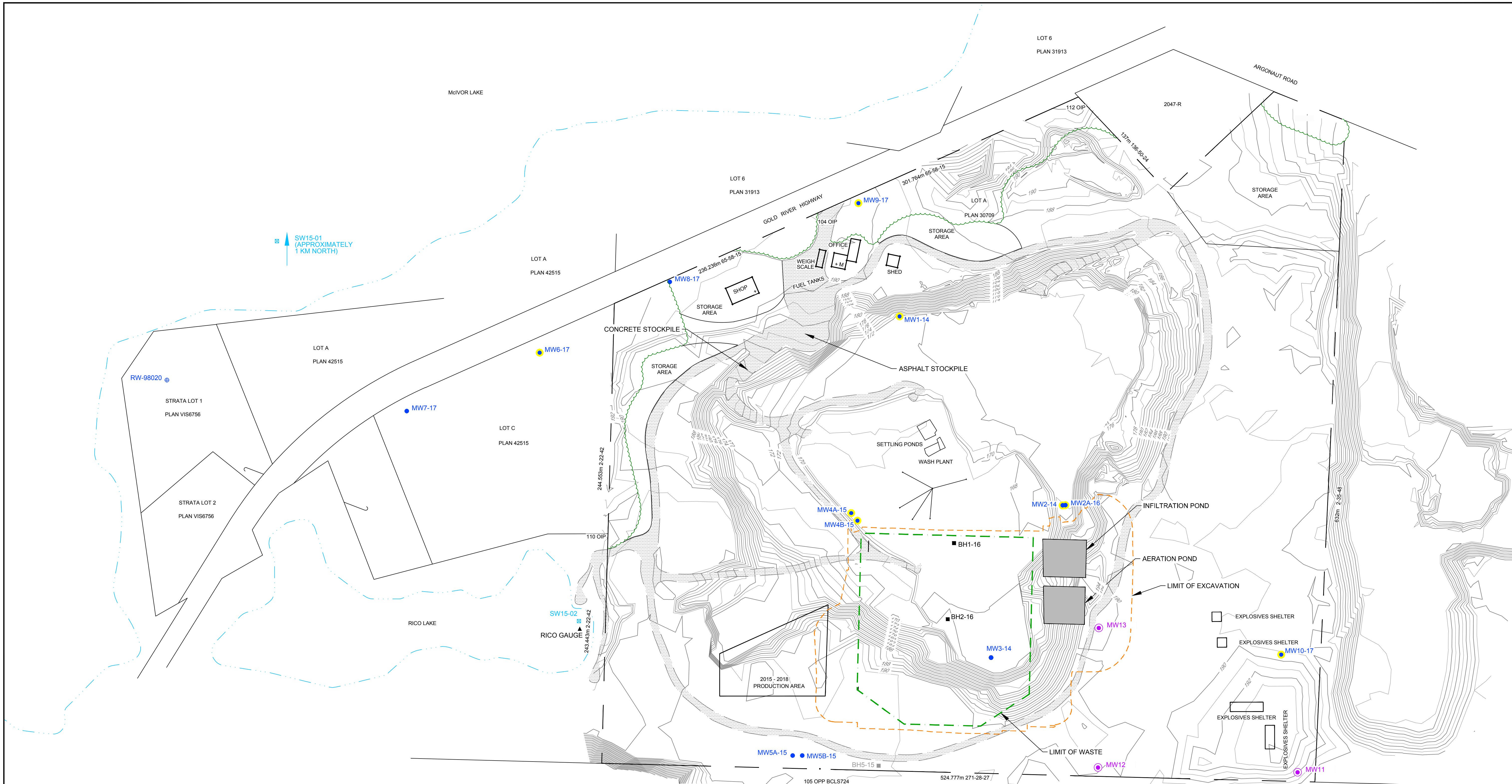
figure 10.2

LANDFILL GAS GENERATION ESTIMATE

2017 DESIGN, OPERATIONS, AND CLOSURE PLAN

UPLAND LANDFILL

Upland Excavations Ltd.



SOURCES:

- TOPOGRAPHICAL SURVEY CONDUCTED BY UPLAND CONTRACTING LTD., JANUARY 29 2015
- TOPOGRAPHIC SURVEY PLAN OF UPLANDS EXCAVATING GRAVEL PIT CONDUCTED BY McELHANNEY ASSOCIATES LAND SURVEYING LTD. COMPLETED ON NOVEMBER 21ST, 2016.

0 40 80 120m

N

LEGEND

176	EXISTING MAJOR CONTOURS
	EXISTING MINOR CONTOUR
	PROPERTY LINE
	EXISTING LAKE
	EXISTING ACCESS ROADWAY
	LIMIT OF WASTE
	LIMIT OF EXCAVATION
	TREES/VEGETATION
MW3-14	EXISTING MONITORING WELL
RW-98020	RESIDENTIAL WELL
BH5-15	EXISTING BOREHOLE
BH5-15	ABANDONED BOREHOLE
SW15-01	SURFACE WATER SAMPLE LOCATION
RICO GAUGE	SURFACE WATER GAUGE
MW2-14	MONITORING WELL INCLUDED IN PROPOSED ENVIRONMENTAL MONITORING PROGRAM
MW12	APPROXIMATE LOCATION OF PROPOSED MONITORING WELL INCLUDED IN PROPOSED ENVIRONMENTAL MONITORING PROGRAM (DURING LANDFILL OPERATIONS)

GHD

UPLAND EXCAVATING LIMITED
PROPOSED UPLAND LANDFILL
2017 DESIGN, OPERATION, AND CLOSURE PLAN

ENVIRONMENTAL MONITORING PROGRAM
PROPOSED MONITORING LOCATIONS

88877-03

May 31, 2017

FIGURE 14.1

CAD File: P:\drawings\88000s\88877\88877 - REPORTS\88877-03(010)\88877-03(010)GN\88877-03(010)GN-WA005.DWG

Table 2.1

Climate Data
2017 Design, Operations, and Closure Plan
Upland Landfill
Campbell River, British Columbia

Month	Daily Average Temperature (Celcius)	Daily Maximum Temperature (Celcius)	Daily Minimum Temperature (Celcius)	Rainfall (mm)	Snowfall (cm) [1]	Precipation (mm) [1]	Average Relative Humidity (0600LST) (%)	Average Relative Humidity (1500LST) (%)
January	2.4	5.5	-0.8	194.6	23.3	217.5	93	84.9
February	3.2	7.2	-0.7	135.5	14.4	149.5	92.4	75.1
March	5.2	9.7	0.7	128.4	11.7	140	91.4	67.8
April	8	13.2	2.8	91.6	0.5	92.1	90.2	59.6
May	11.6	17	6.2	68.4	0	68.4	86.5	57.2
June	14.7	20.1	9.3	62.9	0	62.9	83.7	57.6
July	17.3	23	11.5	39.4	0	39.4	83.8	54.4
August	17.2	23.3	11.1	44.6	0	44.6	87.8	55.1
September	13.7	19.8	7.6	55.2	0	55.2	91.5	59.1
October	8.6	13.1	4.0	161	1.2	162.2	93.3	74
November	4.4	7.7	1.0	222.1	10.5	231.9	93	83.3
December	2.1	4.9	-0.8	204.2	22.6	225.7	92.6	86.3
Annual	**9.0**	**13.7**	**4.3**	**1407.9**	**84.2**	**1489.4**	**89.9**	**67.9**

Notes:
Source: Environment Canada: Climate Normals - Campbell River Airport (Station No. - 1021261), 1981 - 2010 Station Data
[1] 1 cm of snowfall corresponds to 1 mm of precipation

Table 4.1

Average Annual Tonnes of Waste to be Disposed in Landfill
2017 Design, Operations, and Closure Plan
Upland Landfill
Campbell River, British Columbia

Year	Forecasted Average Annual Waste Disposal Rate (Tonne)	Forecasted Cumulative Waste Disposed (tonnes)	Forecasted Average Annual Airpace Consumption (m^3)	Forecasted Cumulative Airspace Consumption (m^3)
2017	32890	32890	25,300	25,300
2018	32890	65780	25,300	50,600
2019	32890	98670	25,300	75,900
2020	32890	131560	25,300	101,200
2021	32890	164450	25,300	126,500
2022	32890	197340	25,300	151,800
2023	32890	230230	25,300	177,100
2024	32890	263120	25,300	202,400
2025	32890	296010	25,300	227,700
2026	32890	328900	25,300	253,000
2027	32890	361790	25,300	278,300
2028	32890	394680	25,300	303,600
2029	32890	427570	25,300	328,900
2030	32890	460460	25,300	354,200
2031	32890	493350	25,300	379,500
2032	32890	526240	25,300	404,800
2033	32890	559130	25,300	430,100
2034	32890	592020	25,300	455,400
2035	32890	624910	25,300	480,700
2036	32890	657800	25,300	506,000
Total	**657,800**		**506,000**	

Apparent Density [1] 1.3 tonnes/m^3

[1]Average Apparent Density of the following waste streams
1) Waste Soil Typical Average Apparent Density - 1.6 tonne/m^3
2) Construction and Demolition Waste Typical Average Apparent Density - 1.0 - 1.2 tonne/m^3

Table 5.1

Landfill Stages
2017 Design, Operations, and Closure Plan
Upland Landfill
Campbell River, British Columbia

Phase	Stage	Approximate Cumulative Airspace (m^3)	Approximate Airspace Per Stage (m^3)	Tonnes per Stage [1]	Cumulative Tonnes
1	**1A**	69,500	69,500	90,350	90,350
1	**1B**	141,000	71,500	92,950	183,300
1	**1C**	201,600	60,600	78,780	262,080
2	**2A**	276,100	74,500	96,850	358,930
2	**2B**	336,200	60,100	78,130	437,060
2	**2C**	367,300	31,100	40,430	477,490
3	**3A**	431,300	64,000	83,200	560,690
3	**3B**	469,000	37,700	49,010	609,700
3	**3C**	506,000	37,000	48,100	657,800
			506,000	**657,800**	

Apparent Density [1] = 1.3 tonnes/m^3

Table 5.2

Material Requirement
2017 Design, Operations, and Closure Plan
Upland Landfill
Campbell River, British Columbia

		Cell Construction			Operations		Final Cover		
		Area		Volume	Volume		Area	Volume	
Phase	**Stage**	**Base Liner Geomembrane Area (m²)**	**Non-Woven Geotextile (m²)**	**Drain Rock (m³)**	**Daily Cover Volume (m³)[1]**	**Intermediate Cover Volume (m³)**	**Final Cover GCL Area (m²)**	**Final Cover Sand (m³)**	**Final Cover Topsoil (m³)**
1	**1A**	21,539	24,242	3,636	5,792	0	0	0	0
1	**1B**	0	18,836	2,825	5,958	3,615	0	0	0
1	**1C**	0	0	0	5,050	1,784	0	0	0
2	**2A**	9,684	19,368	2,905	6,208	2,291	10,488	7,866	1,573
2	**2B**	0	0	0	5,008	2,666	0	0	0
2	**2C**	0	0	0	2,592	1,785	0	0	0
3	**3A**	2,349	4,698	705	5,333	0	8,384	6,288	1,258
3	**3B**	0	0	0	3,142	0	0	0	0
3	**3C**	0	0	0	3,083	0	15,111	11,333	2,267
	Total	**33,572**	**67,144**	**10,072**	**42,167**	**12,140**	**33,983**	**25,487**	**5,097**

[1]Waste to Daily Cover Ratio of 12:1

Table 8.1

Design Storm Parameters
2017 Design, Operations, and Closure Plan
Upland Landfill
Campbell River, British Columbia

Return Period	Type	Depth (mm)	Snowmelt Correction Factor (%)	Climate Change Correction Factor (%)	Rainfall Depth with Snowmelt and Climate Change Correction (mm)	Peak Intensity (mm/hr)	Duration (hour)
5-year	SCS Type 1A	70.0	10	6	81.2	12.75	24
10-year	SCS Type 1A	77.7	10	6	90.1	14.15	24
100-year	SCS Type 1A	101.9	10	6	118.2	18.56	24

Note:

1. 5-year, 10-year and 100-year design storm depths obtained from Environment Canada intensity-duration-frequency data for the Campbell River A (1021261) IDF Station.

Table 8.2

Post Development Conditions Catchment Parameters
2017 Design, Operations, and Closure Plan
Upland Landfill
Campbell River, British Columbia

Subcatchment ID	Area (ha)	Flow length (m)	Slope (%)	Imperviousness (%)	Manning' n		Depression Storage		Infiltration	
					Impervious	Pervious	Impervious (mm)	Pervious (mm)	Maximum (mm/hr)	Minimum (mm/hr)
101	0.79	40	45	0	0.01	0.05	1.27	2.5	7	0.2
102	0.08	40	45	0	0.01	0.05	1.27	2.5	7	0.2
103	0.13	40	45	0	0.01	0.05	1.27	2.5	7	0.2
104	1.35	55	35	0	0.01	0.05	1.27	2.5	7	0.2
105	0.20	30	20	0	0.01	0.05	1.27	2.5	7	0.2
106	0.95	65	22	0	0.01	0.24	1.27	5.1	5	0.1
107	0.51	35	30	0	0.01	0.24	1.27	5.1	5	0.1
108	0.53	35	30	0	0.01	0.24	1.27	5.1	5	0.1
109	0.92	65	22	0	0.01	0.24	1.27	5.1	5	0.1
110	0.18	45	22	0	0.01	0.24	1.27	5.1	5	0.1
111	0.19	45	22	0	0.01	0.24	1.27	5.1	5	0.1
112	0.46	25	15	100	0.01	0.24	1.27	5.1	5	0.1
113	0.29	35	30	0	0.01	0.24	1.27	5.1	5	0.1
114	0.50	25	15	100	0.01	0.24	1.27	5.1	5	0.1
115	0.28	35	30	0	0.01	0.24	1.27	5.1	5	0.1
Total	**7.38**									

Table 8.3

Post Development Conditions Peakflow Summary
2017 Design, Operations, and Closure Plan
Upland Landfill
Campbell River, British Columbia

Subcatchment ID	5-year (m^3/s)	10-year (m^3/s)	100-year (m^3/s)
101	0.03	0.03	0.04
102	0.00	0.00	0.00
103	0.00	0.01	0.01
104	0.05	0.05	0.07
105	0.01	0.01	0.01
106	0.03	0.04	0.05
107	0.02	0.02	0.03
108	0.02	0.02	0.03
109	0.03	0.04	0.05
110	0.01	0.01	0.01
111	0.01	0.01	0.01
112	0.02	0.02	0.02
113	0.01	0.01	0.01
114	0.02	0.02	0.03
115	0.01	0.01	0.01

Table 8.4

Post Development Conditions Runoff Volume Summary
2017 Design, Operations, and Closure Plan
Upland Landfill
Campbell River, British Columbia

Subcatchment ID	5-year (m^3)	10-year (m^3)	100-year (m^3)
101	580	650	870
102	60	70	90
103	100	110	150
104	990	1110	1490
105	150	170	220
106	690	770	1040
107	370	420	560
108	380	430	570
109	660	750	1000
110	130	150	200
111	140	150	210
112	370	410	540
113	210	230	310
114	400	450	590
115	210	230	310

Table 8.5

Channel Performance Summary
2017 Design, Operations, and Closure Plan
Upland Landfill
Campbell River, British Columbia

Channel Section	Length (m)	Slope (m/m)	Cross-Section	Depth (m)	Bottom Width (m)	Left Side Slope (H:V)	Right Side Slope (H:V)	Manning's 'n' Value	100-Year Storm Max. Flowrate (m^3/s)	100-Year Storm Max. Velocity (m/s)	100-Year Storm Max. Depth (m)	100-Year Storm Minimum Freeboard (m)	100-Year Storm Max. Shear Stress (Pa)	Recommended Channel Lining
D101	58	0.003	TRAPEZOIDAL	0.5	0.5	3	3	0.03	0.02	0.02	0.18	0.33	6	Vegetation, Unreinforced
D102	146	0.002	TRAPEZOIDAL	0.5	0.5	3	3	0.03	0.07	0.11	0.16	0.34	3	Vegetation, Unreinforced
D103	32	0.261	TRAPEZOIDAL	0.5	0.5	3	3	0.03	0.07	0.01	0.11	0.39	281	FLEXMAT
D104	175	0.017	TRAPEZOIDAL	0.5	0.5	3	3	0.03	0.14	0.08	0.15	0.36	24	Vegetation, Unreinforced
D105	59	0.003	TRAPEZOIDAL	0.5	0.5	3	3	0.03	0.00	0.00	0.13	0.38	4	Vegetation, Unreinforced
D106	150	0.002	TRAPEZOIDAL	0.5	0.5	3	3	0.03	0.05	0.07	0.14	0.37	3	Vegetation, Unreinforced
D107	34	0.241	TRAPEZOIDAL	0.5	0.5	3	3	0.03	0.06	0.01	0.11	0.39	259	FLEXMAT
D108	180	0.017	TRAPEZOIDAL	0.5	0.5	3	3	0.03	0.15	0.08	0.15	0.36	24	Vegetation, Unreinforced

Table 8.6

Post-Closure Infiltration Pond Performance Summary
2017 Design, Operations, and Closure Plan
Upland Landfill
Campbell River, British Columbia

West Infiltration Pond

Design Storm	Peak Inflow (m^3/s)	Infiltration Discharge (m^3/s)	Maximum Depth (m)	Maximum Elevation (AMSL m)	Maximum Storage (m^3)	Minimum Freeboard (m)	Duration Time (Hour)
5-Year	0.13	0.044	0.16	167.46	439	0.84	12
10-Year	0.14	0.044	0.20	167.50	558	0.80	15
100-Year	0.19	0.044	0.36	167.66	1050	0.64	23

East Infiltration Pond

Design Storm	Peak Inflow (m^3/s)	Infiltration Discharge (m^3/s)	Maximum Depth (m)	Maximum Elevation (AMSL m)	Maximum Storage (m^3)	Minimum Freeboard (m)	Duration Time (Hour)
5-Year	0.13	0.044	0.17	167.47	475	0.83	12
10-Year	0.15	0.044	0.21	167.51	600	0.79	16
100-Year	0.19	0.044	0.38	167.68	1130	0.62	24

Table 9.1

Forecasted Leachate Quality Profile
2017 Design, Operations, and Closure Plan
Upland Landfill
Campbell River, British Columbia

Parameters	Units	Historical Results from Similar Landfills for Comparison											Treatment Efficiency			
		HWMF Lowest Concentration Observed in Leachate 2012-2015(1)	HWMF Average Concentration Observed in Leachate 2012-2015 (2)	HWMF Highest Concentration Observed in Leachate 2012 - 2015(3)	Confiential BC Contaminated Soil Landfill - Average Concentrations Observed in Leachate 2012(14)	Confidential BC Contaminated Soil Landfill - Average Concentration Observed in Leachate 2013 (16)	Highest observed - C&D Levis Landfill, Quebec 2003 (4)	Highest observed - Mayer Waste Disposal Site 1994-2001 (5)	Highest observed - Inter-Recycling Systems Landfill 1988-2001 (6)	Forecasted Upland Landfill Leachate Concentrations			Maximum Percent Reduction From Leachate Treatment	Maximum Concentration Reduction Resulting From Leachate Treatment	Forecasted Upland Landfill Treated Leachate Concentrations	
										Minimum	Maximum	**CSR Schedule 6 DW**			Minimum	Maximum
GENERAL CHEMISTRY																
Alkalinity (total)	mg/L	327	1152	2670	-	-	--	1550	3050	500	2500	-	90%	2250	50	250
Ammonia-N	mg/L	1.07	20.1	45.6	24.1	25.7	--	27	--	1	30	-	90%	27	0.10	3
BOD	mg/L	8.3	13.5	18.9	9	10	17	69	648	10	50	-	65%	32.5	3.5	17.5
Chloride (Cl) (dissolved)	mg/L	75	1642	4300	710	667	243	98.9	702	100	1500	250	83%	1250	16.7	250
COD	mg/L	52	431	1450	300	390	132	517	--	50	500	-	70%	350	15	150
Conductivity(4)	us/cm	1800	7974	25100	4100	3920	--	2730	6900	200	7500	-	-	-	200	7500
Hardness	mg/L	581	1855	4980	980	1050	--	1341	3100	750	2500	-	-	-	750	2500
pH(4)	pH units	6.84	7.35	8.06	7.02	6.88	6.2-7.3	6.2-7.1	6.1-8.4	6	8	-	-	-	6	8
Phenols	mg/L	0.005	0.044	0.096	-	-	0.026	0.0075	0.172	0.005	0.1	-	90%	0.09	0.0005	0.01
Sulphate (S04)	mg/L	36	529	1770	40	40	742	521	356	50	1000	500	50%	500	25	500
Sulphide	mg/L	0.023	1.979	7	-	-	-	-	-	0.1	5	0.05	99%	4.95	0.001	0.05
Total Suspended Solids (TSS)	mg/L	13.7	27.2	39.2	100	237	-	-	-	10	150	-	50%	75	5	75
Total Dissolved Solids (TDS)	mg/L	1180	5742	18400	-	-	-	-	-	2000	10000	-	50%	5000	1000	5000
Total Kjeldahl Nitrogen (TKN)	mg/L	2.89	26.3	61.3	36.1	43.1	-	-	-	3	60	-	65%	39	1.05	21
Phosphorus	mg/L	0.08	0.31	0.83	0.2(15)	-	-	-	-	0.1	0.5	-	-	-	0.1	0.5
HYDROCARBONS																
HEPH	mg/L	0.49	1.10	2.21	-	-	-	-	-	0.5	2	-	-	-	0.5	2
LEPH	mg/L	0.36	1.08	2.54	-	-	-	-	-	0.5	2	-	75%	1.5	0.125	0.5
METALS																
Aluminum (Dissolved)	mg/L	0.022	0.063	0.124	0.100	0.070				0.01	0.1		-	-	0.01	0.1
Arsenic	mg/L	0.001	0.009	0.022	0.008	0.042	-	0.001	0.019 (10)	0.001	0.04	0.01	75%	0.03	0.00025	0.01
Arsenic (Dissolved)	mg/L	0.006	0.010	0.020	0.003	0.003				0.001	0.04		75%	0.03	0.00025	0.01
Barium	mg/L	0.060	0.284	0.571	1.000	3.760	-	-	0.97	0.05	0.7	1	-	-	0.05	0.7
Barium (Dissolved)	mg/L	0.059	0.289	0.571	0.550	0.724				0.05	0.7		-	-	0.05	0.7
Boron	mg/L	1.74	7.81	13.6	10.4	10.9	-	-	-	5	10	5	50%	5	2.5	5
Boron (Dissolved)	mg/L	1.71	7.78	13.3	11.4	11.4				5	10		50%	5	2.5	5
Cadmium	mg/L	0.0001	0.0001	0.0001	0.0003	0.0003	<0.001	0.0006	0.005	0.0001	0.0003	0.005	-	-	0.0001	0.0003
Cadmium (Dissolved)	mg/L	0.0001	0.0001	0.0001	0.0005	0.0005				0.0001	0.0003		-	-	0.0001	0.0003
Calcium	mg/L	179	548	1520	262	288	-	376	720	200	700	-	-	-	200	700
Calcium (Dissolved)	mg/L	179	550	1540	243	226				200	700		-	-	200	700
Chromium	mg/L	0.002	0.011	0.022	0.006	0.020	0.11	0.054	0.241	0.005	0.05	0.05	-	-	0.005	0.05
Chromium (Dissolved)	mg/L	0.001	0.009	0.020	0.007	0.007				0.005	0.05		-	-	0.005	0.05
Cobalt	mg/L	0.001	0.002	0.007	0.003	0.005	-	0.02	0.018	0.001	0.01	-	-	-	0.001	0.01
Cobalt (Dissolved)	mg/L	0.001	0.002	0.005	0.003	0.004				0.001	0.01		-	-	0.001	0.01
Copper	mg/L	0.002	0.043	0.165	0.007	0.023	0.32	0.06	0.067	0.005	0.05	1	-	-	0.005	0.05
Copper (Dissolved)	mg/L	0.007	0.031	0.076	0.007	0.007				0.005	0.05		-	-	0.005	0.05
Iron	mg/L	0.418	5.46	25.5	47.6	267	69	65	180	1	70	6.5	91%	63.5	0.09	6.5
Iron (Dissolved)	mg/L	0.032	3.31	26.4	0.130	2.39				0.1	7		7%	0.5	0.09	6.5
Lead	mg/L	0.0015	0.0024	0.003	0.001	0.038	<0.05	0.062	0.053	0.001	0.01	0.01	-	-	0.001	0.01
Lead (Dissolved)	mg/L	--	--	--	0.001	0.001				0.001	0.01		-	-	0.001	0.01
Magnesium	mg/L	30	115	265	77.8	77.7	-	111	365	30	300	100	67%	200	10	100
Magnesium (Dissolved)	mg/L	30	118	274	75.7	71.2				30	300		67%	200	10	100
Manganese	mg/L	0.300	1.93	4.00	1.47	0.846	-	6.01	2.62	1	5	0.55	89%	4.45	0.11	0.55
Manganese (Dissolved)	mg/L	0.297	1.81	4.03	1.31	0.360				1	5		89%	4.45	0.11	0.55
Mercury	mg/L	--	--	--	0.00003	0.00001	<0.0002	<0.00005	<0.00005	0.00001	0.00003	0.001	-	-	0.00001	0.00003
Mercury (Dissolved)	mg/L	--	--	--	0.00001	0.00001				0.00001	0.00001		-	-	0.00001	0.00001
Molybdenum	mg/L	0.0017	0.0018	0.0019	0.001	0.001	-	<0.05	0.006	0.001	0.002	0.25	-	-	0.001	0.002
Molybdenum (Dissolved)	mg/L	0.0012	0.0016	0.0020	0.001	0.001				0.001	0.002		-	-	0.001	0.002
Nickel	mg/L	0.0075	0.0120	0.0199	0.020	0.017	0.13	0.02	0.086	0.0075	0.02	-	-	-	0.0075	0.02
Nickel (Dissolved)	mg/L	0.0052	0.0114	0.0203	0.010	0.016				0.0075	0.02		-	-	0.0075	0.02
Selenium	mg/L	ND	ND	ND	0.005	0.004	-	0.021	0.046	0.001	0.005	0.01	-	-	0.001	0.005
Selenium (Dissolved)	mg/L	-	-	-	0.004	0.004				0.001	0.005		-	-	0.001	0.005
Silver	mg/L	0.0001	0.0001	0.0001	0.0002	0.0002	-	0.0002	<0.0001	0.0001	0.00002	-	-	-	0.0001	0.00002
Silver (Dissolved)	mg/L	--	--	--	0.0002	0.0002				0.0001	0.0002		-	-	0.0001	0.0002
Sodium	mg/L	107	1153	4300	541	516	-	256	889	100	1000	200	80%	800	20	200
Sodium (Dissolved)	mg/L	92.3	1173	4350	577	518				100	1000		80%	800	20	200
Zinc	mg/L	0.027	0.238	1.34	0.050	0.110	0.72	2.12	2.57	0.05	2	5	-	-	0.05	2
Zinc (Dissolved)	mg/L	0.006	0.137	1.01	0.020	0.030				0.025	1		-	-	0.025	1

Notes for Table:
(1) Chemical analyses results - HWMF surface water - Highest concentration -1995 (Appendix B).
(2) Chemical analyses results - HWMF ash leachate - Highest concentration -1995 (Appendix B).
(3) Chemical analyses results - HWMF cell seepage - Highest concentration - 2004 (Appendix B).
(4) Highest concentration reported for the C&D Landfill in Levis, Quebec in 2005 (Appendix C).
(5) Highest concentration reported for the Mayer Industrial Landfill Site between 1994 and 2001 (Appendix C).
(6) Highest concentration reported for the Inter-Recycling Systems Landfill Site between 1988 and 2001 (Appendix C).
(7) Based on reported ranges from above mentioned C&D landfills.
(9) Upland beackground groundwater conditions include average hardness of 70 mg/l
(10) Only the total concentration will be reduced through settling, the dissolved component will not be removed. The parameter is expected to be present primarily in the dissolved form
(11) Removal is dependent on the form of the parameter present in the leachate
(12) Upland background groundwater conditions include average temperature of 12.79 degree celcius
(13) Upland background groundwater conditions include average ph measure in the field of 7.46
(14) Confidential Landfill Leachate - Treatment Program 2013 - Tables 5,6,7. Concentrations represent average of 4 samples.
(15) Concentration represents average of 2 samples.
(16) Confidential Landfill Leachate - Leachate Treatment Program 2013 - Tables 5,6,7. Concentrations represent average of 3 samples.

Table 9.2

HELP Model Results
2017 Design, Operations, and Closure Plan
Upland Landfill
Campbell River, British Columbia

HELP MODEL	Percolation into Waste (m/year)	Percolation through Base Liner (m/year)
Daily Cover	1.202	0.00000581
Intermediate Cover	1.052	0.00000534
Future Final Cover	0.017	0.00000011

Table 9.3

Cover Areas
2017 Design, Operations, and Closure Plan
Upland Landfill
Campbell River, British Columbia

Stage	Areas (m^2)			
Stage	Daily Cover	Intermediate Cover	Final Cover	Total Area (m^2)
1A	11,870	0	0	11,870
1B	9,354	11,870	0	21,224
1C	15,466	5,744	0	21,210
2A	13,002	7,451	9,947	30,400
2B	11,637	8,816	9,947	30,400
2C	14,545	5,907	9,947	30,399
3A	16,280	0	17,865	34,145
3B	16,280	0	17,865	34,145
3C	0	0	34,147	34,147

Table 9.4

Estimated Leachate Generation Per Stage
2017 Design, Operations, and Closure Plan
Upland Landfill
Campbell River, British Columbia

Phase	Stage	Volume (m^3) Daily Cover	Intermediate Cover	Final Cover	Total Annual Leachate Generation (m^3)	Minimum Daily Leachate Generation (m^3) (1)	Maximum Daily Leachate Generation (m^3) (2)	Average Daily Leachate Generation (m^3/day)
1	**1A**	14,268	0	0	14,268	12	74	39
1	**1B**	11,244	12,487	0	23,731	20	123	65
1	**1C**	18,590	6,043	0	24,633	21	128	67
2	**2A**	15,628	7,838	169	23,636	20	123	65
2	**2B**	13,988	9,274	169	23,431	20	122	64
2	**2C**	17,483	6,214	169	23,866	20	124	65
3	**3A**	19,569	0	304	19,872	17	103	54
3	**3B**	19,569	0	304	19,872	17	103	54
3	**3C**	0	0	580	580	0.5	3	2

Notes
(1) Minimum daily leachate generation occurs in July based on precipitation data
(2) Maximum daily leachate generation occurs in November based on precipitation data

Table 9.5

Leachate Treatment Capacity Summary
2017 Design, Operations, and Closure Plan
Upland Landfill
Campbell River, British Columbia

Month	Days	Percent of Annual Precipitation[1]	Stage 1C Monthly Leachate Generation (m3)	Monthly Average Daily Leachate Generation (m3)	Leachate Generation Accounting for Potential Precipitation Increases (+6%)(m3) [2]	Annual Average Daily Leachate Generation (m3)	Leachate Treatment Design Capacity (m3)
January	31	14.60%	3597	116	123	67	136
February	28	10.04%	2473	88	94	67	136
March	31	9.40%	2315	75	79	67	136
April	30	6.18%	1523	51	54	67	136
May	31	4.59%	1131	36	39	67	136
June	30	4.22%	1040	35	37	67	136
July	31	2.65%	652	21	22	67	136
August	31	2.99%	738	24	25	67	136
September	30	3.71%	913	30	32	67	136
October	31	10.89%	2683	87	92	67	136
November	30	15.57%	3835	128	136	67	136
December	31	15.15%	3733	120	128	67	136

Notes

[1]Quantity of precipitation per each month divided by annual precipitation * 100

[2]Maximum monthly average daily leachate generation plus a six percent increase to illustrate potential leachate generation rates due to climate change

Table 10.1

Waste Characterization
2017 Design, Operations, and Closure Plan
Upland Landfill
Campbell River, British Columbia

Waste Type	Percent of Total Waste Composition	Percent Relatively Inert	Percent Moderately Decomposable	Percent Decomposable
Waste Soil	50%	100%	0%	0%
Construction, Demolition and Land Clearing Debris	50%	50%	50%	0%
Total	**100%**	**75%**	**25%**	**0%**

Table 10.2

Landfill Gas Generation Summary
2017 Design, Operations, and Closure Plan
Upland Landfill
Campbell River, British Columbia

Year	Annual Waste Tonnage (tonnes)	Methane Generation (tonnes CH4/year)	Total Waste in Place (tonnes)
2017	32,890	0	32,890
2018	32,890	44	65,780
2019	32,890	86	98,670
2020	32,890	126	131,560
2021	32,890	163	164,450
2022	32,890	199	197,340
2023	32,890	233	230,230
2024	32,890	265	263,120
2025	32,890	295	296,010
2026	32,890	324	328,900
2027	32,890	351	361,790
2028	32,890	377	394,680
2029	32,890	402	427,570
2030	32,890	426	460,460
2031	32,890	448	493,350
2032	32,890	469	526,240
2033	32,890	489	559,130
2034	32,890	508	592,020
2035	32,890	526	624,910
2036	32,890	544	657,800
2037	0	560	657,800
2038	0	532	657,800
2039	0	505	657,800
2040	0	479	657,800
2041	0	455	657,800
2042	0	433	657,800
2043	0	411	657,800
2044	0	391	657,800
2045	0	372	657,800
2046	0	353	657,800
2047	0	336	657,800
2048	0	320	657,800
2049	0	305	657,800
2050	0	290	657,800
2051	0	276	657,800
2052	0	263	657,800
2053	0	251	657,800
2054	0	240	657,800
2055	0	228	657,800
2056	0	218	657,800
2057	0	208	657,800
2058	0	199	657,800
2059	0	190	657,800
2060	0	181	657,800
2061	0	173	657,800

Table 10.2

Landfill Gas Generation Summary
2017 Design, Operations, and Closure Plan
Upland Landfill
Campbell River, British Columbia

Year	Annual Waste Tonnage (tonnes)	Methane Generation (tonnes CH4/year)	Total Waste in Place (tonnes)
2062	0	166	657,800
2063	0	159	657,800
2064	0	152	657,800
2065	0	145	657,800
2066	0	139	657,800

Note:

This table presents the results of the landfill gas (LFG) assessment from the anticipated year where waste placement will begin to the estimated year of closure with anticipated annual waste tonnages.

Table 10.3

Landfill Gas Generation Results
2017 Design, Operations, and Closure Plan
Upland Landfill
Campbell River, British Columbia

	Relatively Inert	Moderately Decomposable	Decomposable	
Gas Production potential, Lo =	20	120	160	m^3 CH_4/tonne
Waste Composition (2006 SWMP)	75.0%	25.0%	0.0%	

lag time before start of gas production, lag =	1	yr	
Historical Data Used (years)	30		
1st Year of Historical Data Used	2017		
Proposed year of closure	2036		
methane (by volume)	50%		
carbon dioxide (by volume)	50%		
methane (density)	0.6557	kg/m^3	(25°C,1ATM)
carbon dioxide (density)	1.7988	kg/m^3	(25°C,1ATM)

Year	Annual Tonnage (tonnes)	Cumulative Waste-in-place (tonnes)	Waste Tonnage			Methane Generation Rate, k			Annual Methane Production (tonnes/yr)	Landfill Gas Production (m^3/hr)	Greenhouse Gas Emissions (as CO_2e/year)
			Relatively Inert (tonnes)	Moderately Decomposable (tonnes)	Decomposable (tonnes)	Relatively Inert ($year^{-1}$)	Moderately Decomposable ($year^{-1}$)	Decomposable ($year^{-1}$)			
2017	32,890	32,890	24,668	8,223	0	0.02	0.06	0.11	0.0	0.0	0
2018	32,890	65,780	24,668	8,223	0	0.02	0.06	0.11	44.2	15.4	928
2019	32,890	98,670	24,668	8,223	0	0.02	0.06	0.11	86.1	30.0	1,808
2020	32,890	131,560	24,668	8,223	0	0.02	0.06	0.11	125.8	43.8	2,641
2021	32,890	164,450	24,668	8,223	0	0.02	0.06	0.11	163.4	56.9	3,431
2022	32,890	197,340	24,668	8,223	0	0.02	0.06	0.11	199.0	69.3	4,179
2023	32,890	230,230	24,668	8,223	0	0.02	0.06	0.11	232.8	81.1	4,889
2024	32,890	263,120	24,668	8,223	0	0.02	0.06	0.11	264.9	92.2	5,562
2025	32,890	296,010	24,668	8,223	0	0.02	0.06	0.11	295.3	102.8	6,200
2026	32,890	328,900	24,668	8,223	0	0.02	0.06	0.11	324.1	112.9	6,806
2027	32,890	361,790	24,668	8,223	0	0.02	0.06	0.11	351.5	122.4	7,381
2028	32,890	394,680	24,668	8,223	0	0.02	0.06	0.11	377.5	131.4	7,927
2029	32,890	427,570	24,668	8,223	0	0.02	0.06	0.11	402.2	140.0	8,445
2030	32,890	460,460	24,668	8,223	0	0.02	0.06	0.11	425.6	148.2	8,937
2031	32,890	493,350	24,668	8,223	0	0.02	0.06	0.11	447.9	155.9	9,405
2032	32,890	526,240	24,668	8,223	0	0.02	0.06	0.11	469.0	163.3	9,849
2033	32,890	559,130	24,668	8,223	0	0.02	0.06	0.11	489.1	170.3	10,272
2034	32,890	592,020	24,668	8,223	0	0.02	0.06	0.11	508.3	177.0	10,673
2035	32,890	624,910	24,668	8,223	0	0.02	0.06	0.11	526.4	183.3	11,055
2036	32,890	657,800	24,668	8,223	0	0.02	0.06	0.11	543.8	189.3	11,419
2037	0	657,800	0	0	0	0.02	0.06	0.11	560.2	195.1	11,765
2038	0	657,800	0	0	0	0.02	0.06	0.11	531.7	185.1	11,166
2039	0	657,800	0	0	0	0.02	0.06	0.11	504.8	175.8	10,600
2040	0	657,800	0	0	0	0.02	0.06	0.11	479.3	166.9	10,065
2041	0	657,800	0	0	0	0.02	0.06	0.11	455.3	158.5	9,560
2042	0	657,800	0	0	0	0.02	0.06	0.11	432.5	150.6	9,083
2043	0	657,800	0	0	0	0.02	0.06	0.11	411.1	143.1	8,632
2044	0	657,800	0	0	0	0.02	0.06	0.11	390.8	136.1	8,206
2045	0	657,800	0	0	0	0.02	0.06	0.11	371.6	129.4	7,803
2046	0	657,800	0	0	0	0.02	0.06	0.11	353.4	123.1	7,422
2047	0	657,800	0	0	0	0.02	0.06	0.11	336.3	117.1	7,062
2048	0	657,800	0	0	0	0.02	0.06	0.11	320.0	111.4	6,721
2049	0	657,800	0	0	0	0.02	0.06	0.11	304.7	106.1	6,399
2050	0	657,800	0	0	0	0.02	0.06	0.11	290.2	101.0	6,094
2051	0	657,800	0	0	0	0.02	0.06	0.11	276.5	96.3	5,805
2052	0	657,800	0	0	0	0.02	0.06	0.11	263.5	91.7	5,533
2053	0	657,800	0	0	0	0.02	0.06	0.11	251.2	87.4	5,274
2054	0	657,800	0	0	0	0.02	0.06	0.11	239.5	83.4	5,030
2055	0	657,800	0	0	0	0.02	0.06	0.11	228.5	79.6	4,798
2056	0	657,800	0	0	0	0.02	0.06	0.11	218.0	75.9	4,579
2057	0	657,800	0	0	0	0.02	0.06	0.11	208.1	72.5	4,371
2058	0	657,800	0	0	0	0.02	0.06	0.11	198.8	69.2	4,174
2059	0	657,800	0	0	0	0.02	0.06	0.11	189.9	66.1	3,988
2060	0	657,800	0	0	0	0.02	0.06	0.11	181.5	63.2	3,811
2061	0	657,800	0	0	0	0.02	0.06	0.11	173.5	60.4	3,643
2062	0	657,800	0	0	0	0.02	0.06	0.11	165.9	57.8	3,485
2063	0	657,800	0	0	0	0.02	0.06	0.11	158.8	55.3	3,334
2064	0	657,800	0	0	0	0.02	0.06	0.11	152.0	52.9	3,191
2065	0	657,800	0	0	0	0.02	0.06	0.11	145.5	50.7	3,055
2066	0	657,800	0	0	0	0.02	0.06	0.11	139.4	48.5	2,927

Sources:
-Landfill Gas Generation Assessment Procedure Guidance Report, Conestoga-Rovers & Associates, March 2009
-Annual waste tonnage data is estimated.

Table 13.1

Groundwater Compliance Forecast
2017 Design, Operations, and Closure Plan
Upland Landfill
Campbell River, British Columbia

Parameters	Units	Average Pre-Landfilling Concentrations (1) 2015 - 2017	Forecasted Upland Landfill Leachate Concentrations		Forecasted Upland Landfill Treated Leachate Concentrations		Contaminant Masses & Source Volumes (2)	Existing	Landfill Leakage		Infiltration Pond		Infiltration of Runoff and Lateral Drainage from Landfill Cap	Infiltration Downgradient of Landfill	Final Forecasted Groundwater Concentrations (3)		Compliance Criteria: BC Contaminated Site Regulation Schedule 6 &10	Downgradient Dilution: Additional mass due to downgradient infiltration (500 m past Site boundary)		Forecasted Groundwater Concentrations (500 m beyond Site Boundary)		Confirmatory Comparison: BC Contaminated Site Regulation Schedule 6 & 10
			Minimum	Maximum	Minimum	Maximum	Units	Volume of Source							Minimum	Maximum	Drinking Water (DW)	m3/day	746	Minimum	Maximum	Aquatic Life (AW)
			mg/L	mg/L	mg/L	mg/L	m3/day	710	0.00033		67		3.5	225	mg/L	mg/L		L/day	746000	mg/L	mg/L	
							L/day	710,000	0.33		67,000		3,500	225,000								
GENERAL CHEMISTRY								Contaminant Masses	Minimum	Maximum	Minimum	Maximum										
Alkalinity (total)	mg/L	54.7	500	2500	50	250	mg/day	38837000	165	826	3350000	16750000	191450	12307500	54.39	67.71	-	mg/day	40806200	54.52	62.17	-
Ammonia-N	mg/L	0.08	1	30	0.10	3	mg/day	56800	0.33	9.9	6700	201000	280	18000	0.08	0.27	-	mg/day	59680	0.08	0.19	11.3 [a]
BOD	mg/L	2.07	10	50	3.5	17.5	mg/day	1469700	3.30	16.5	234500	1172500	7245	465750	2.17	3.10	-	mg/day	1544220	2.12	2.66	-
Chloride (Cl) (dissolved)	mg/L	4.15	100	1500	16.7	250	mg/day	2946500	33.0	495	1116666.667	16750000	14525	933750	4.98	20.53	250	mg/day	3095900	4.63	13.55	1500
COD	mg/L	39.1	50	500	15	150	mg/day	27761000	16.5	165	1005000	10050000	136850	8797500	37.49	46.49	-	mg/day	29168600	38.18	43.34	-
Conductivity(4)	us/cm	137	200	7500	200	7500	us/cm	-	-	-	-	-	-	-	200.00	7500.00	-	-	-	-	-	-
Hardness	mg/L	60	750	2500	750	2500	mg/day	42600000	248	826	50250000	167500000	210000	13500000	105.98	222.59	-	mg/day	44760000	86.39	153.34	-
pH(4)	pH units	7.86	6	8	6	8	pH units	-	-	-	-	-	-	-	6.00	8.00	-	-	-	-	-	-
Phenols	mg/L	0.0	0.005	0.1	0.0005	0.01	mg/day	0	0.00165	0.03	33.5	670	0	0	0.00003	0.00067	0.01	mg/day	0.0	0.00002	0.0004	-
Sulphate (S04)	mg/L	5.72	50	1000	25	500	mg/day	4061200	16.5	330	1675000	33500000	20020	1287000	7.00	38.66	500	mg/day	4267120	6.46	24.63	1000
Sulphide	mg/L	0.006	0.1	5	0.001	0.05	mg/day	4260	0.033	1.65	67	3350	21	1350	0.0057	0.0089	0.05	mg/day	4476	0.0058	0.01	0.02
Total Suspended Solids (TSS)	mg/L	390	10	150	5	75	mg/day	276900000	3.30	49.5	335000	5025000	1365000	87750000	364.35	369.01	-	mg/day	290940000	375.27	377.95	-
Total Dissolved Solids (TDS)	mg/L	31	2000	10000	1000	5000	mg/day	22010000	660	3302	67000000	335000000	108500	6975000	95.57	362.11	-	mg/day	23126000	68.07	221.08	-
Total Kjeldahl Nitrogen (TKN)	mg/L	0.143	3	60	1.05	21	mg/day	101530	0.99	19.81	70350	1407000	501	32175	0.20	1.53	-	mg/day	106678	0.18	0.94	-
Phosphorus	mg/L	0.551	0.1	0.5	0.1	0.5	mg/day	391210	0.033	0.17	6700	33500	1928.5	123975	0.52	0.55	-	mg/day	411046	0.53	0.55	-
HYDROCARBONS																						
HEPH	mg/L	0.0	0.5	2	0.5	2	mg/day	0	0.17	0.66	33500	134000	0	0	0.03	0.13	-	mg/day	0	0.02	0.08	-
LEPH	mg/L	0.0	0.5	2	0.125	0.5	mg/day	0	0.17	0.66	8375	33500	0	0	0.008	0.033	-	mg/day	0	0.005	0.02	0.5
METALS																						
Aluminum	mg/L	-	0.1	1	0.1	1		-	0.033022033	0.330220329	6700	67000			-	-	-	mg/day	-	-	-	-
Aluminum (Dissolved)	mg/L	0.00737	0.01	0.1	0.01	0.1	mg/day	5233	0.0033	0.033	670	6700	25.8	1658	0.01	0.01	9.5	mg/day	5498.02	0.007	0.01	-
Arsenic	mg/L	-	0.001	0.04	0.00025	0.01	mg/day	-	0.00033022	0.013	16.75	670			-	-	-	mg/day	-	-	-	-
Arsenic (Dissolved)	mg/L	0.00014	0.001	0.04	0.00025	0.01	mg/day	99	0.00033	0.013	16.75	670	0.49	32	0.0001	0.0008	0.01	mg/day	104.44	0.0001	0.001	0.05
Barium	mg/L	-	0.05	0.7	0.05	0.7	mg/day	-	0.016511016	0.231	3350	46900			-	-	-	mg/day	-	-	-	-
Barium (Dissolved)	mg/L	0.0014	0.05	0.7	0.05	0.7	mg/day	994	0.017	0.23	3350	46900	5	315	0.00	0.05	1	mg/day	1044.4	0.003	0.03	10
Boron	mg/L	-	5	10	2.5	5	mg/day	-	1.651101644	3.302203288	167500	335000			-	-	-	mg/day	-	-	-	-
Boron (Dissolved)	mg/L	0.0	5	10	2.5	5	mg/day	0	1.7	3.30	167500	335000	0	0	0.17	0.33	5	mg/day	0	0.10	0.19	50
Cadmium	mg/L	-	0.0001	0.0003	0.0001	0.0003	mg/day	-	3.3022E-05	9.90661E-05	6.7	20.1			-	-	-	mg/day	-	-	-	-
Cadmium (Dissolved)	mg/L	0.00001	0.0001	0.0003	0.0001	0.0003	mg/day	7.1	3.3E-05	9.9E-05	6.7	20.1	0.04	2	0.00002	0.00003	0.005	mg/day	7.460	0.00001	0.00002	0.0003-0.0006 [b]
Calcium	mg/L	-	200	700	200	700	mg/day	-	66.04406575	231.1542301	13400000	46900000			-	-	-	mg/day	-	-	-	-
Calcium (Dissolved)	mg/L	18.842	200	700	200	700	mg/day	13377820	66.0	231	13400000	46900000	65947	4239450	30.91	64.23	-	mg/day	14056132	25.77	44.90	-
Chromium	mg/L	-	0.005	0.05	0.005	0.05	mg/day	-	0.001651102	0.016511016	335	3350			-	-	-	mg/day	-	-	-	-
Chromium (Dissolved)	mg/L	0.0	0.005	0.05	0.005	0.05	mg/day	0	0.0017	0.017	335	3350	0	0	0.0003	0.0033	0.05	mg/day	0	0.0002	0.0019	0.09
Cobalt	mg/L	-	0.001	0.01	0.001	0.01	mg/day	-	0.00033022	0.003302203	67	670			-	-	-	mg/day	-	-	-	-
Cobalt (Dissolved)	mg/L	0.0	0.001	0.01	0.001	0.01	mg/day	0	0.0003	0.0033	67	670	0.00	0	0.0001	0.0007	-	mg/day	0.000	0.0000	0.0004	0.04
Copper	mg/L	-	0.005	0.05	0.005	0.05	mg/day	-	0.001651102	0.016511016	335	3350			-	-	-	mg/day	-	-	-	-
Copper (Dissolved)	mg/L	0.0008	0.005	0.05	0.005	0.05	mg/day	568	0.0017	0.017	335	3350	2.8	180	0.0011	0.0041	1	mg/day	596.800	0.001	0.003	0.03-0.08 [b]
Cyanide	mg/L	-	0.057	0.057	0.057	0.057	mg/day	-	0.018822559	0.018822559	3819	3819			-	-	-	mg/day	-	-	-	-
Cyanide (Dissolved)	mg/L	0.0			0	0	mg/day	-	0	0	0	0			-	-	0.2 (SAD)	mg/day	-	-	-	0.05 (WAD)
Iron	mg/L	-	1	70	0.09	6.5	mg/day	-	0.33	23.1	6221	435500	-	-	-	-	-	mg/day	-	-	-	-
Iron (Dissolved)	mg/L	0.056	0.1	7	0.09	6.5	mg/day	39760	0.033	2.3	6221	435500	196	12600	0.06	0.49	6.5	mg/day	41776.0	0.06	0.30	-
Lead	mg/L	-	0.001	0.01	0.001	0.01	mg/day	-	0.00033022	0.003302203	67	670			-	-	-	mg/day	-	-	-	-
Lead (Dissolved)	mg/L	0.0	0.001	0.01	0.001	0.01	mg/day	0	0.00033	0.0033	67	670	0	0	0.000067	0.00067	0.01	mg/day	0.0	0.00004	0.00038	0.05-0.06 [b]
Magnesium	mg/L	-	30	300	10	100	mg/day	-	9.906609863	99.06609863	670000	6700000			-	-	-	mg/day	-	-	-	-
Magnesium (Dissolved)	mg/L	3.28	30	300	10	100	mg/day	2328800	9.9	99.1	670000	6700000	11480	738000	3.73	9.72	100	mg/day	2446880	3.537	6.98	-
Manganese	mg/L	-	1	5	0.11	0.55	mg/day	-	0.330220329	1.651101644	7370	36850			-	-	-	mg/day	-	-	-	-
Manganese (Dissolved)	mg/L	0.03	1	5	0.11	0.55	mg/day	21300	0.33	1.7	7370	36850	105	6750	0.035	0.065	0.55	mg/day	22380.00	0.033	0.05	-
Mercury	mg/L	-	0.00001	0.00003	0.00001	0.00003	mg/day	-	3.3022E-06	9.90661E-06	0.67	2.01			-	-	-	mg/day	-	-	-	-
Mercury (Dissolved)	mg/L	0.0	0.00001	0.00001	0.00001	0.00001	mg/day	0	3.3E-06	3.3E-06	0.67	0.67	0.0	0	0.0000007	0.0000007	0.001	mg/day	0.00	0.0000004	0.0000004	0.001
Molybdenum	mg/L	-	0.001	0.002	0.001	0.002	mg/day	-	0.00033022	0.000660441	67	134			-	-	-	mg/day	-	-	-	-
Molybdenum (Dissolved)	mg/L	0.0	0.001	0.002	0.001	0.002	mg/day	0	0.00033	0.0007	67	134	0.0	0	0.0001	0.0001	0.25	mg/day	0.0	0.0000	0.0001	10
Nickel	mg/L	-	0.0075	0.02	0.0075	0.02	mg/day	-	0.002476652	0.006604407	502.5	1340			-	-	-	mg/day	-	-	-	-
Nickel (Dissolved)	mg/L	0.0	0.0075	0.02	0.0075	0.02	mg/day	0	0.0025	0.007	502.5	1340	0.0	0	0.0005	0.0013	-	mg/day	0.0	0.0003	0.0008	0.65-1.5 [b]
Selenium	mg/L	-	0.001	0.005	0.001	0.005	mg/day	-	0.00033022	0.001651102	67	335			-	-	-	mg/day	-	-	-	-
Selenium (Dissolved)	mg/L	0.0002	0.001	0.005	0.001	0.005	mg/day	142	0.00033	0.002	67	335	0.70	45	0.0003	0.0005	0.01	mg/day	149.200	0.0002	0.0004	0.01
Silver	mg/L	-	0.0001	0.00002	0.0001	0.00002	mg/day	-	3.3022E-05	6.60441E-06	6.7	1.34			-	-	-	mg/day	-	-	-	-
Silver (Dissolved)	mg/L	0.0	0.0001	0.0002	0.0001	0.0002	mg/day	0	3.3E-05	6.6E-05	6.7	13.4	0	0	0.0000067	0.0000133	-	mg/day	0.00	0.000004	0.000008	0.0005-0.015
Sodium	mg/L	-	100	1000	20	200	mg/day	-	33.02203288	330.2203288	1340000	13400000			-	-	-	mg/day	-	-	-	-
Sodium (Dissolved)	mg/L	3.89	100	1000	20	200	mg/day	2761900	33.0	330	1340000	13400000	13615	875250	4.96	16.96	200	mg/day	2901940	4.51	11.39	-
Zinc	mg/L	-	0.05	2	0.05	2	mg/day	-	0.016511016	0.660440658	3350	134000			-	-	-	mg/day	-	-	-	-
Zinc (Dissolved)	mg/L	0.002	0.025	1	0.025	1	mg/day	1420	0.008	0.33	1675	67000	7	450	0.0035	0.0685	5	mg/day	1492.0	0.0029	0.040	0.075-0.9 [b]

Notes for Table:
(1) Concentrations have been calculated using the average concentration of each sample collected from the overburden, sand and gravel aquifer between 2015 and 2017.
For the purposes of predicting the mass inputs, concentrations of 0.0 mg/L have been used whereever samples were below detection limits (ND or less than the reporting limit).
(2) Contaminant masses are calculated by multipling the forcasted concentration by the volume of the respective source
(3) Final Forecasted Groundwater Concentrations = (sum of masses)/(sum of source volumes)
(4) The forecasted concentration approach is inappropriate for pH and conductivity.
pH and conductivity are not expected to fall outside of the min. and max. range in pre-Landfill, leachate, or effluent.
\- not analyzed or no standard/criteria available.
ND - not detected above the respective laboratory reporting limit
[a] - Limit varies with pH. Ranges are calculated using average pre-landfilling and final predicted concentrations
[b] - Limit varies with Hardness. Ranges are calculated using average pre-landfilling and final predicted concentrations
(SAD)/(WAD) - strong acid dissolvable/weak acid dissolvable
exceeds the BC Drinking Water Supply Guideline
exceeds the BC Fresh Water Aquatic Life Guideline 500 m beyond the Site boundary

Table 14.1

Well, Borehole and Test Pit Completion Details
2017 Design, Operations, and Closure Plan
Upland Landfill
Campbell River, British Columbia

Monitoring ID	Installation Date	Completed By	Borehole Depth (mBGS)	Easting	Northing	2015 Reference Elevation Ground Surface (mAMSL)[2]	2015 Reference Elevation TOR (mAMSL)[2]	2017 Reference Elevation Ground Surface (mAMSL)[1]	2017 Reference Elevation TOR (mAMSL)[1]	Stick-up (m)	Screened Interval (mBGS)		Screen Interval (mAMSL)		Screen Length (m)	Well Diameter (mm)	Primary Constinuent of Completed Unit
Date:																	
MW1-14	12/4/2014	RWD	10.97	330788.539	5541791.638	154.5	172.9	-	-	1.1	11.0	4.9	160.8	149.6	6.1	50.8	Sand/gravel
MW2-14	12/4/2014	RWD	21.64	330961.402	5541591.181	155.8	156.5	-	-	0.8	21.6	15.5	151.4	140.2	6.1	50.8	Sand/gravel
MW2A-16	1/27/2016	Drillwell	45.42	330964.560	5541591.419	155.8	156.6	173.1	173.9	0.8	40.5	37.5	132.6	118.3	6.1	50.8	Sand
MW3-14	12/4/2014	RWD	18.59	330885.439	5541429.793	150.3	151.3	-	-	1.0	17.4	11.3	150.2	139.0	6.1	50.8	Sand/gravel
MW4A-15	8/5/2015	Blue Max	21.33	330737.351	5541583.042	151.2	152.0	-	-	0.8	21.4	19.8	147.2	131.4	1.5	50.8	Bedrock
MW4B-15	8/5/2015	Blue Max	18.28	330743.926	5541575.024	151.1	152.0	-	-	0.9	18.3	15.2	150.1	135.9	3.0	50.8	Sand
MW5A-15	8/7/2015	Blue Max	10.66	330675.167	5541325.831	174.0	174.6	-	-	0.6	10.7	9.1	180.6	164.8	1.5	50.8	Bedrock
MW5B-15	8/7/2015	Blue Max	8.23	330685.323	5541325.831	191.3	174.7	-	-	1.7	7.9	4.9	182.4	186.4	3.0	50.8	Sand/Silt with clay
MW6-17	3/22/2017	Drillwell	11.89	330407.086	5541753.092	-	-	185.5	185.4	-0.1	11.3	9.8	174.2	175.7	1.5	50.8	Sand
MW7-17	3/14/2017	Drillwell	5.03	330266.457	5541691.359	-	-	186.9	187.5	0.7	4.3	2.7	182.6	184.1	1.5	50.8	Gravel
MW8-17	2/22/2017	Blue Max	28.96	330544.895	5541828.138	-	-	191.3	192.5	1.2	18.8	15.8	172.5	175.5	3.0	50.8	Gravel
MW9-17	3/14/2017	Drillwell	33.53	330744.892	5541911.675	-	-	190.9	191.7	0.8	33.5	30.5	157.3	160.4	3.0	50.8	Sand/gravel
MW10-17	3/27/2017	Drillwell	47.87	331208.625	5541441.665	-	-	188.2	189.1	0.8	46.3	43.2	142.0	145.0	3.0	50.8	Sand
RW-98020	5/13/2008	RWD	60.96	330012.000	5541724.000	178.3	179.6	-	-	1.3	61.0	1.8	134.7	176.5	41.8	152.4	Bedrock
BH1-16	1/27/2016	Drillwell	24.08	330846.010	5541551.180	168.41	-	-	-	-	-	-	-	-	-	-	Bedrock
BH2-16	1/28/2016	Drillwell	16.46	330839.010	5541470.180	167.83	-	-	-	-	-	-	-	-	-	-	Bedrock
BH5-15	8/6/2015	Blue Max	24.38	330765.701	5541327.331	ns	-	-	-	-	-	-	-	-	-	-	Sand/gravel
TP1-17	3/23/2017	Upland	4.57	330375.872	5541665.807	-	-	182.14	-	-	-	-	-	-	-	-	Sand with gravel
TP2-17	3/23/2017	Upland	2.44	330340.223	5541649.458	-	-	182.78	-	-	-	-	-	-	-	-	Bedrock
TP3-17	3/23/2017	Upland	5.49	330445.9487	5541608.703	-	-	182.61	-	-	-	-	-	-	-	-	Bedrock
TP4-17	3/23/2017	Upland	4.11	330471.1766	5541750.688	-	-	191.23	-	-	-	-	-	-	-	-	Sand with gravel
TP5-17	3/23/2017	Upland	5.64	330467.1592	5541418.59	-	-	189.44	-	-	-	-	-	-	-	-	Silty Sand
TP6-17	3/24/2017	Upland	5.79	330407.0856	5541753.092	-	-	191.89	-	-	-	-	-	-	-	-	Sand with gravel
TP7-17	3/24/2017	Upland	6.40	330509.0192	5541457.215	-	-	191.82	-	-	-	-	-	-	-	-	Sand with gravel
TP8-17	3/24/2017	Upland	3.35	330492.9906	5541417.832	-	-	192.15	-	-	-	-	-	-	-	-	Bedrock
TP9-17	3/24/2017	Upland	0.61	330535.6659	5541369.794	-	-	191.99	-	-	-	-	-	-	-	-	Bedrock

Notes:
1 - Surveys completed by McElhanney on April 6, 2016 and March 16 and 31, 2017
2 - Survey completed by Upland Excavating Ltd. on January 29th, 2015, March 8, 2016 and April 6th, 2016. Elevations measured with respect to AMSL.
mBGS - metres below ground surface
mAMSL - metres above mean sea level
TOR - top of riser
ns - not surveyed
RWD - Red Williams Well Drilling Ltd.
Upland - Upland Excavating Ltd.
Drillwell - Drillwell Enterprises Ltd.
Blue Max - Blue Max Drilling Inc.

Table 14.2

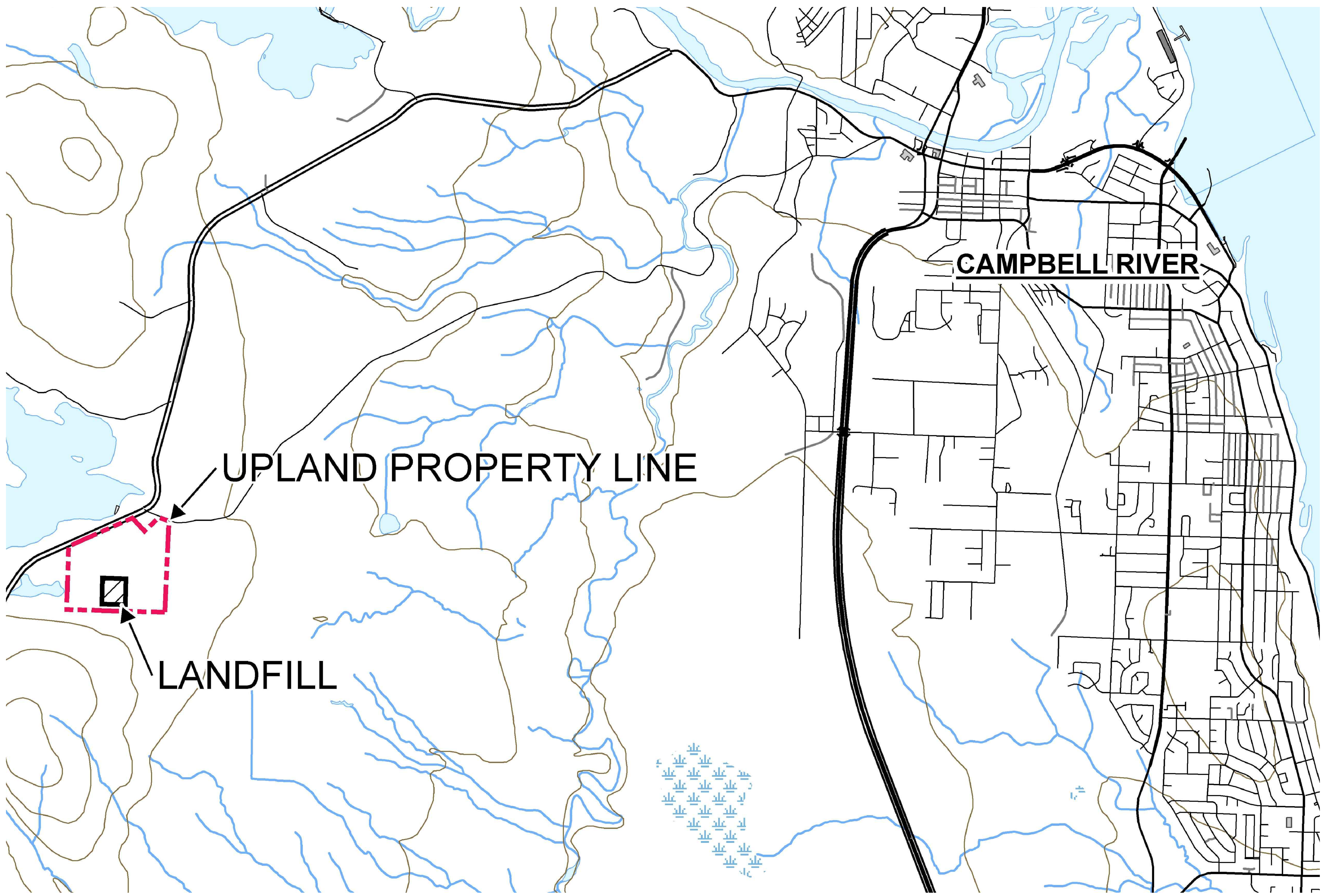
Hydraulic Monitoring Results
2017 Design, Operations, and Closure Plan
Upland Landfill
Campbell River, British Columbia

Monitoring ID	Borehole Depth (m BGS)	2015/2016 Reference Elevation TOR (m AMSL)[2]	2017 Reference Elevation TOR (m AMSL)[1]	Depth to Water (m BTOR)									Water Elevation (m AMSL)											Hydraulic Conductivity (cm/s)	Screened Unit/Aquifer
Date:				**11-Sep-15**	**17-Sep-15**	**5-Oct-15**	**25-Jan-16**	**29-Jan-16**	**15-Feb-16**	**8-Mar-16**	**15-Mar-17**	**6-Apr-17**	**11-Sep-15**	**17-Sep-15**	**5-Oct-15**	**25-Jan-16**	**29-Jan-16**	**15-Feb-16**	**8-Mar-16**	**6-Apr-16**	**15-Mar-17**	**6-Apr-17**		**Primary Constituent**
MW1-14	10.97	172.9	-	5.6	6.3	6.1	6.0	-	-	-	8.1	7.7	167.3	166.6	166.9	166.9	-	-	-	-	164.8	165.2	-	Sand/gravel (S&G Aquifer
MW2-14	21.64	173.8	-	14.5	14.7	15.2	14.7	-	14.6	-	15.9	15.8	159.4	159.1	158.6	159.1	-	159.3	-	-	158.0	158.0	-	Sand/gravel (S&G Aquifer)
MW2A-16	45.42	173.9	173.9	-	-	-	14.5	-	14.5	-	15.9	15.8	-	-	-	159.3	-	159.3	-	-	158.0	158.1	-	Sand (S&G Aquifer)
MW3-14	18.59	168.6	-	12.8	12.7	12.8	11.3	-		-	12.1	12.1	155.8	155.9	155.8	157.2	-	-	-	-	156.5	156.4	-	Sand/gravel (S&G Aquifer)
MW4A-15	21.33	169.3	-	3.9	4.3	4.9	4.0	-	-	-	5.7	3.4	165.4	165.0	164.4	165.3	-	-	-	-	163.6	165.9	2.2×10^{-2}	Bedrock (S&G Aquifer)
MW4B-15	18.28	169.3	-	4.1	4.5	5.1	4.2	-	-	-	5.9	5.7	165.2	164.8	164.1	165.0	-	-	-	-	163.3	163.6	2.0×10^{-2}	Sand (S&G Overburden)
MW5A-15	10.66	191.9	-	9.0	9.0	8.3	7.3	-	-	-	8.1	7.7	182.9	182.9	183.6	184.6	-	-	-	-	183.8	184.2	1.4×10^{-5}	Bedrock Ridge (S&G Aquifer)
MW5B-15	8.22	192.0	-	7.1	7.2	7.0	5.4	-	-	-	7.1	6.1	184.9	184.9	185.0	186.6	-	-	-	-	184.9	185.9	-	Sand/Silt with clay (S&G Aquifer)
MW6-17	11.28	-	185.4	-	-	-	-	-	-	-	-	7.5	-	-	-	-	-	-	-	-	-	177.9	-	Sand (S&G Aquifer)
MW7-17	4.29	-	187.5	-	-	-	-	-	-	-	3.3	2.9	-	-	-	-	-	-	-	-	184.2	184.6	-	Gravel (Shallow Aquifer)
MW8-17	18.80	-	192.5	-	-	-	-	-	-	-	19.7	19.7	-	-	-	-	-	-	-	-	172.8	172.8	-	Gravel (S&G Aquifer)
MW9-17	33.54	-	191.7	-	-	-	-	-	-	-	24.8	24.4	-	-	-	-	-	-	-	-	166.8	167.2	-	Sand/gravel (S&G Aquifer)
MW10-17	46.25	-	189.1	-	-	-	-	-	-	-	-	39.0	-	-	-	-	-	-	-	-	-	150.1	-	Sand (S&G Aquifer)
RW-98020	60.96	196.9	-	-	-	-	-	-	17.1	-	-	-	-	-	-	-	-	179.9	-	-	-	-	-	Bedrock Ridge
McIvor Lake	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	177.5[(3)]	-	177.9[(2)]	177.0[(2)]	177.6[(3)]	177.6[(3)]	-	-
SW15-02 Rico Lake	-	180.33*		-	-	-	-	0.88	-	0.91	0.06	0.09	-	-	-	-	181.2	-	181.2[(2)]	180.8[(2)]	180.4	180.4	-	-

Notes:
1 - Surveys completed by McElhanney on April 6, 2016 and March 16 and 31, 2017
2 - Survey completed by Upland Excavating Ltd. on January 29th, 2015, March 8, 2016 and April 6th, 2016. Elevations measured with respect to AMSL.
3 - Based on BC Hydro record of water elevations at Ladore Dam recorded every three hours. (https://www.bchydro.com/energy-in-bc/our_system/transmission_reservoir_data/previous_reservoir_elevations/vancouver_island/ladore_ldr.html)

* Surface water gauge reference elevation refers to the bottom of the gauge. (0 m on gauge = 180.33 m amsl)
m BGS - metres below ground surface
m AMSL - metres above mean sea level (WGS1984)
TOR - top of riser
S&G - Sand and gravel

UPLAND LANDFILL
UPLAND EXCAVATING LTD.
BRITISH COLUMBIA
2017 DESIGN, OPERATIONS, AND CLOSURE PLAN



LOCATION MAP

SOURCE:

CANVEC EDITION 1.1 DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED. NATIONAL ROAD NETWORK 2.0 GEOBASE ESRI BASE DATA 2005.

DRAWING INDEX

DWG NO.	REV NO.	DATE	TITLE
C-01	0	MAY 2017	EXISTING CONDITIONS
C-02A	0	MAY 2017	SITE OPERATIONS
C-02B	0	MAY 2017	LANDFILL EXCAVATION PLAN
C-03	0	MAY 2017	BASE / LINER GRADES
C-04	0	MAY 2017	LEACHATE COLLECTION SYSTEM (TOP OF GRANULAR DRAINAGE BLANKET)
C-05	0	MAY 2017	FINAL GRADES (TOP OF FINAL COVER)
C-06	0	MAY 2017	CROSS-SECTIONS
C-07	0	MAY 2017	FILL PLAN PHASE I: STAGE 1A - 1C
C-08	0	MAY 2017	FILL PLAN PHASE II: STAGE 2A - 2C
C-09	0	MAY 2017	FILL PLAN PHASE III: STAGE 3A - 3C
C-10	0	MAY 2017	LINER AND LEACHATE COLLECTION DETAILS
C-11	0	MAY 2017	LEACHATE COLLECTION SYSTEM SUMP AND RISER I
C-12	0	MAY 2017	LEACHATE COLLECTION SYSTEM SUMP AND RISER II
C-13	0	MAY 2017	PERIMETER TIE-IN DETAILS I
C-14	0	MAY 2017	PERIMETER TIE-IN DETAILS II

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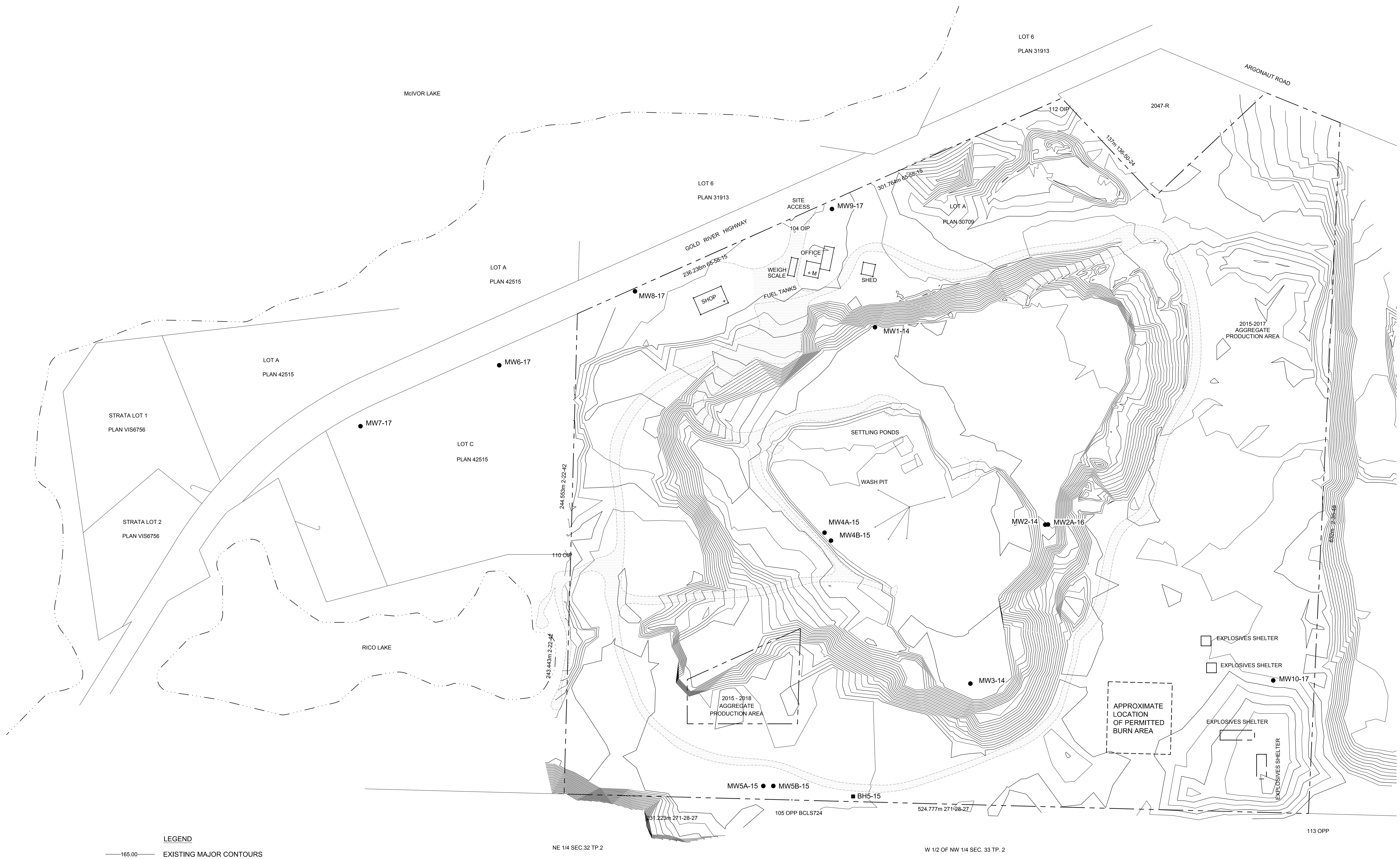

LEGEND

165.00	EXISTING MAJOR CONTOURS
	EXISTING MINOR CONTOUR
	PROPERTY LINE
	EXISTING LAKE SHORELINE
	EXISTING ACCESS ROADWAY
MW3-14	EXISTING MONITORING WELLS

SOURCE: TOPOGRAPHICAL SURVEY CONDUCTED BY McELHANNEY ASSOCIATES LAND SURVEYING LTD. , NOVEMBER 2016

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Project
2017 DESIGN, OPERATIONS AND CLOSURE PLAN

No.	Issue	Drawn	Approved	Date
4	RE-ISSUED FOR MOE REVIEW	TW	GF	MAY 2017
3	UPDATED TOPOGRAPHICAL SURVEY	TW	GF	NOV 2016
2	MOE REVIEW	KD	DB	MAY 2016
1	DRAFT - STAKEHOLDER CONSULTATION	TW	DB	FEB 2016

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Drafting Check	D. BARTON	Design Check	S.STURGEON
Project Manager	G. FERRARO	Date	MAY 2017
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Title
EXISTING CONDITIONS

Sheet No.
C-01

Sheet 1 of 15

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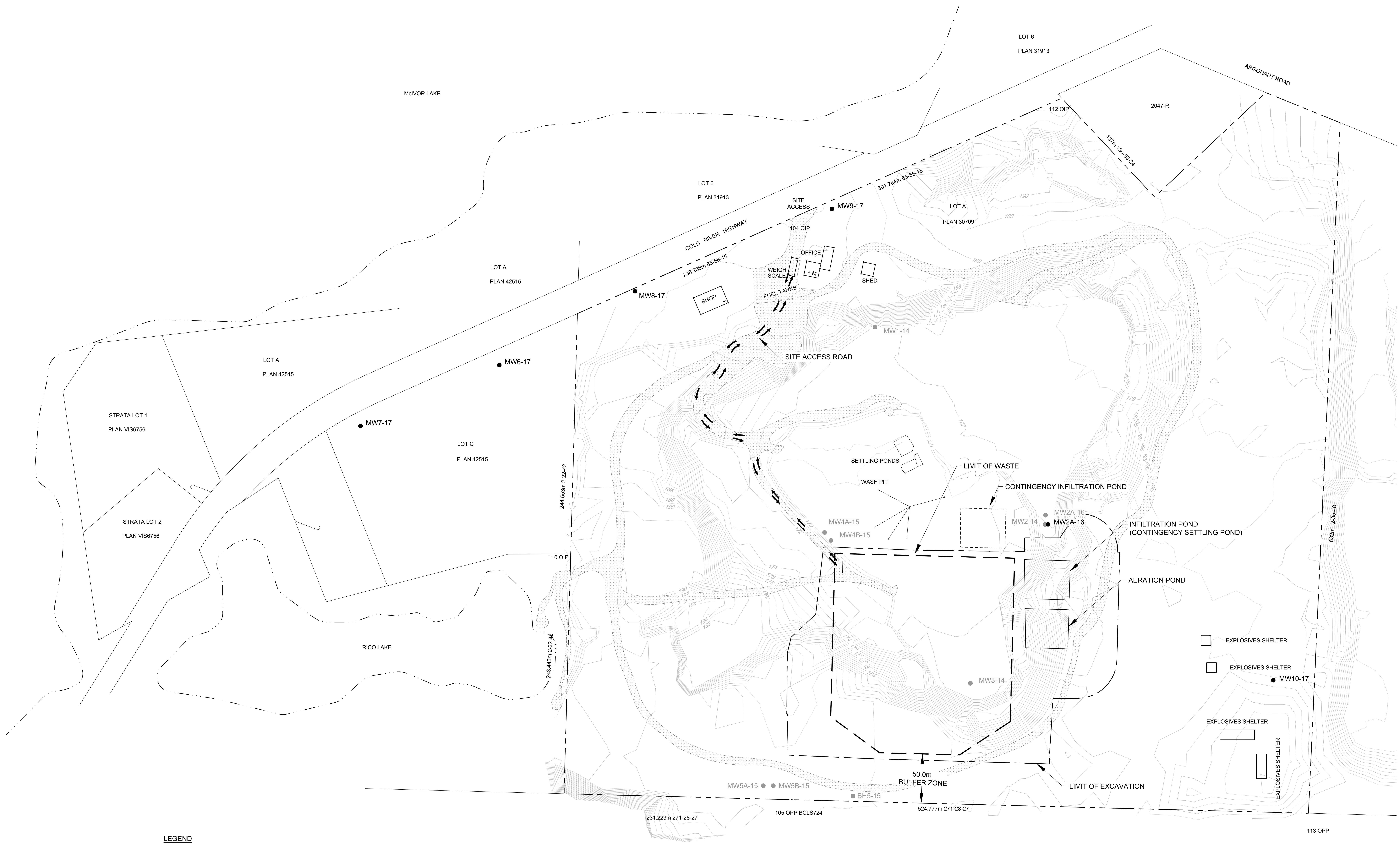

LEGEND

EXISTING MAJOR CONTOURS	LIMIT OF WASTE
EXISTING MINOR CONTOUR	LIMIT OF EXCAVATION
PROPERTY LINE	MW3-14 EXISTING MONITORING WELL
EXISTING LAKE SHORELINE	BH5-15 EXISTING BOREHOLE
EXISTING ACCESS ROADWAY	

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Project
2017 DESIGN, OPERATIONS AND CLOSURE PLAN

No.	Issue	Drawn	Approved	Date
4	RE-ISSUED FOR MOE REVIEW	TW	GF	MAY 2017
3	UPDATED TOPOGRAPHICAL SURVEY	TW	GF	NOV 2016
2	MOE REVIEW	KD	DB	MAY 2016
1	DRAFT - STAKEHOLDER CONSULTATION	TW	DB	FEB 2016

Drawn	T.WAGSTAFF	Designer	D. BARTON
Drafting Check	D. BARTON	Design Check	S.STURGEON
Project Manager	G. FERRARO	Date	MAY 2017
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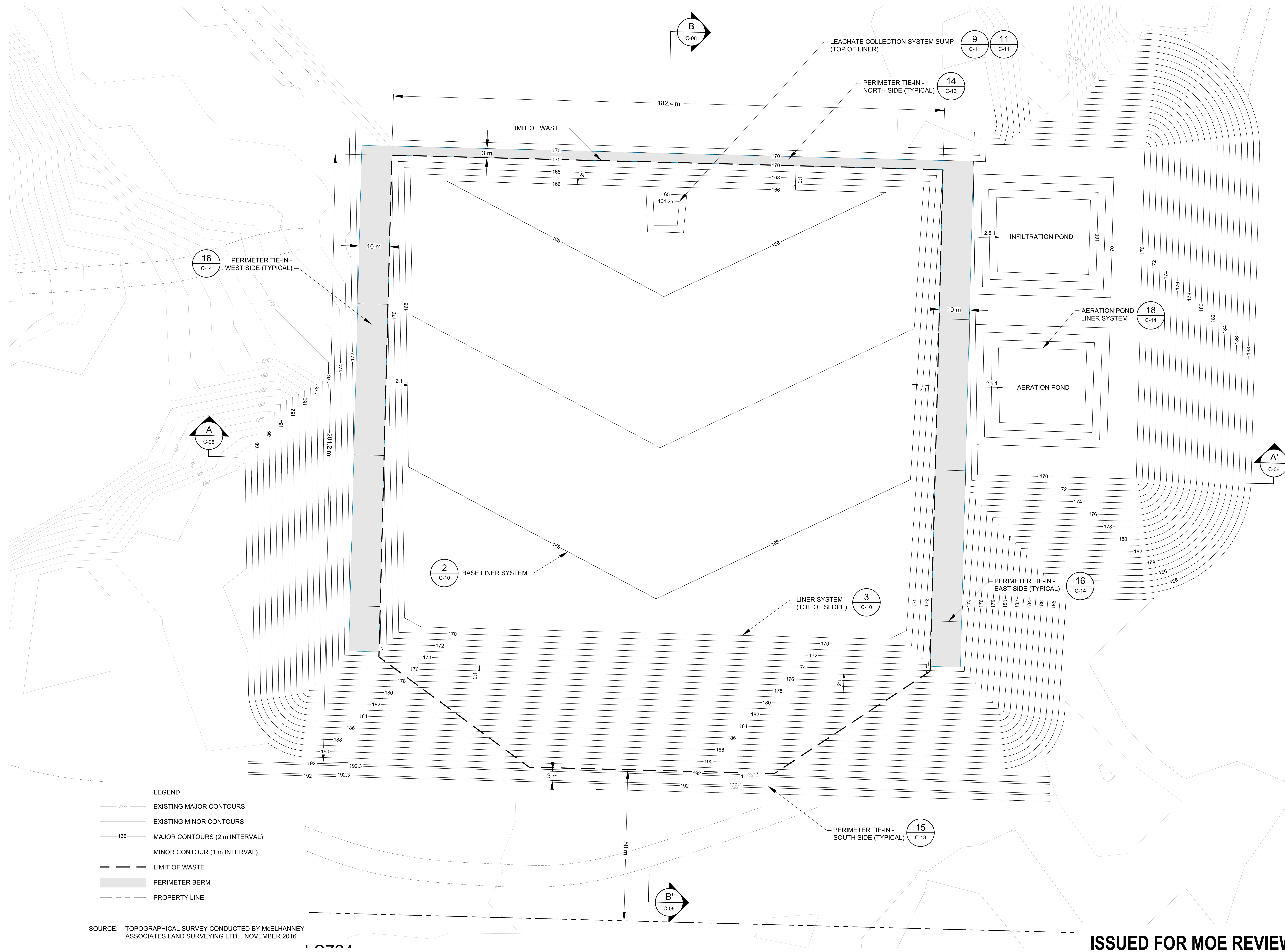
Project No. 88877-03

Title
SITE OPERATIONS

Sheet No.
C-02A

Sheet 2 of 15



LEGEND

- EXISTING MAJOR CONTOURS
- EXISTING MINOR CONTOURS
- MAJOR CONTOURS (2 m INTERVAL)
- MINOR CONTOUR (1 m INTERVAL)
- LIMIT OF WASTE
- PERIMETER BERM
- PROPERTY LINE

SOURCE: TOPOGRAPHICAL SURVEY CONDUCTED BY McELHANNEY ASSOCIATES LAND SURVEYING LTD. , NOVEMBER 2016

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Project: 2017 DESIGN, OPERATIONS AND CLOSURE PLAN

No.	Issue	Drawn	Approved	Date
4	RE-ISSUED FOR MOE REVIEW	TW	GF	MAY 2017
3	UPDATED TOPOGRAPHICAL SURVEY	TW	GF	NOV 2016
2	MOE REVIEW	KD	DB	MAY 2016
1	DRAFT - STAKEHOLDER CONSULTATION	TW	DB	FEB 2016

Drawn	T.WAGSTAFF	Designer	D. BARTON
Drafting Check	D. BARTON	Design Check	S.STURGEON
Project Manager	G. FERRARO	Date	MAY 2017
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Project No. 88877-03

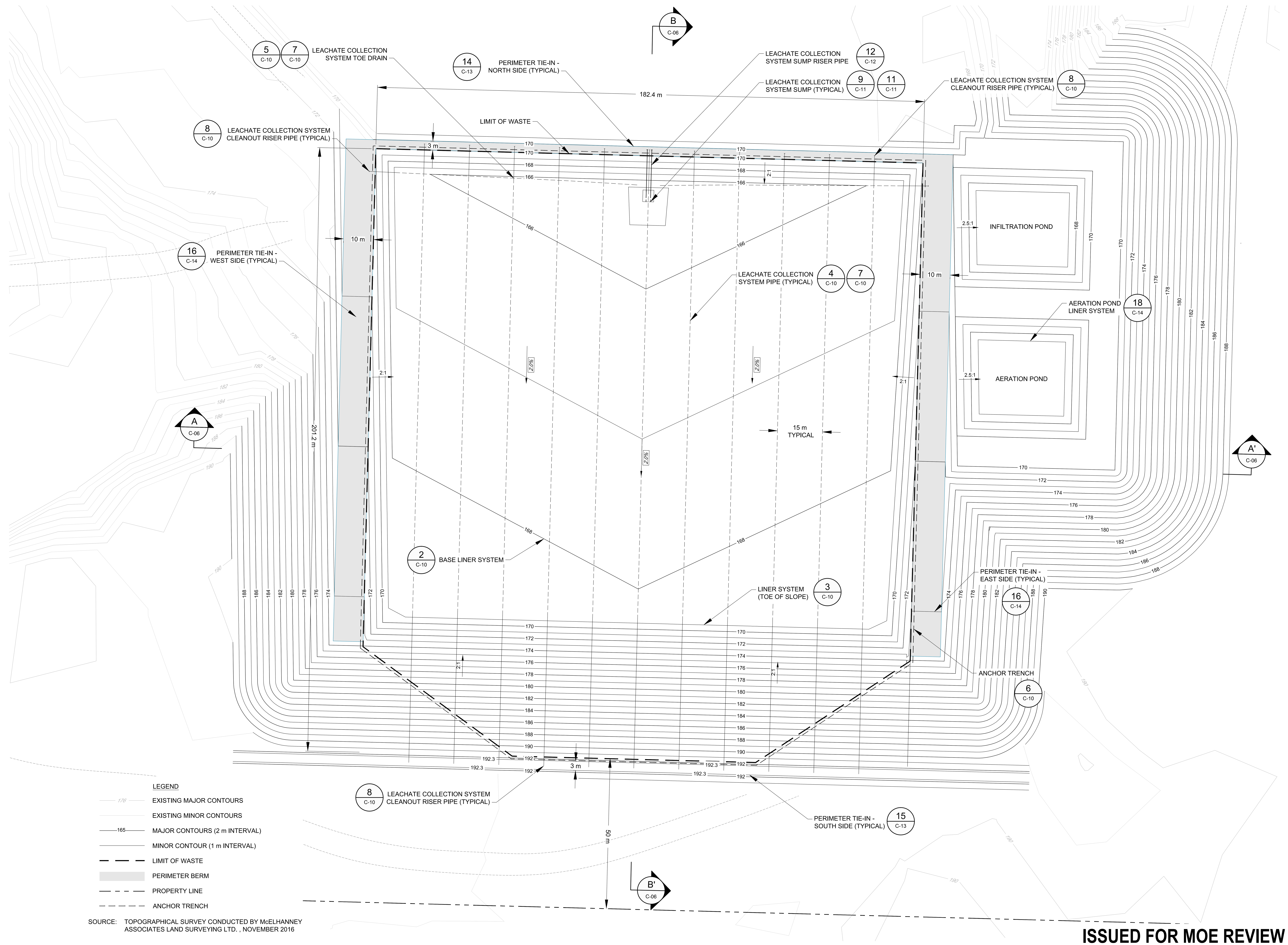
Title

LANDFILL EXCAVATION PLAN

Sheet No.

C-02B

Plot Date: 1 June 2017 - 1:36 PM Plotted By: Tyler Wagstaff CAD File: P:\drawings\88000s\88877\88877 - REPORTS\88877-03(010)\88877-03(010)CI\88877-03(010)CI-WA002B.dwg



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Project
2017 DESIGN, OPERATIONS AND CLOSURE PLAN

No.	Issue	Drawn	Approved	Date
4	RE-ISSUED FOR MOE REVIEW	TW	GF	MAY 2017
3	UPDATED TOPOGRAPHICAL SURVEY	TW	GF	NOV 2016
2	MOE REVIEW	KD	DB	MAY 2016
1	DRAFT - STAKEHOLDER CONSULTATION	TW	DB	FEB 2016

Drawn	T.WAGSTAFF	Designer	D. BARTON
Drafting Check	D. BARTON	Design Check	S.STURGEON
Project Manager	G. FERRARO	Date	MAY 2017
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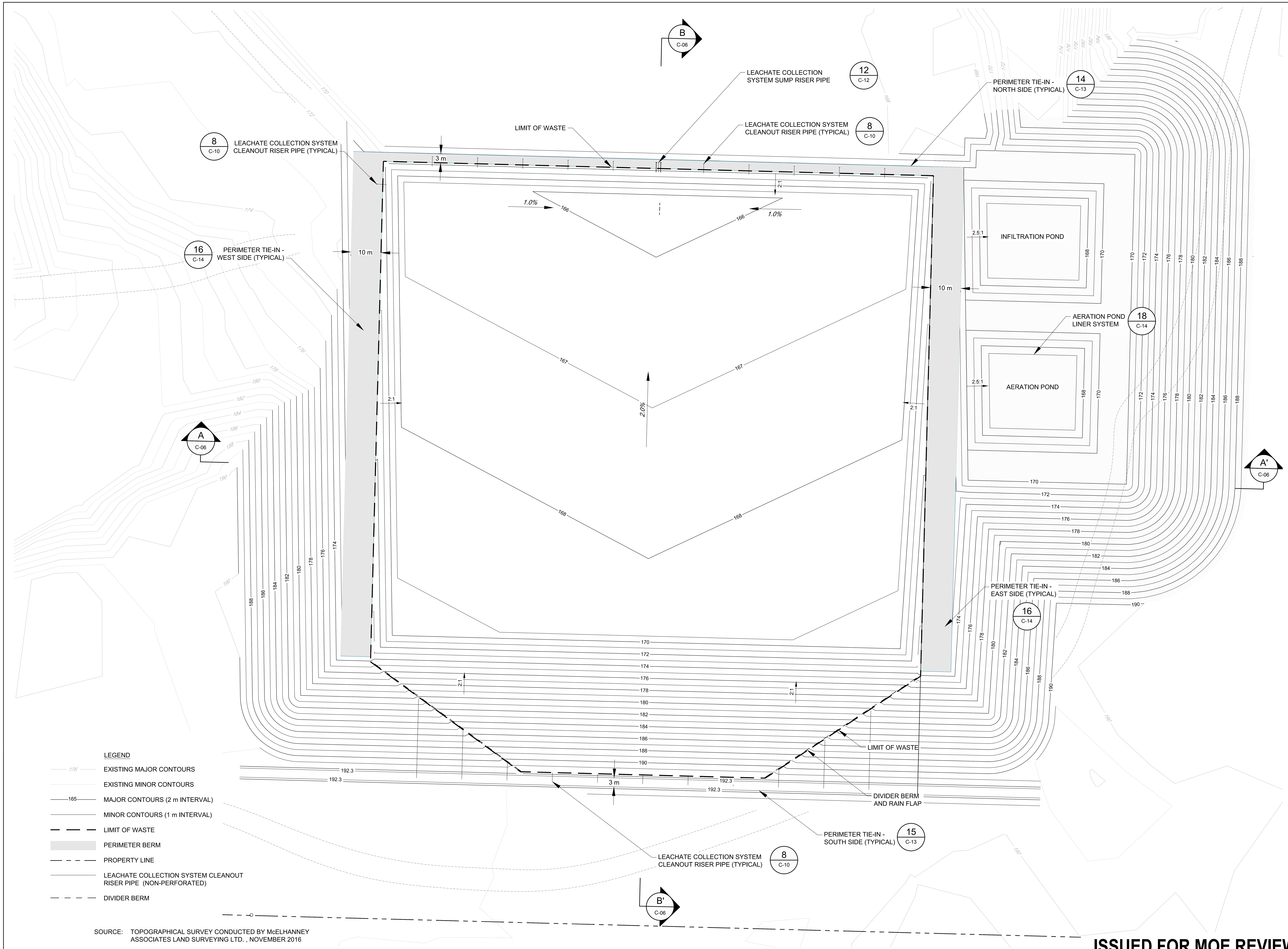
Project No. 88877-03

Title
BASE / LINER GRADES

Sheet No.
C-03

Sheet 4 of 15

Plot Date: 29 May 2017 - 5:08 PM Plotted By: Tyler Wagstaff CAD File: P:\drawings\88000s\88877\88877 - REPORTS\88877-03(010)\88877-03(010)CI\88877-03(010)CI-WA003.dwg



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2017 DESIGN, OPERATIONS AND CLOSURE PLAN

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Drafting Check	D. BARTON	Design Check	S.STURGEON
Project Manager	G. FERRARO	Date	MAY 2017
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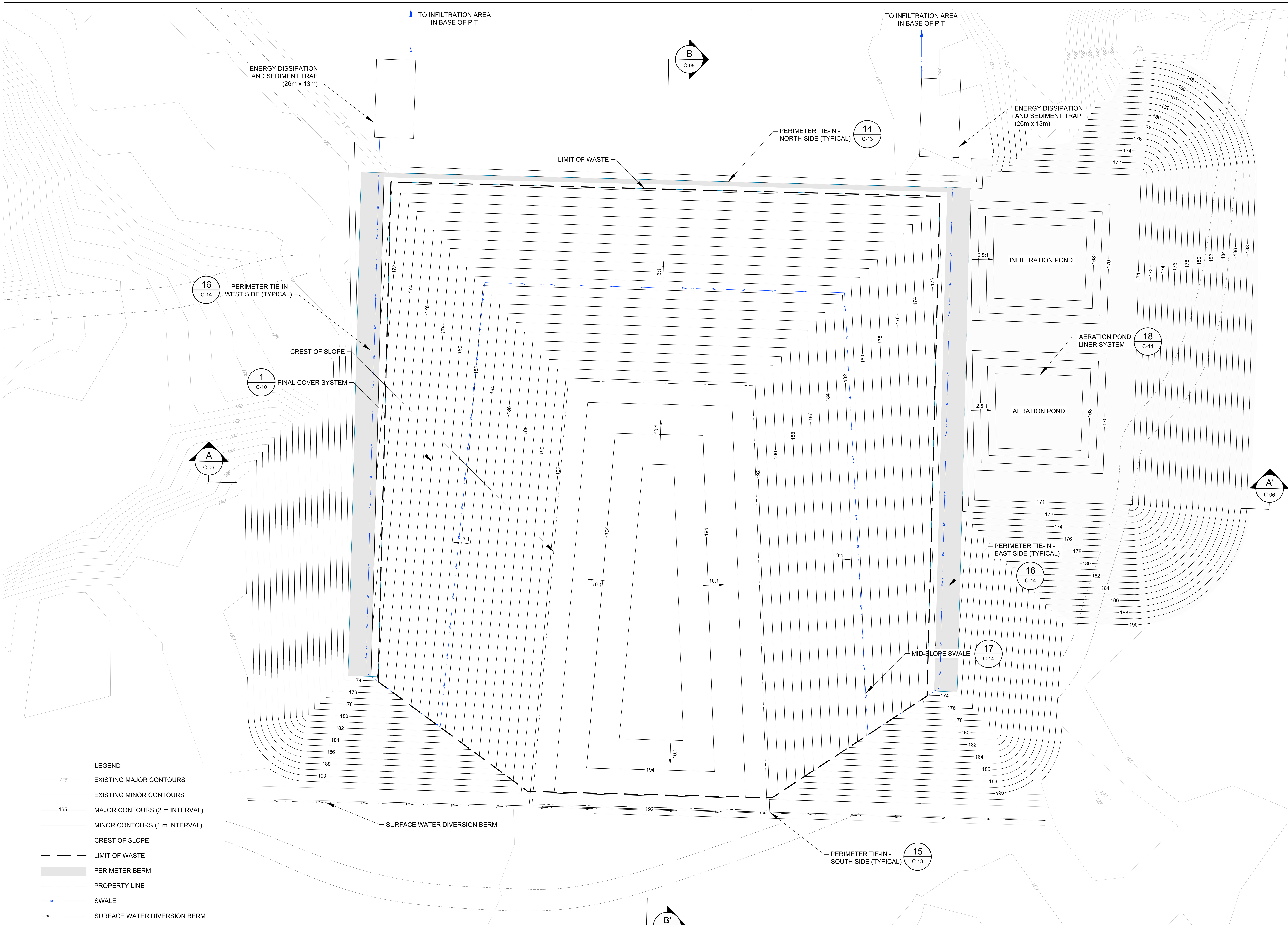
Project No. **88877-03**

Title
LEACHATE COLLECTION SYSTEM (TOP OF GRANULAR DRAINAGE BLANKET)

Sheet No.
C-04

Sheet 5 of 15

Plot Date: 29 May 2017 - 5:11 PM Plotted By: Tyler Wagstaff CAD File: P:\drawings\88000s\88877\88877 - REPORTS\88877-03(010)\88877-03(010)CI\88877-03(010)CI-WA004.dwg



SOURCE: TOPOGRAPHICAL SURVEY CONDUCTED BY McELHANNEY ASSOCIATES LAND SURVEYING LTD. , NOVEMBER 2016

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Drafting Check	D. BARTON	Design Check	S.STURGEON
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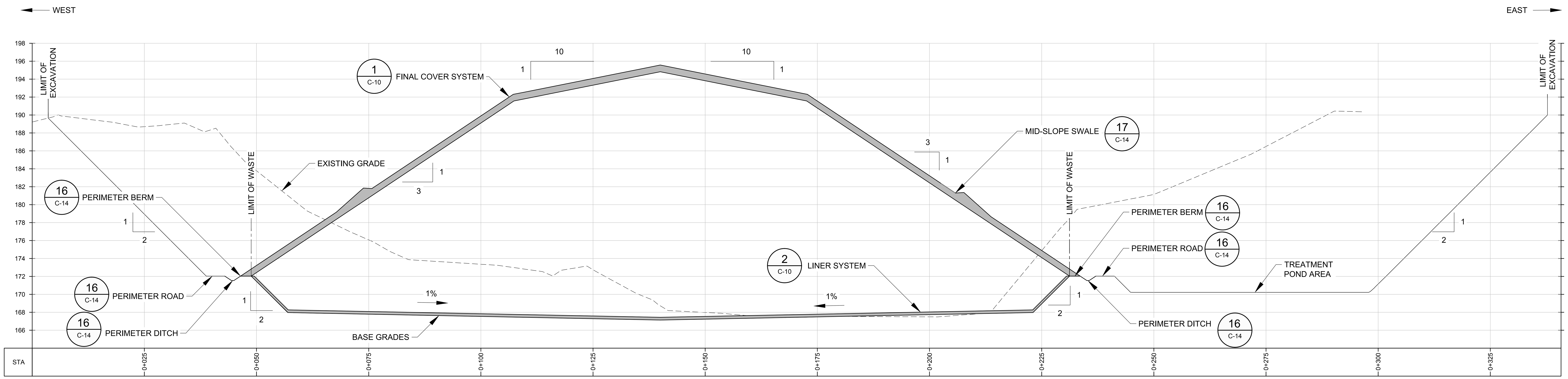
Project No. 88877-03

Title
FINAL GRADES (TOP OF FINAL COVER)

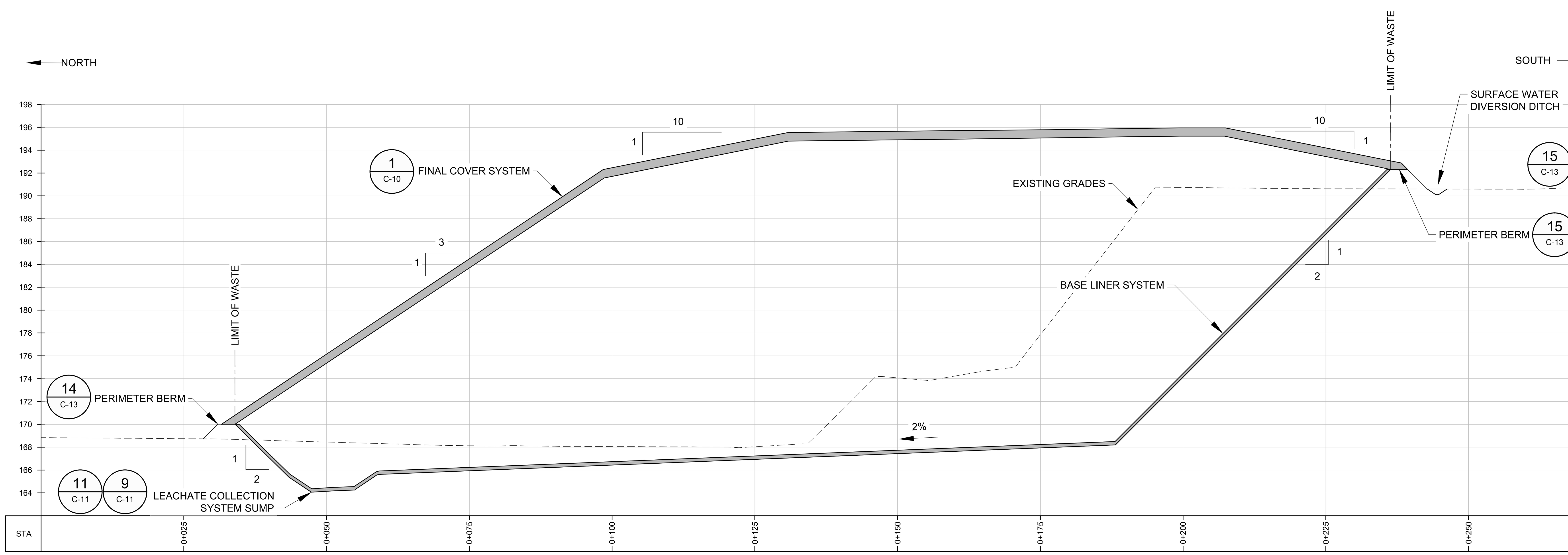
Sheet No.
C-05

Sheet 6 of 15

Plot Date: 29 May 2017 - 5:51 PM Plotted By: Tyler Wagstaff CAD File: P:\drawings\88000s\88877\88877 - REPORTS\88877-03(010)\88877-03(010)CI\88877-03(010)CI-WA005.dwg



SECTION A-A' C-2B
HORZ: 1:500
VERT: 1:250



SECTION B-B' C-2B
HORZ: 1:500
VERT: 1:250

SOURCE: TOPOGRAPHICAL SURVEY CONDUCTED BY McELHANNEY ASSOCIATES LAND SURVEYING LTD. , NOVEMBER 2016

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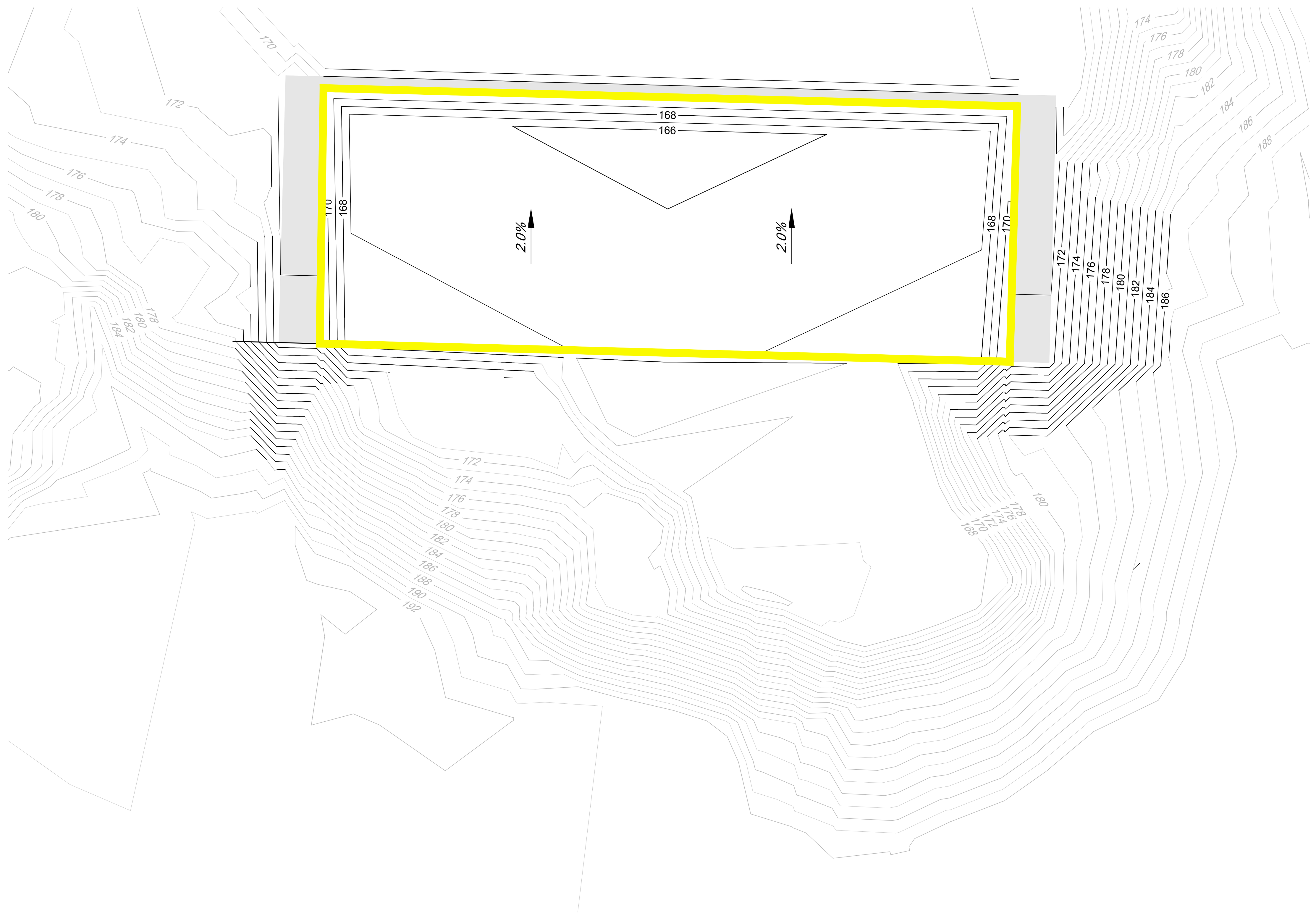
Project No. 88877-03

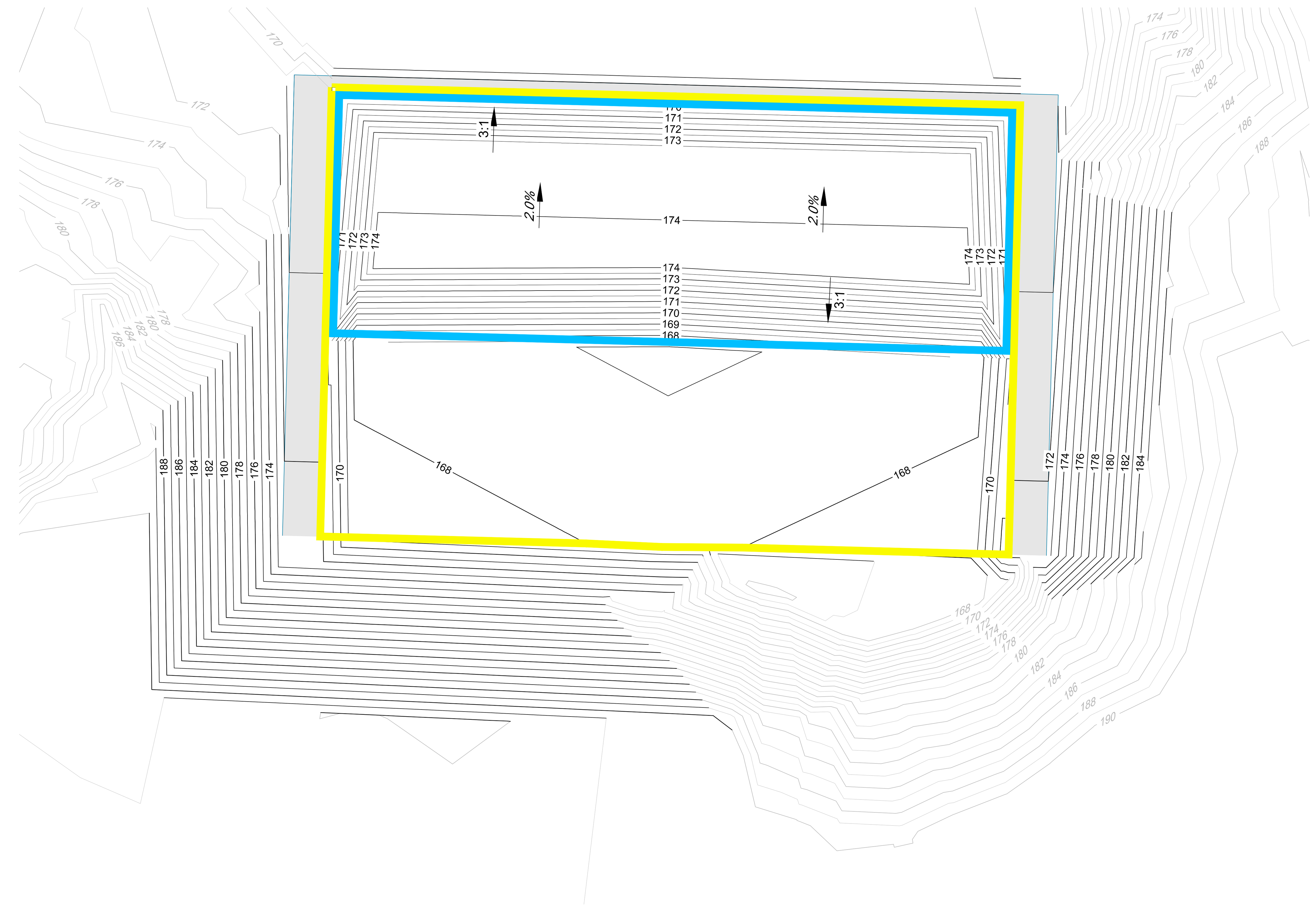
Title
CROSS-SECTIONS

Sheet No.
C-06

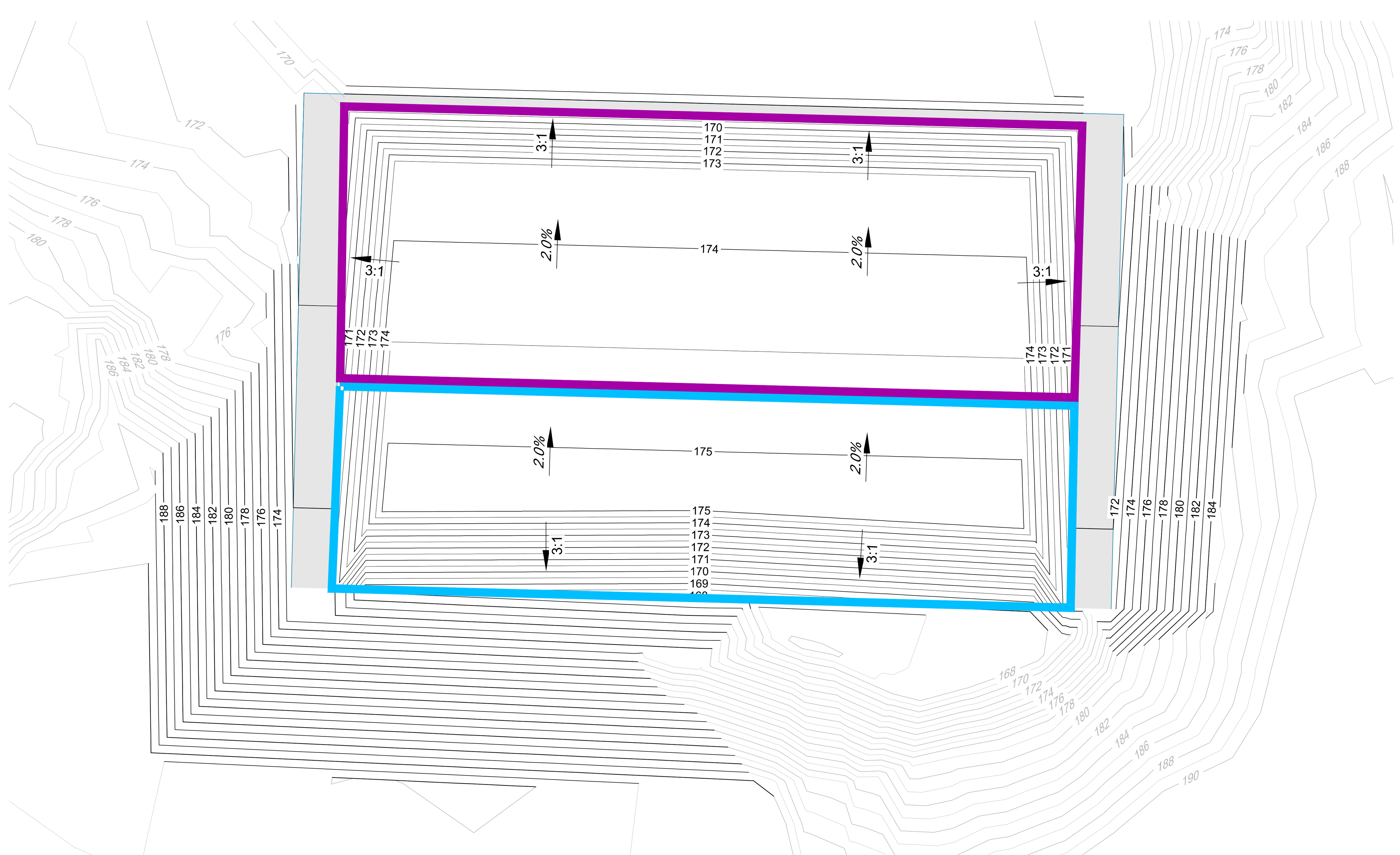
Sheet 7 of 15



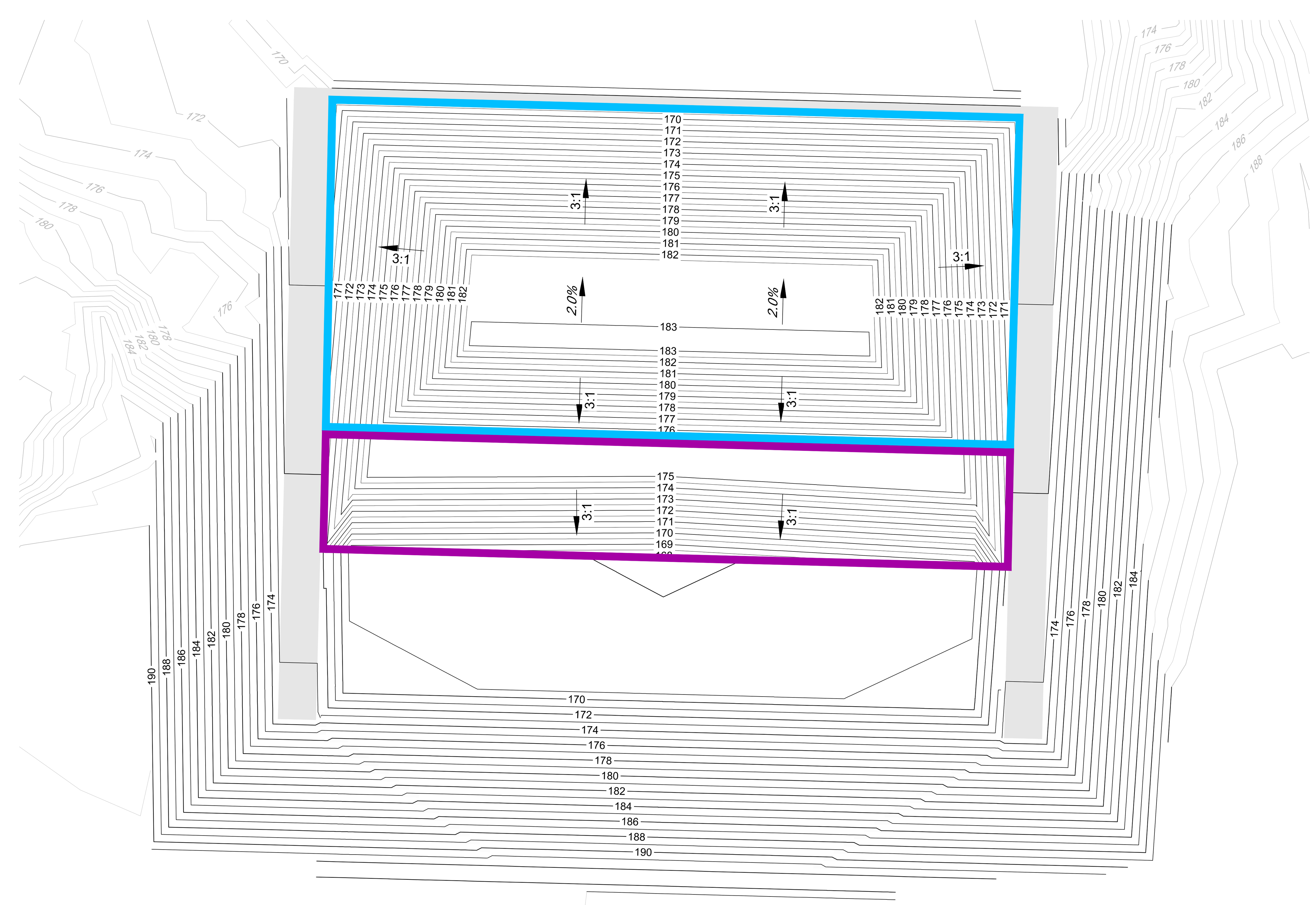
PHASE I



PHASE I: STAGE 1A



PHASE I: STAGE 1B



PHASE I: STAGE 1C

LEGEND

- BASE LINER AREA
- DAILY COVER AREA
- INTERMEDIATE COVER AREA
- FINAL COVER AREA

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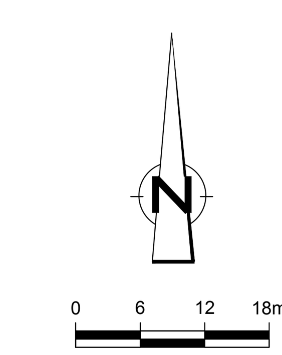

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Project Manager **G. FERRARO**	Date **MAY 2017**
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Title
FILL PLAN
PHASE 1: STAGE 1A - 1C

Sheet No.
C-07

Sheet 8 of 15

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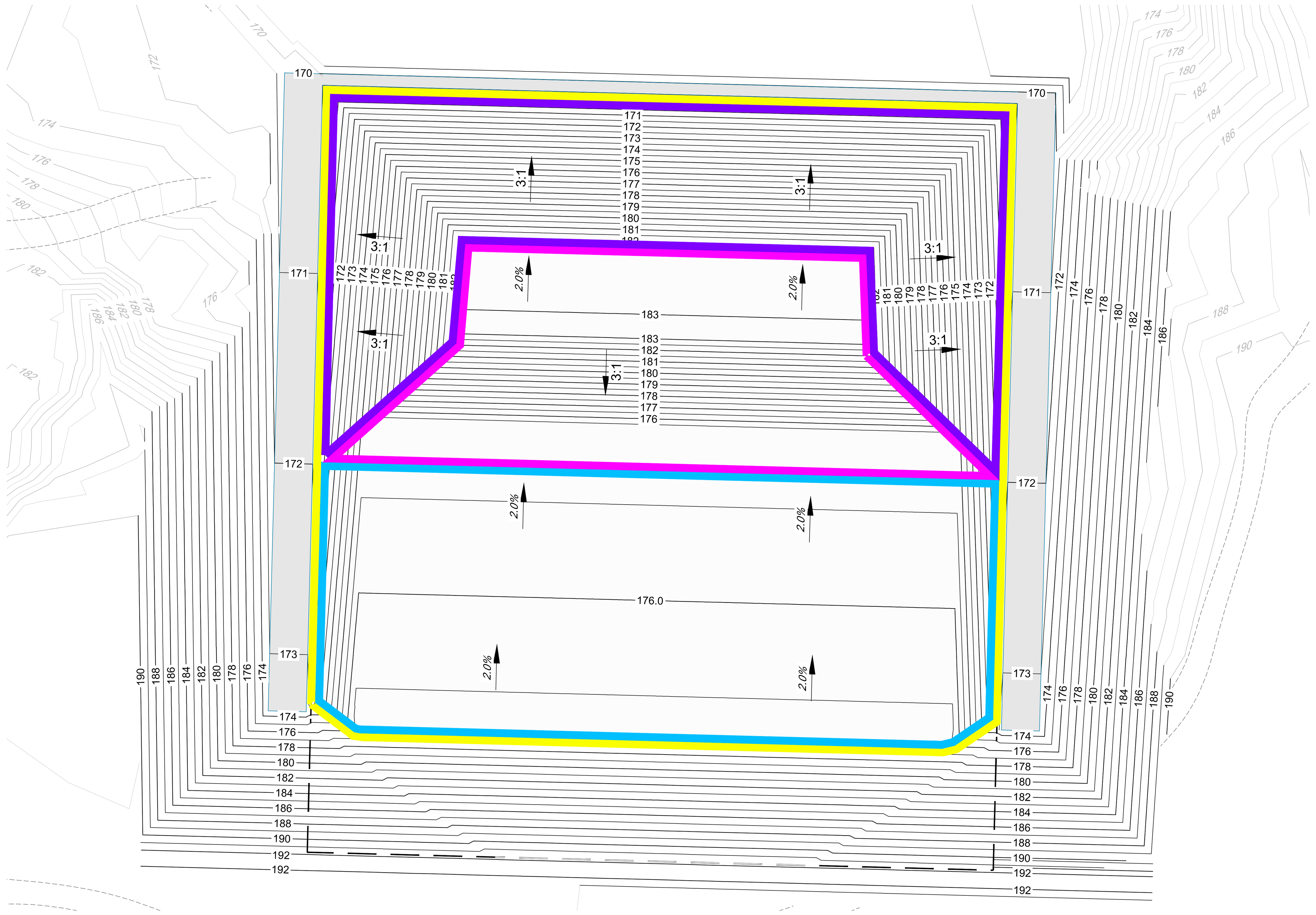
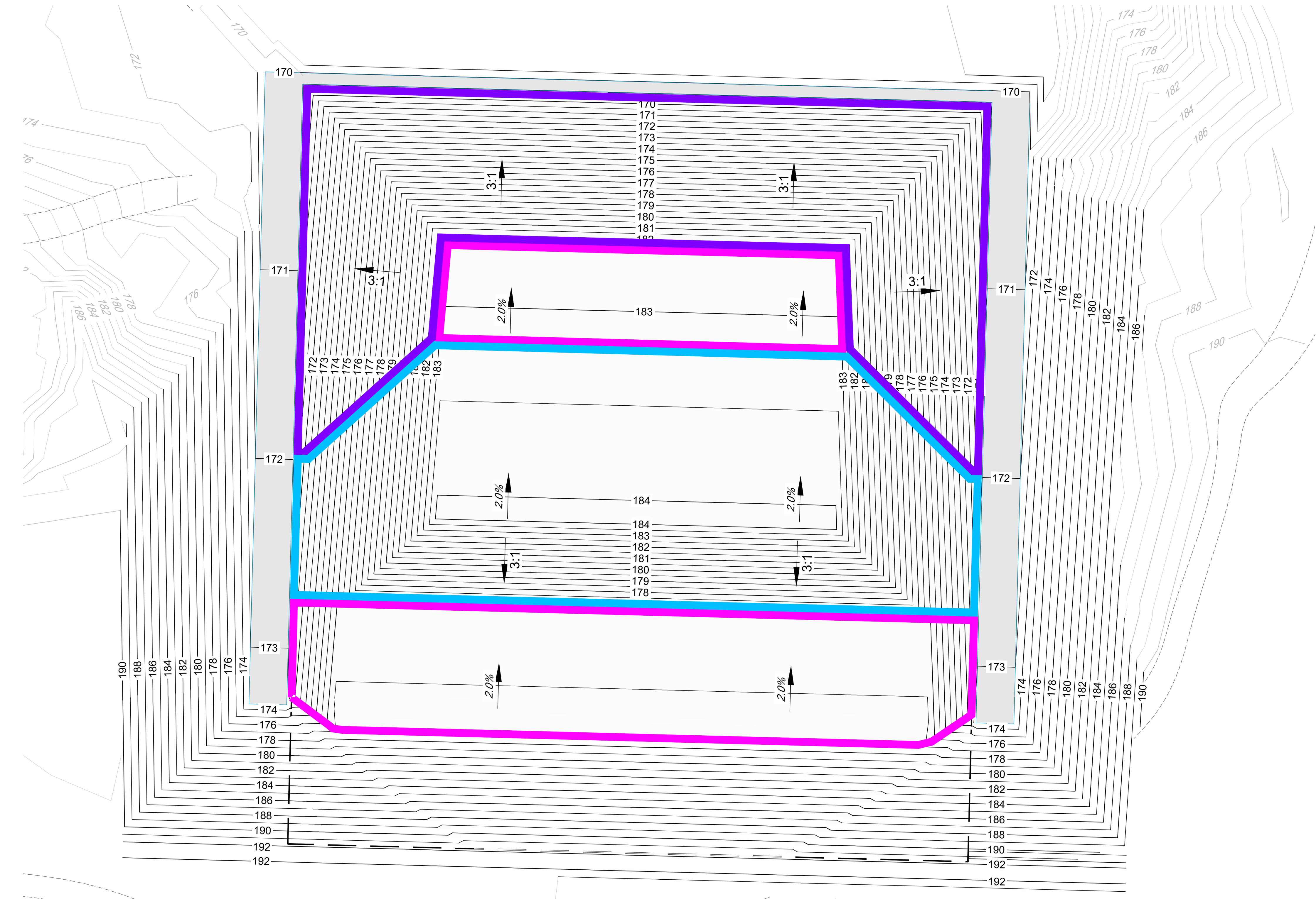
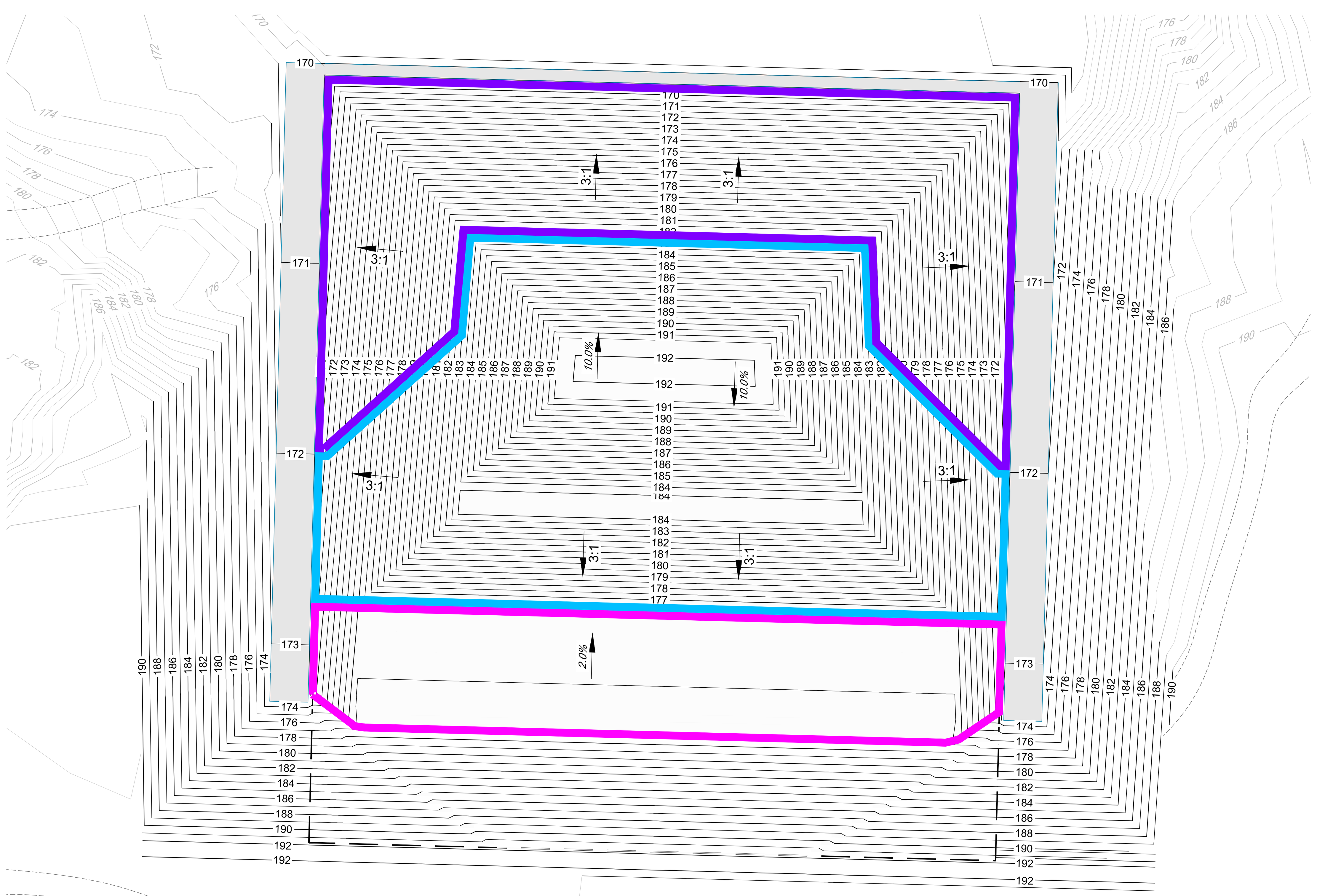


PHASE II: STAGE 2A



PHASE II: STAGE 2B



PHASE II: STAGE 2C

LEGEND

- BASE LINER AREA
- DAILY COVER AREA
- INTERMEDIATE COVER AREA
- FINAL COVER AREA

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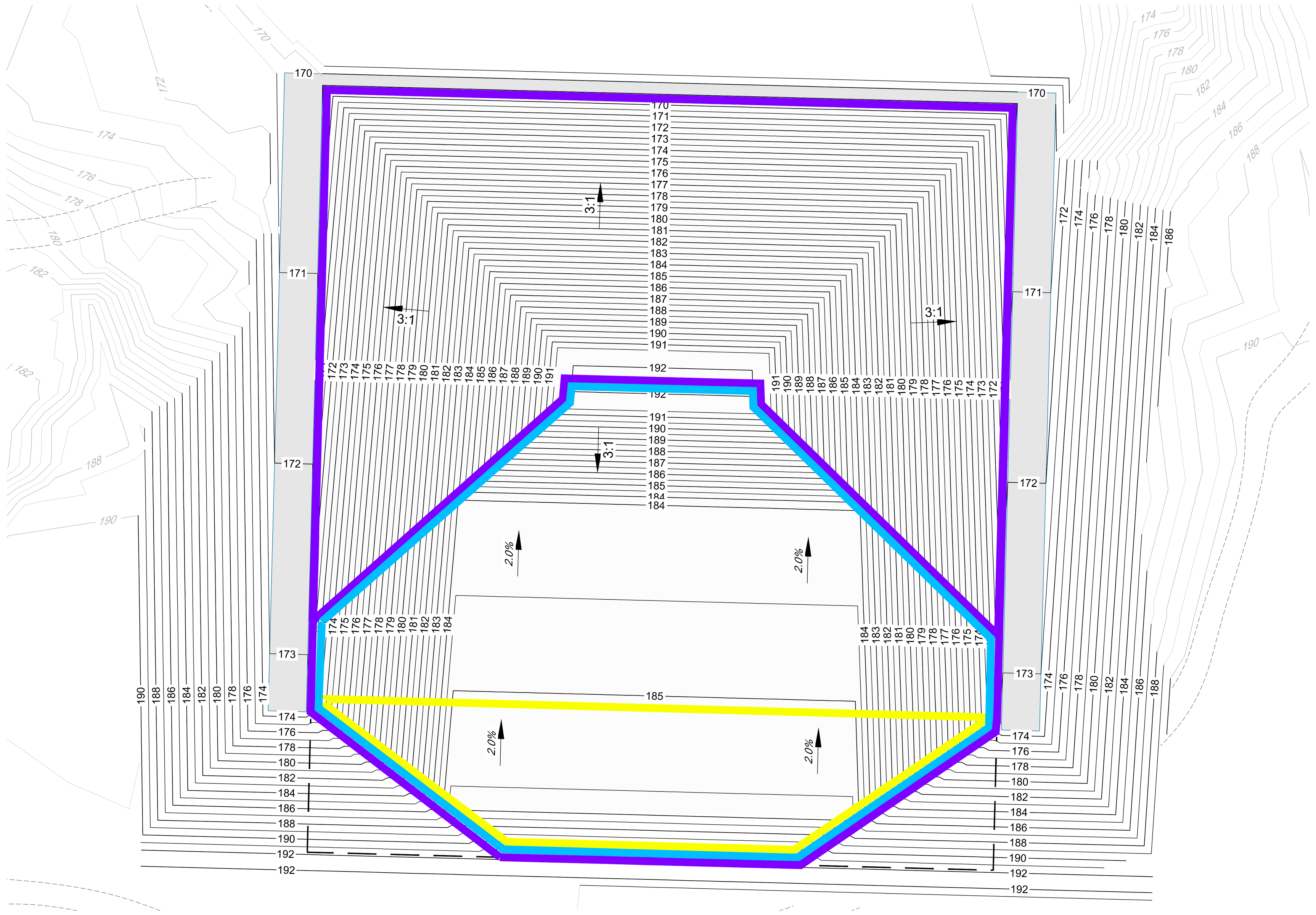
Project No. 88877-03

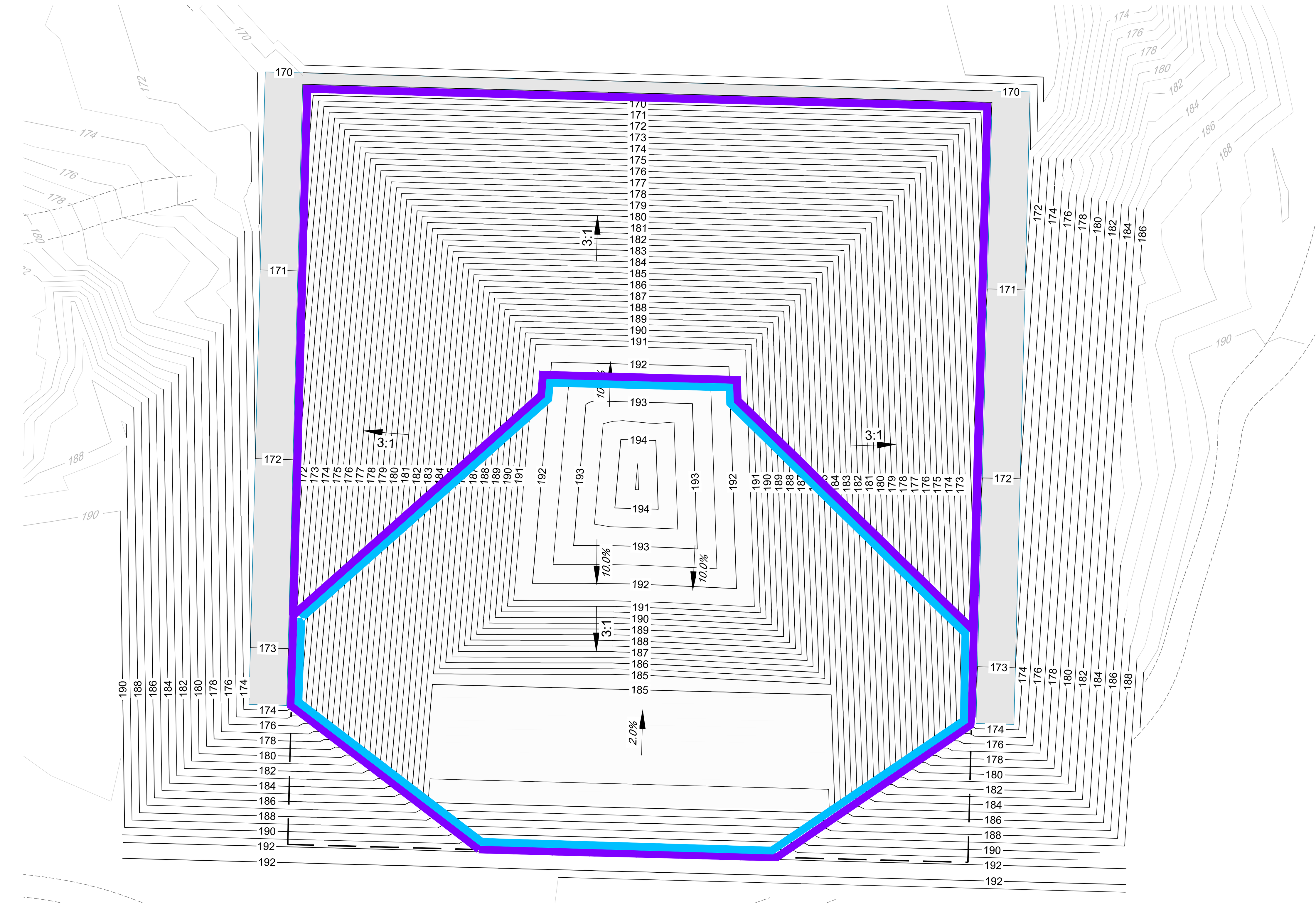
Title
FILL PLAN
PHASE II: STAGE 2A - 2C

Sheet No.
C-08

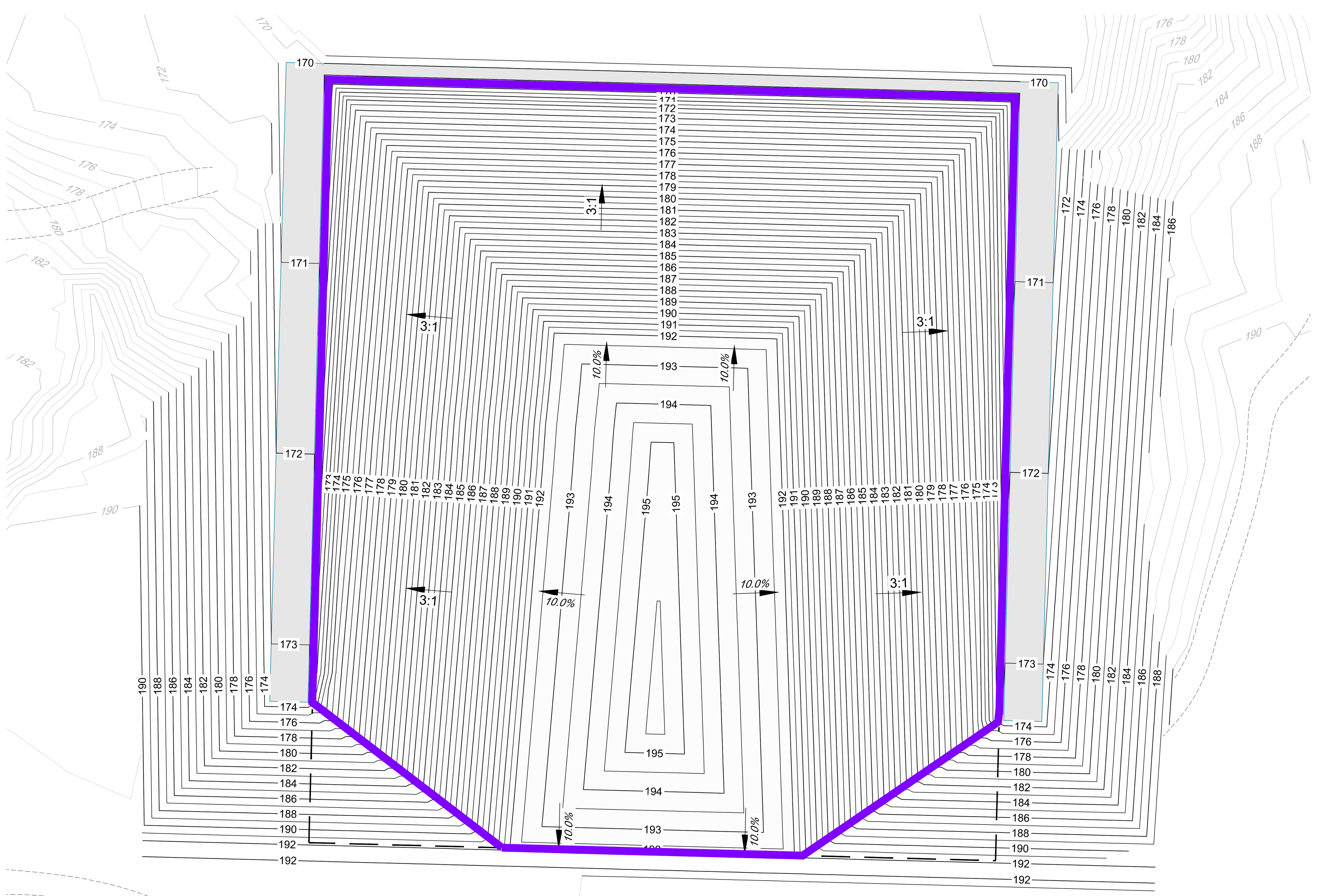
Plot Date: 29 May 2017 - 5:17 PM Plotted By: Tyler Wagstaff CAD File: P:\drawings\88000s\88877\88877 - REPORTS\88877-03(010)\88877-03(010)CI\88877-03(010)CI-WA008.dwg



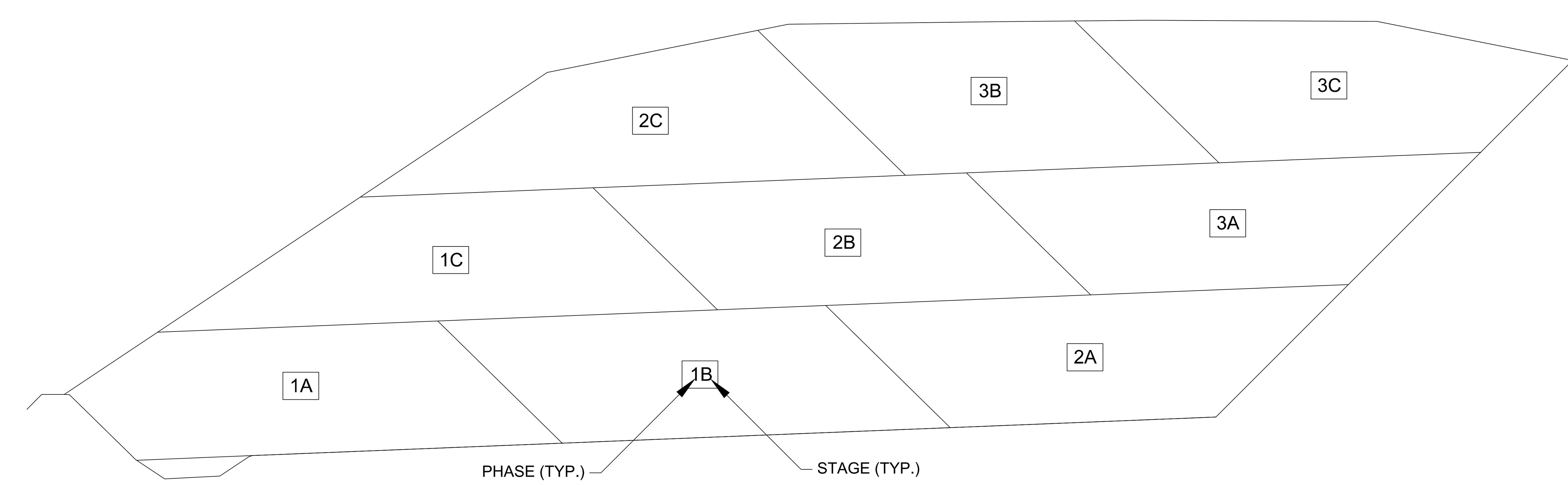
PHASE III: STAGE 3A



PHASE III: STAGE 3B



PHASE III: STAGE 3C



FILL SEQUENCE

HOR. SCALE 1:600
VERT. SCALE 1:300

LEGEND

BASE LINER AREA

DAILY COVER AREA

INTERMEDIATE COVER AREA

FINAL COVER AREA

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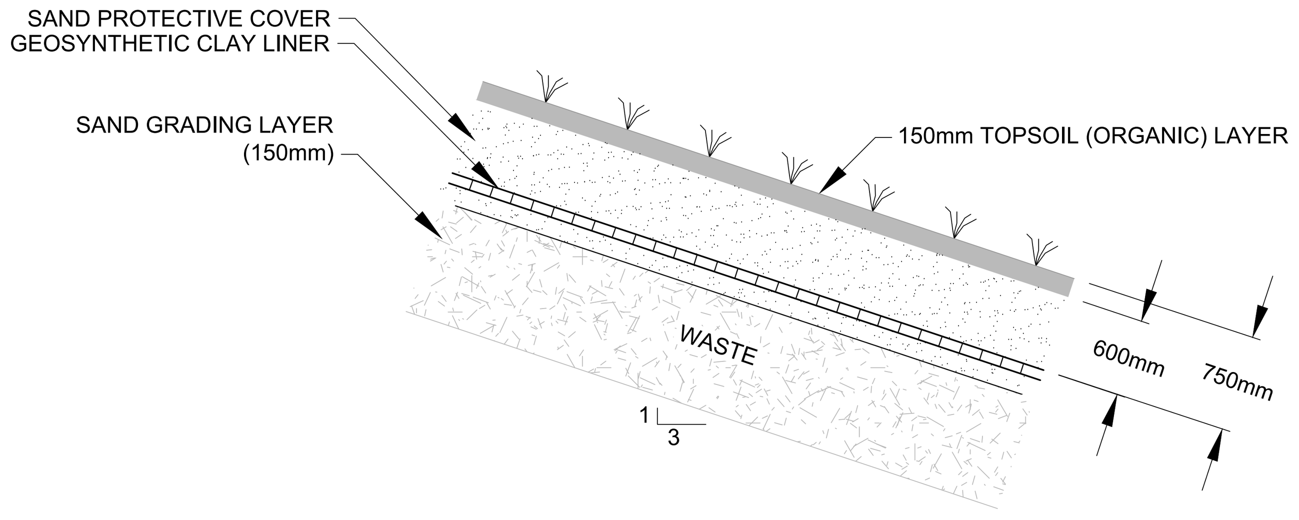
Project No. **88877-03**

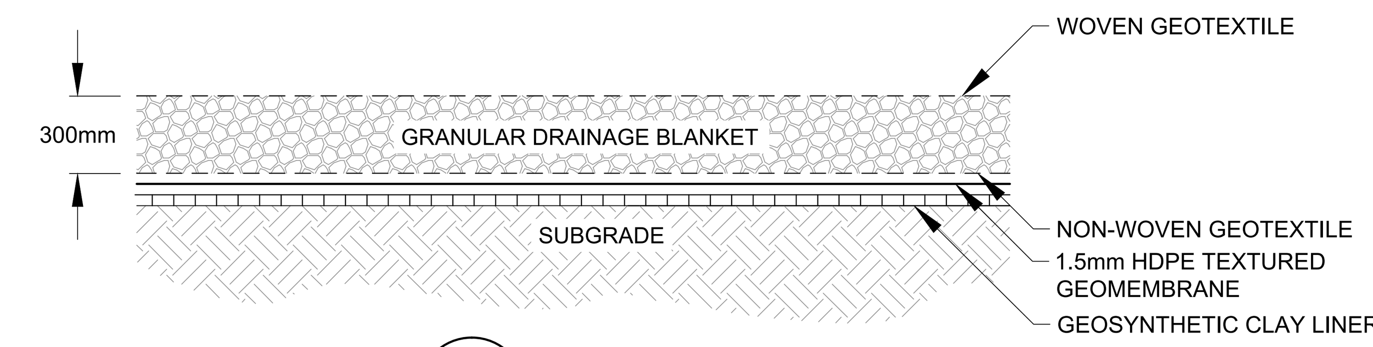
Title
FILL PLAN
PHASE III: STAGE 3A - 3C

Sheet No.
C-09

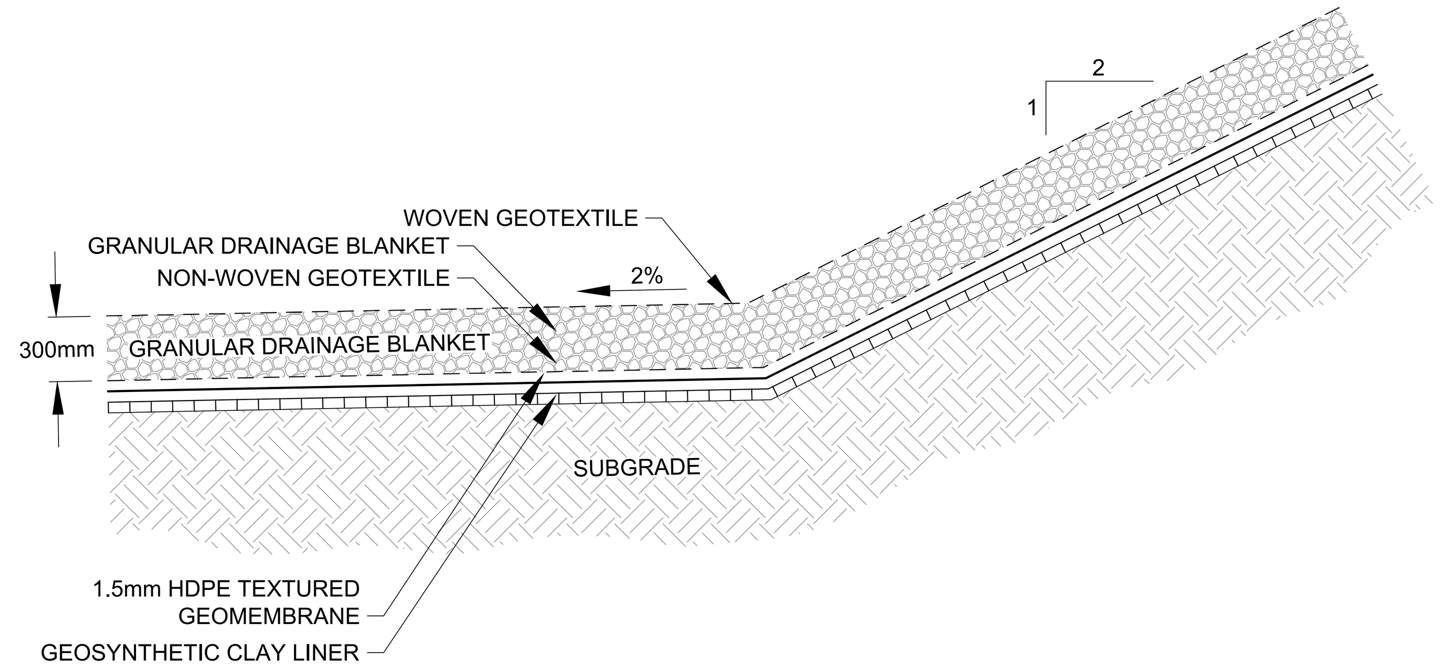
Sheet **10** of **15**



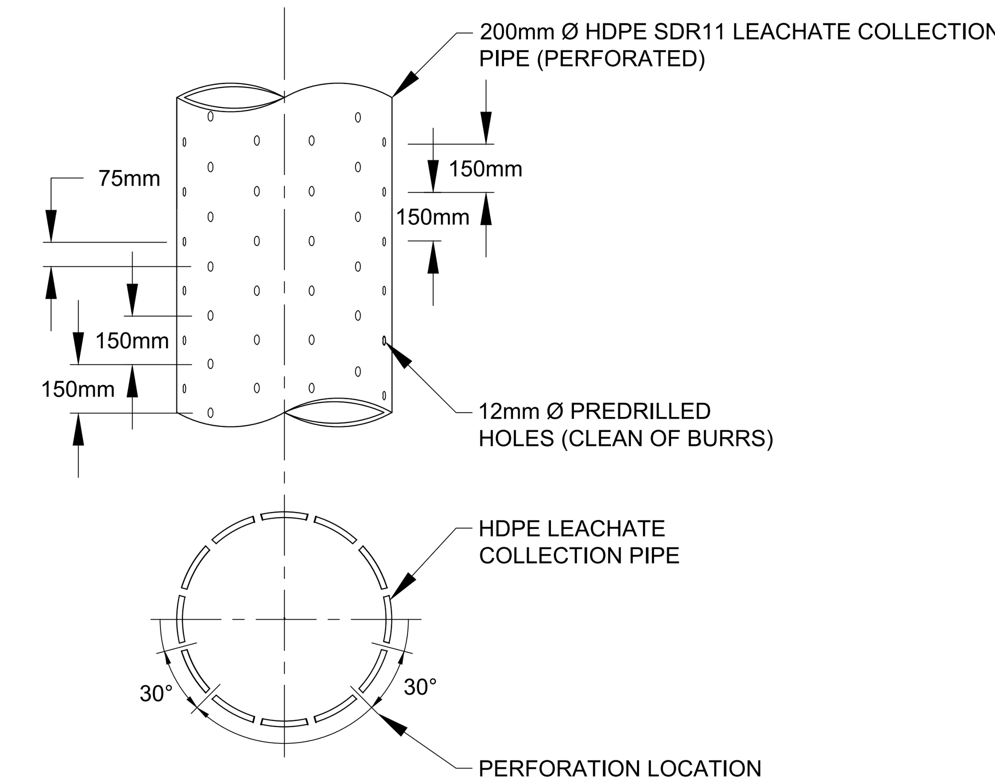
DETAIL 1 FINAL COVER SYSTEM
1:50 C-05



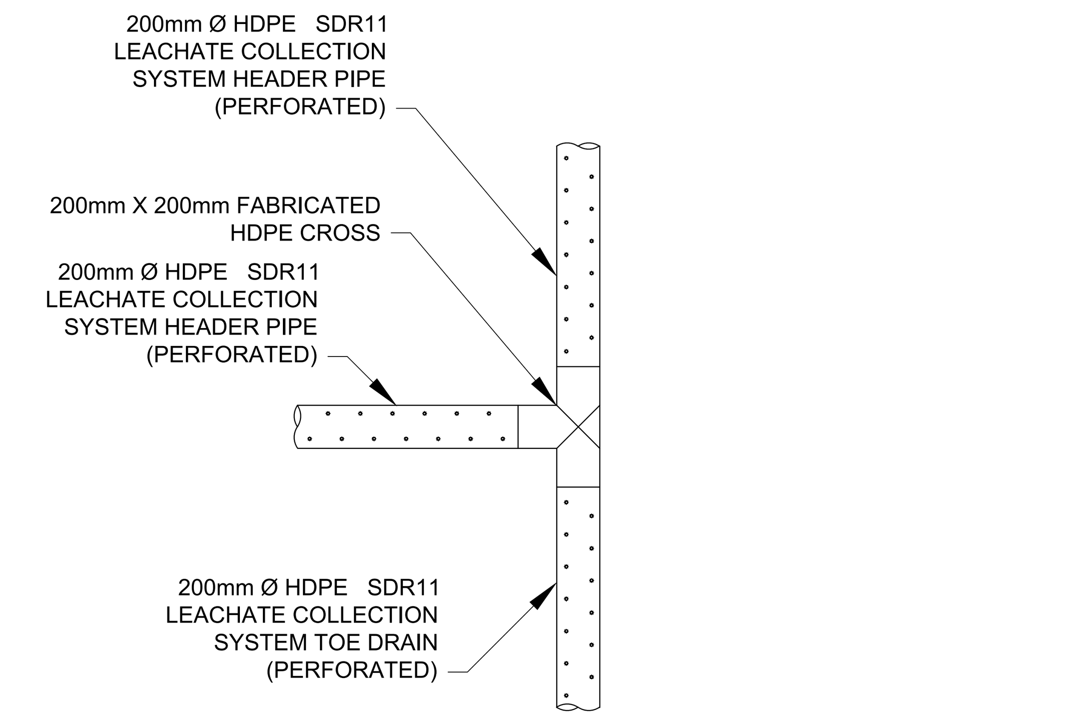
DETAIL 2 BASE LINER SYSTEM
1:25 C-2B



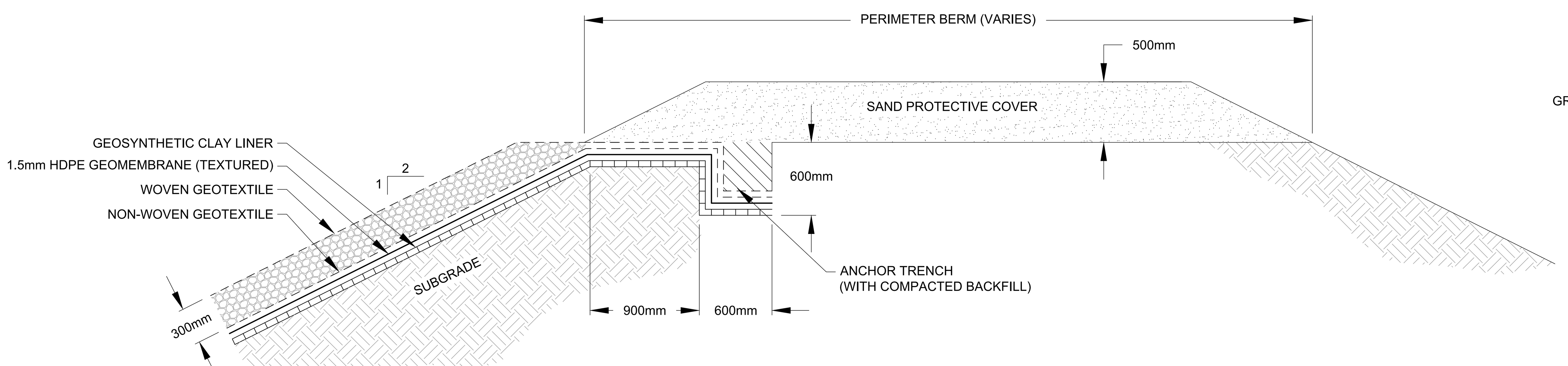
DETAIL 3 LINER SYSTEM (TOE OF SLOPE)
1:30 C-2B



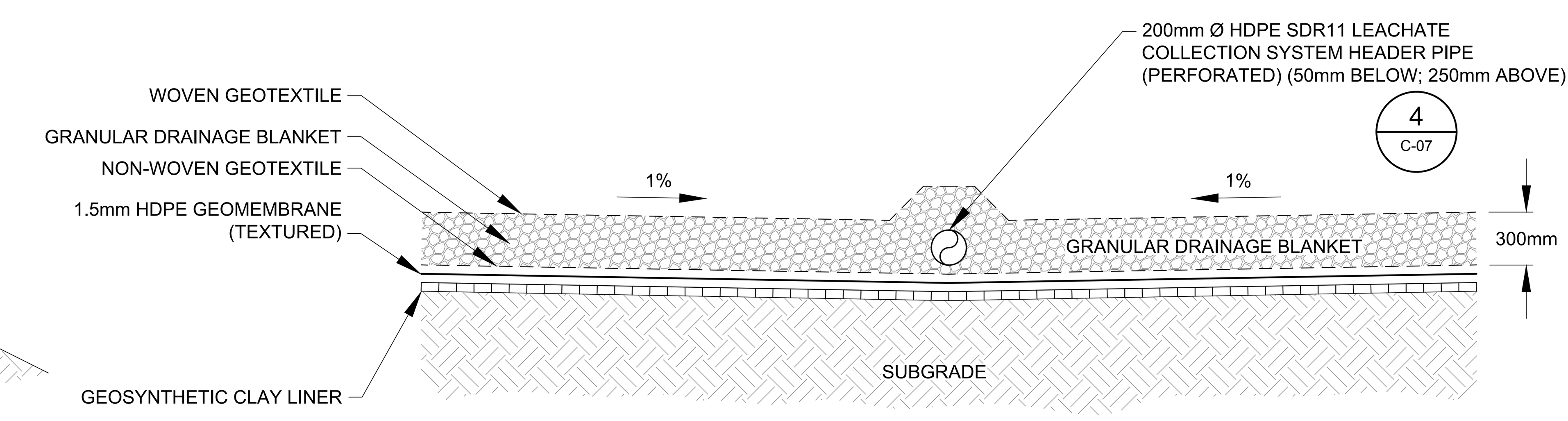
DETAIL 4 LEACHATE COLLECTION SYSTEM TOE DRAIN / LEACHATE COLLECTION SYSTEM PIPE PERFORATIONS
N.T.S. C-03



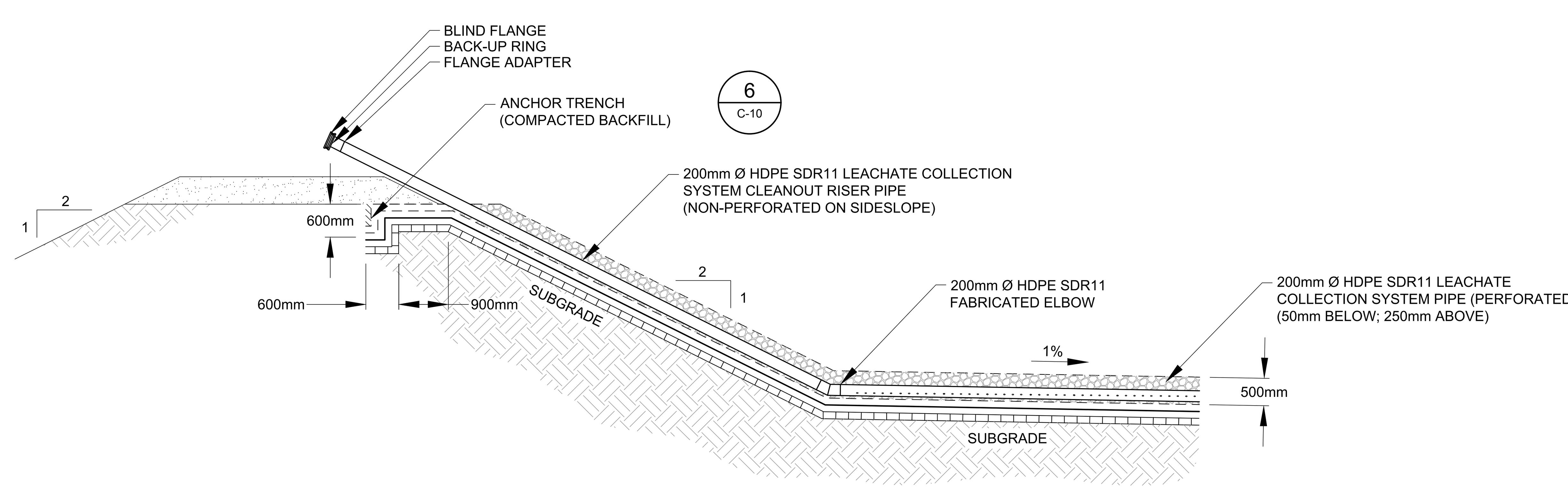
DETAIL 5 LEACHATE COLLECTION SYSTEM TOE DRAIN / LEACHATE COLLECTION SYSTEM PIPE CONNECTION
1:30 C-03



DETAIL 6 ANCHOR TRENCH (TYPICAL)
1:30 C-03



DETAIL 7 LEACHATE COLLECTION SYSTEM TOE DRAIN / LEACHATE COLLECTION SYSTEM PIPE PERFORATIONS
1:30 C-03



DETAIL 8 LEACHATE COLLECTION SYSTEM CLEANOUT RISER PIPE (TYPICAL)
1:75 C-03

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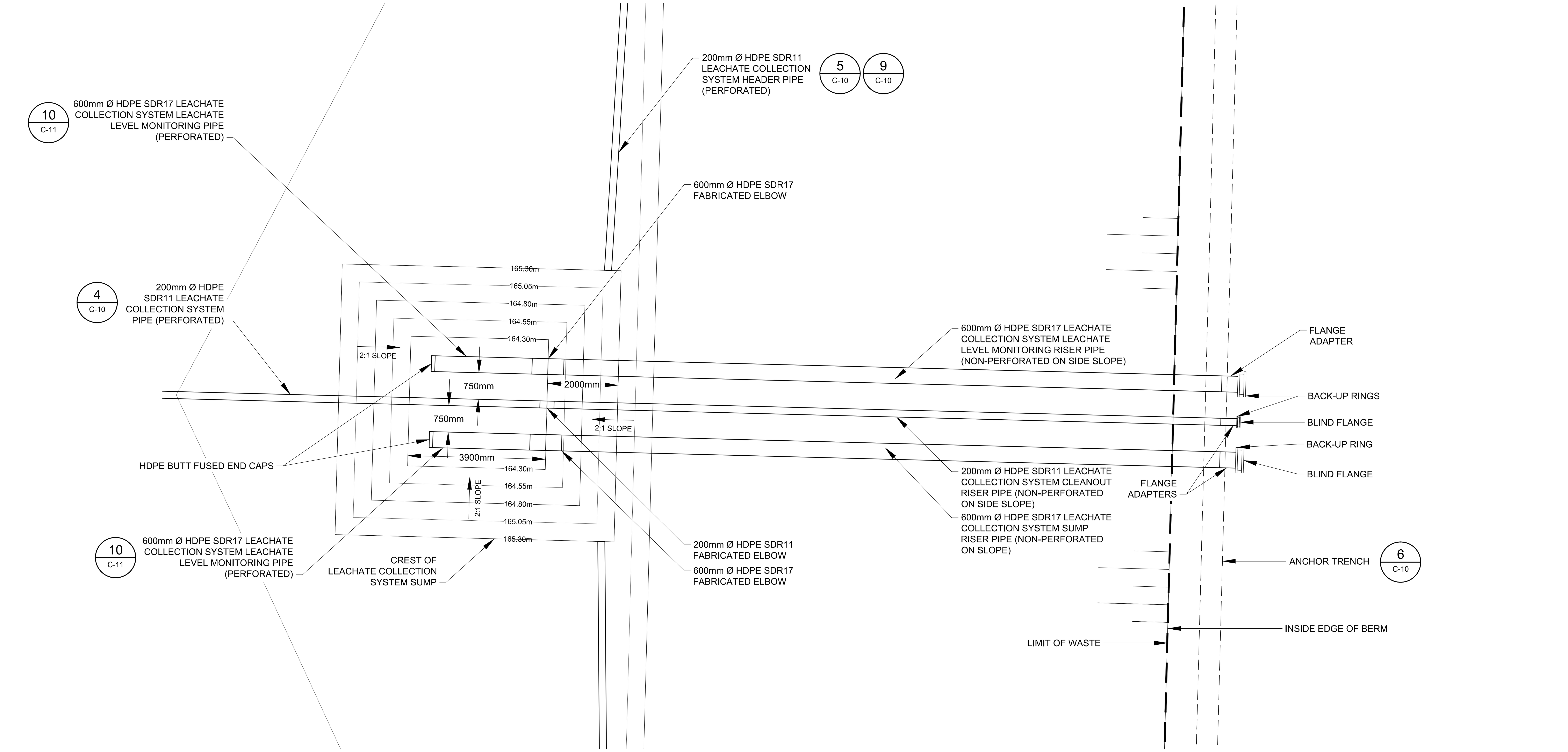
Title
LINER AND LEACHATE COLLECTION SYSTEM DETAILS

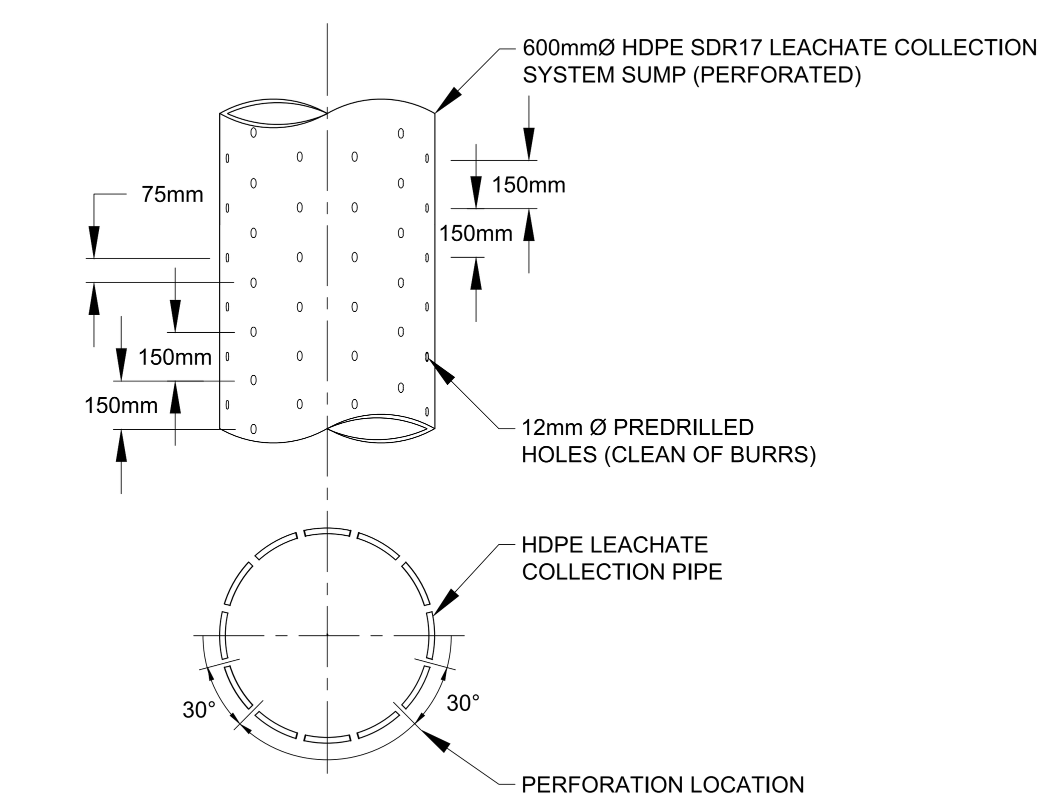
Sheet No.
C-10

Sheet 11 of 15

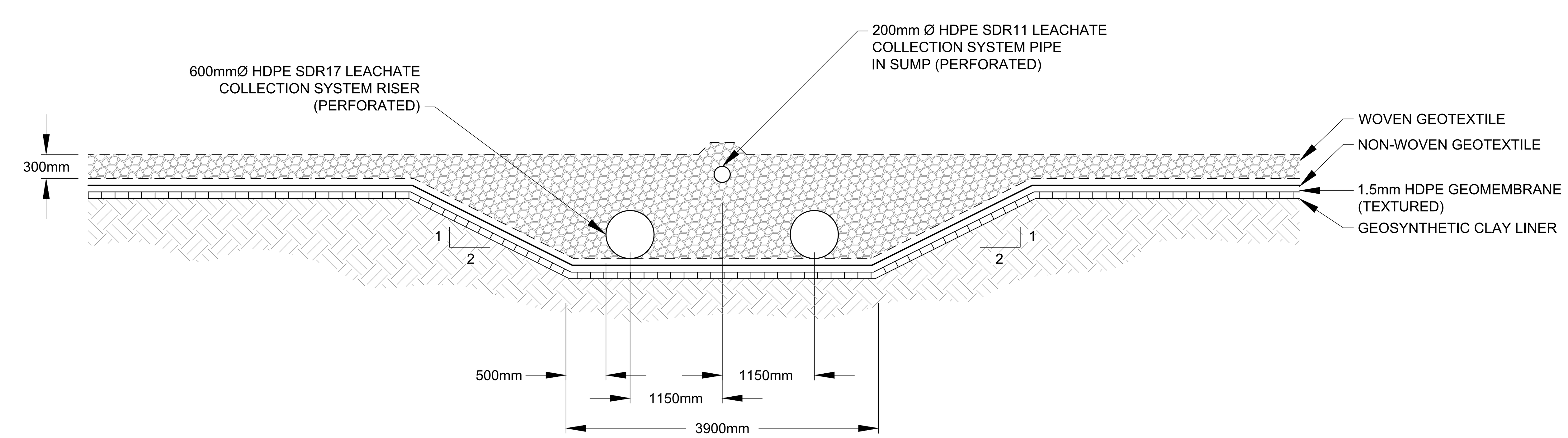
Plot Date: 29 May 2017 - 5:22 PM Plotted By: Tyler Wagstaff CAD File: P:\drawings\88000s\88877\88877 - REPORTS\88877-03(010)\88877-03(010)CI\88877-03(010)CI-WA010.dwg



DETAIL 9 LEACHATE COLLECTION SYSTEM SUMP (TYPICAL) (TOP OF LINER)
1:75 C-03



DETAIL 10 600mmØ LEACHATE COLLECTION SYSTEM SUMP PIPE PERFORATIONS
NTS C-03



DETAIL 11 LEACHATE COLLECTION SYSTEM SUMP
1:50 C-03

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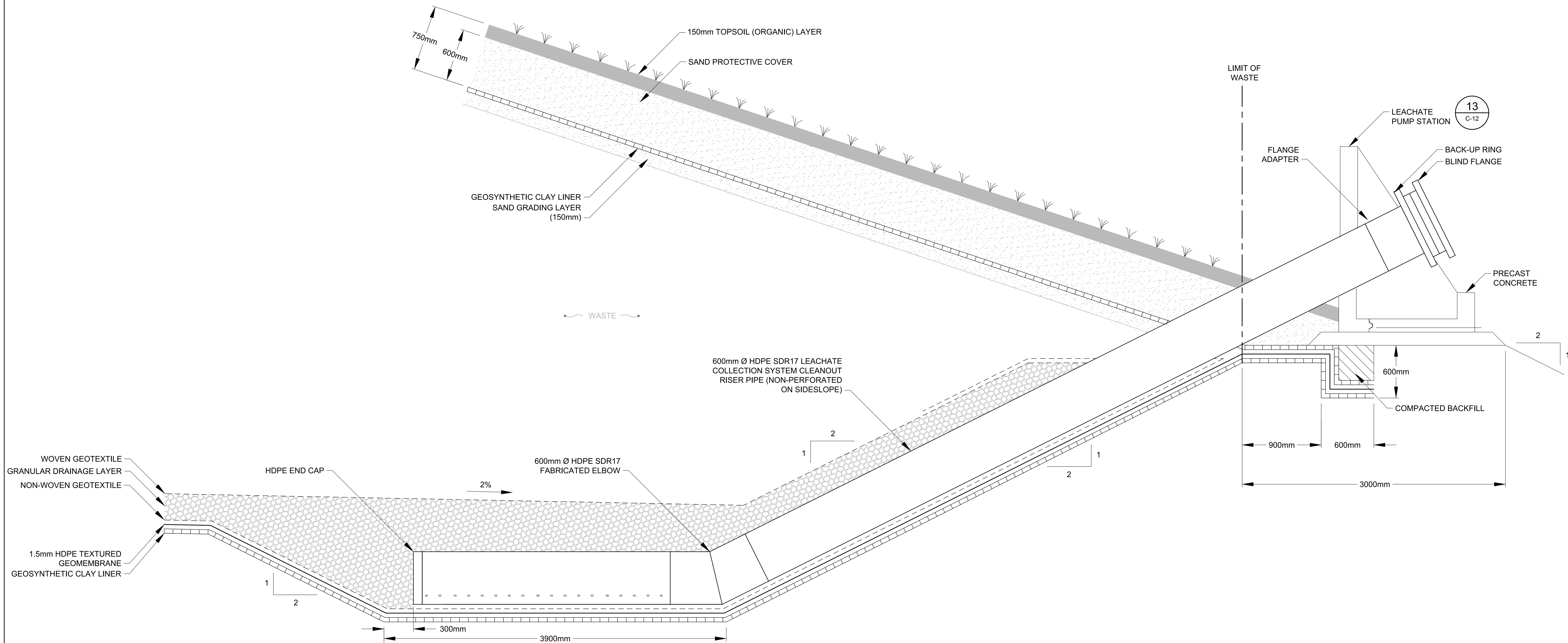
Project No. 88877-03

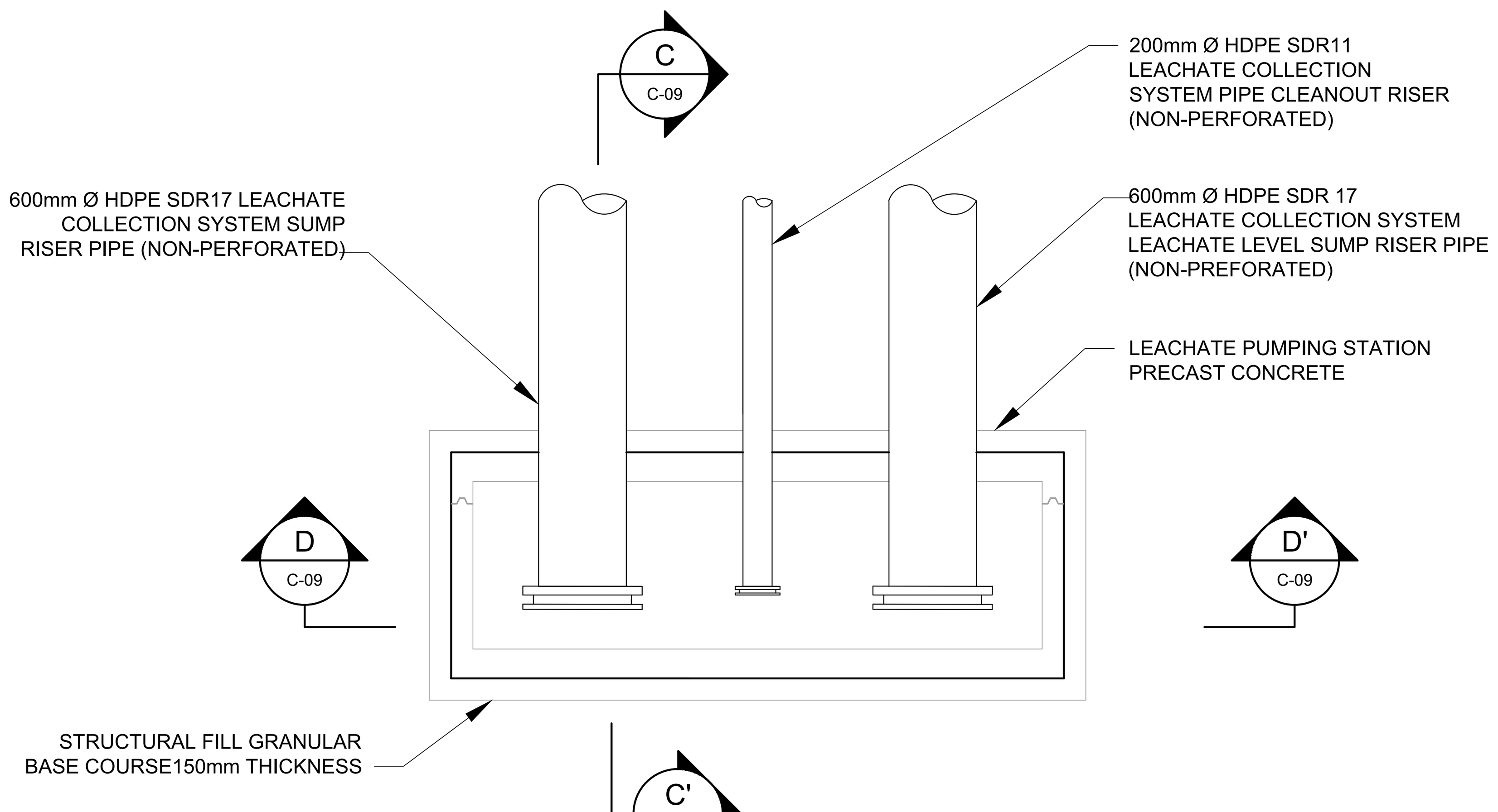
Title
LEACHATE COLLECTION SYSTEM SUMP AND RISERS I

Sheet No.
C-11

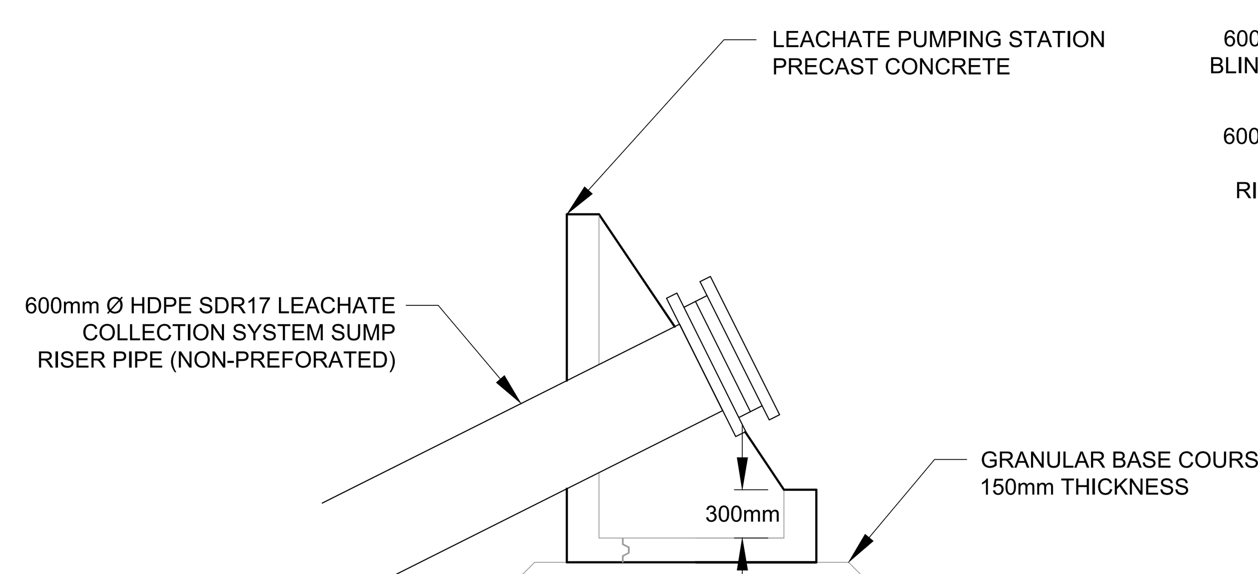
Sheet 12 of 15



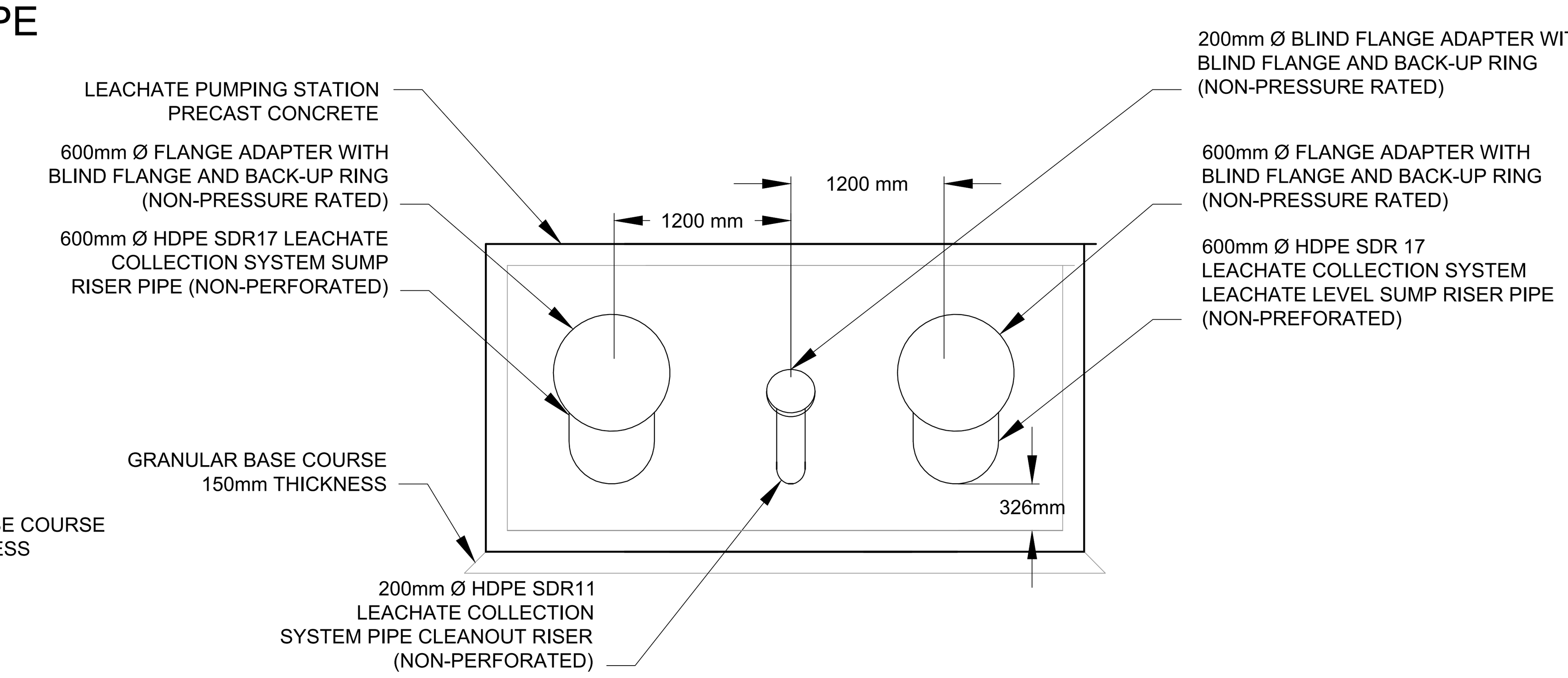
DETAIL 12 (C-03) LEACHATE COLLECTION SYSTEM SUMP, SUMP RISER PIPE, AND LEACHATE LEVEL MONITORING PIPE
1:25



DETAIL 13 (C-12) LEACHATE PUMP STATION (PLAN VIEW)
1:40



SECTION C-C' (C-12)
1:40



SECTION D-D' (C-12)
1:40

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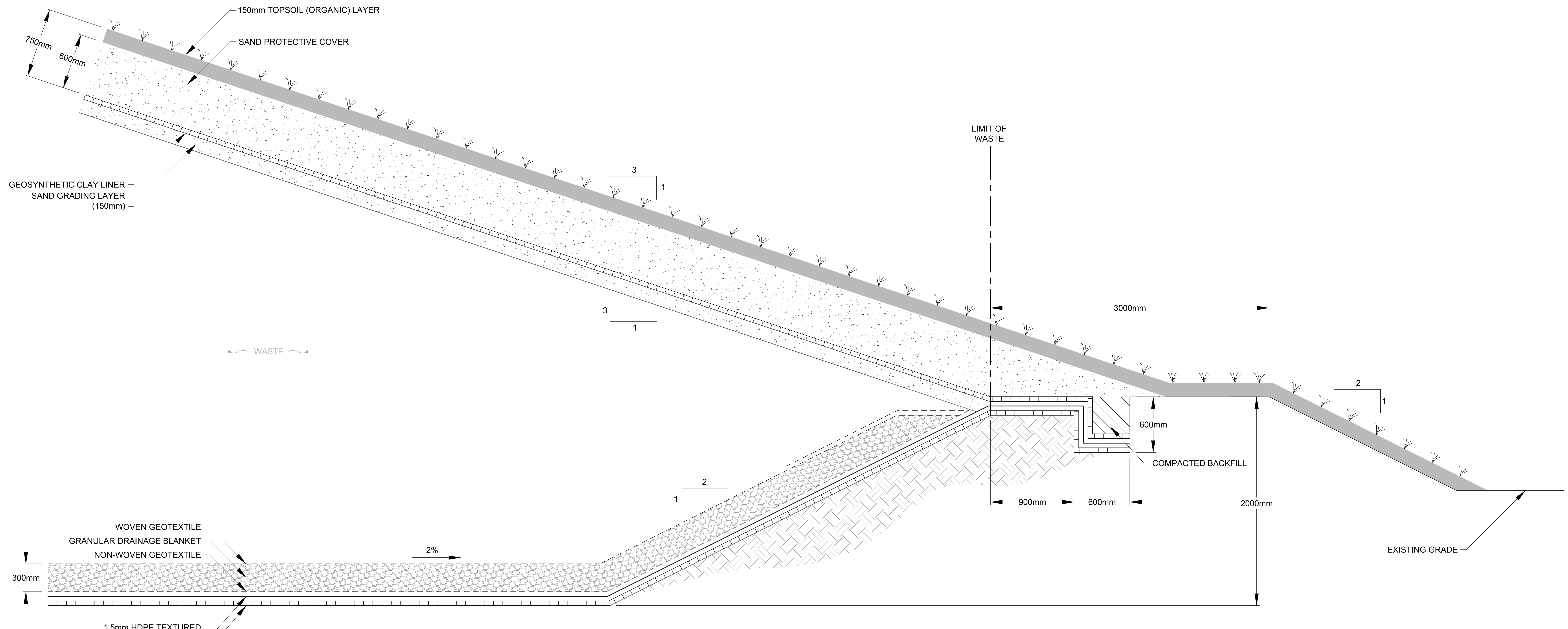
Project No. 88877-03

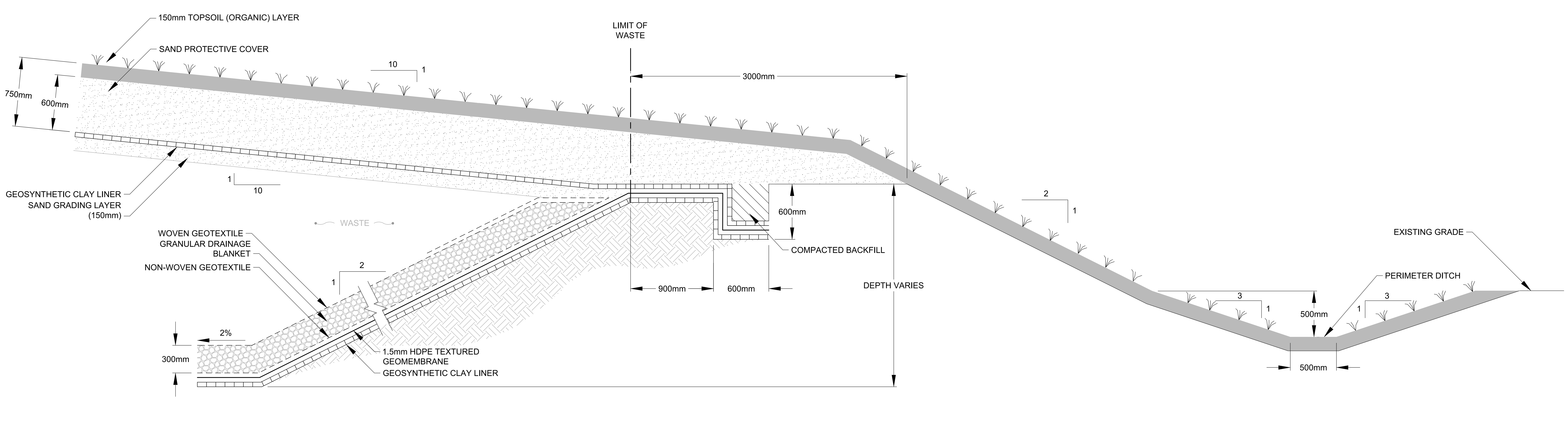
Title
LEACHATE COLLECTION SYSTEM SUMP AND RISERS II

Sheet No.
C-12

Sheet 13 of 15



DETAIL 14 PERIMETER TIE-IN DETAIL ON NORTH SIDE (TYPICAL)
1:25 C-2B



DETAIL 15 PERIMETER TIE-IN DETAIL ON SOUTH SIDE (TYPICAL)
1:25 C-2B

ISSUED FOR MOE REVIEW

GHD
10271 Shellbridge Way, Suit 165
Richmond British Columbia V6X 2W8 Canada
T 604 214 0510 F 604 214 0525 W www.ghd.com

Client
UPLAND EXCAVATING LTD.

Project
2017 DESIGN, OPERATIONS AND CLOSURE PLAN

No.	Issue	Drawn	Approved	Date
3	RE-ISSUED FOR MOE REVIEW	TW	GF	MAY 2017
2	MOE REVIEW	KD	DB	MAY 2016
1	DRAFT - STAKEHOLDER CONSULTATION	TW	DB	FEB 2016

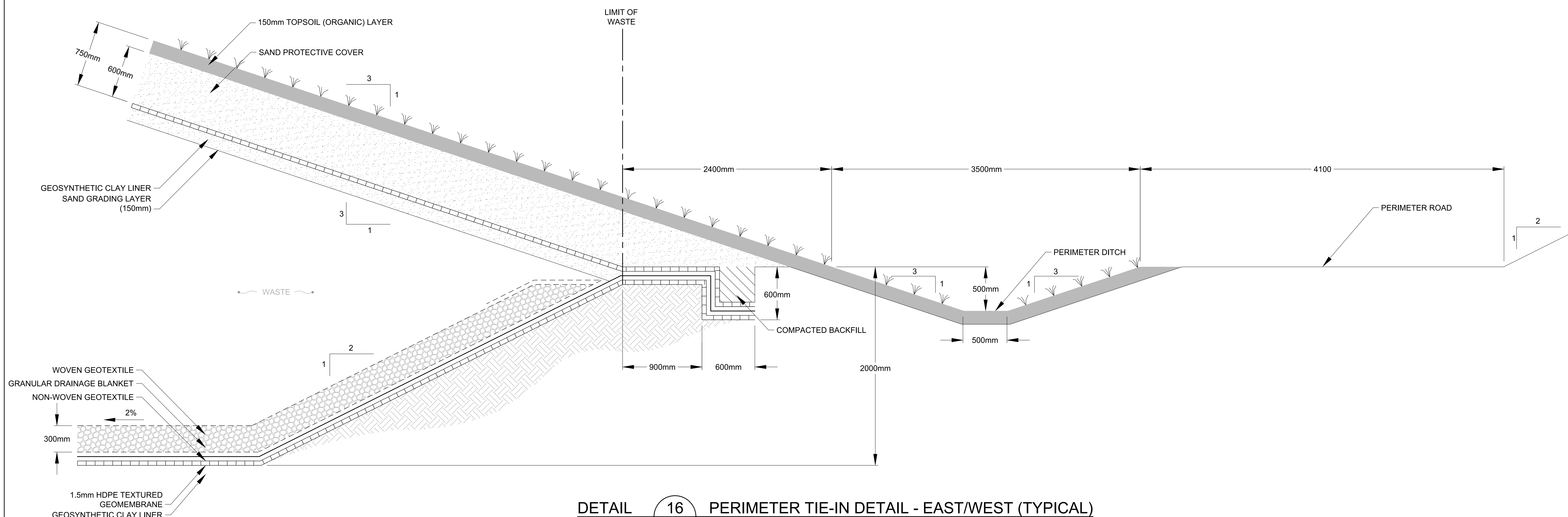
Drawn	T.WAGSTAFF	Designer	D. BARTON
Drafting Check	D. BARTON	Design Check	S.STURGEON
Project Manager	G. FERRARO	Date	MAY 2017
This document shall not be used for construction unless signed and sealed for construction.		Scale	1:25
Original Size	ANSI D	Bar is 20mm on original size drawing 0 20mm	

Project No. 88877-03

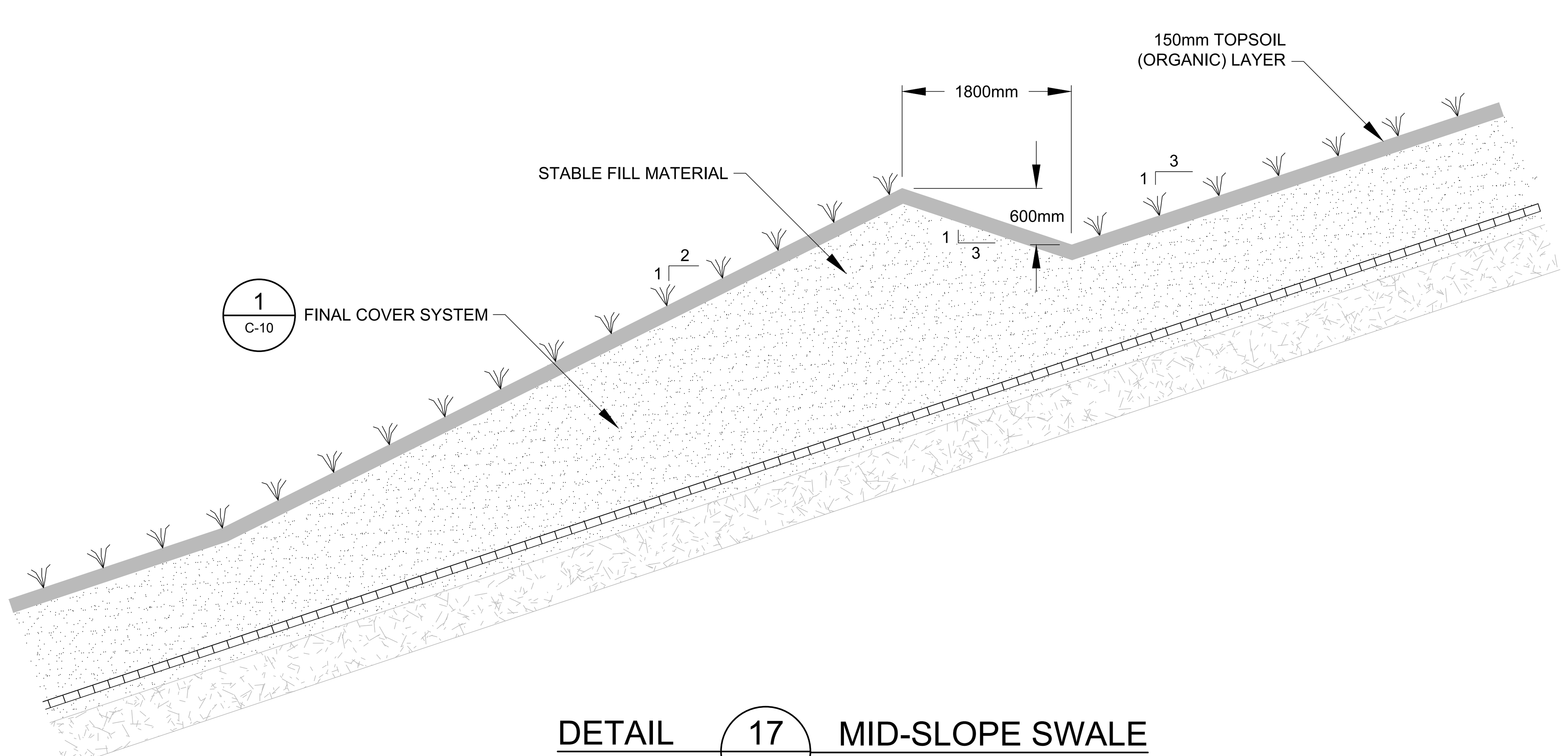
Title
PERIMETER TIE-IN DETAILS I

Sheet No.
C-13

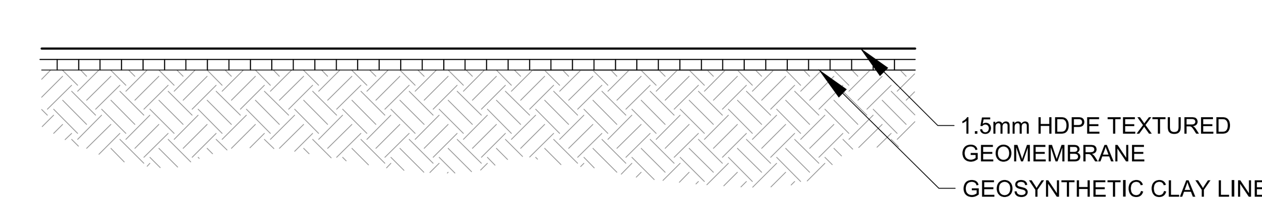
Sheet 14 of 15



DETAIL 16 PERIMETER TIE-IN DETAIL - EAST/WEST (TYPICAL)
1:25 C-2B



DETAIL 17 MID-SLOPE SWALE
1:50 C-05



DETAIL 18 AERATION POND LINER SYSTEM
1:25 C-02B

ISSUED FOR MOE REVIEW

GHD
10271 Shellbridge Way, Suit 165
Richmond British Columbia V6X 2W8 Canada
T 604 214 0510 **F** 604 214 0525 **W** www.ghd.com

Client
UPLAND EXCAVATING LTD.

Project
UPDATED DESIGN, OPERATIONS AND CLOSURE PLAN

No.	Issue	Drawn	Approved	Date
3	RE-ISSUED FOR MOE REVIEW	TW	GF	MAY 2017
2	MOE REVIEW	KD	DB	MAY 2016
1	DRAFT - STAKEHOLDER CONSULTATION	TW	DB	FEB 2016

Drawn	T.WAGSTAFF	Designer	D. BARTON
Drafting Check	D. BARTON	Design Check	S.STURGEON
Project Manager	G. FERRARO	Date	MAY 2017
This document shall not be used for construction unless signed and sealed for construction.		Scale	1:25
Original Size	ANSI D	Bar is 20mm on original size drawing	0 20mm

Project No. 88877-03

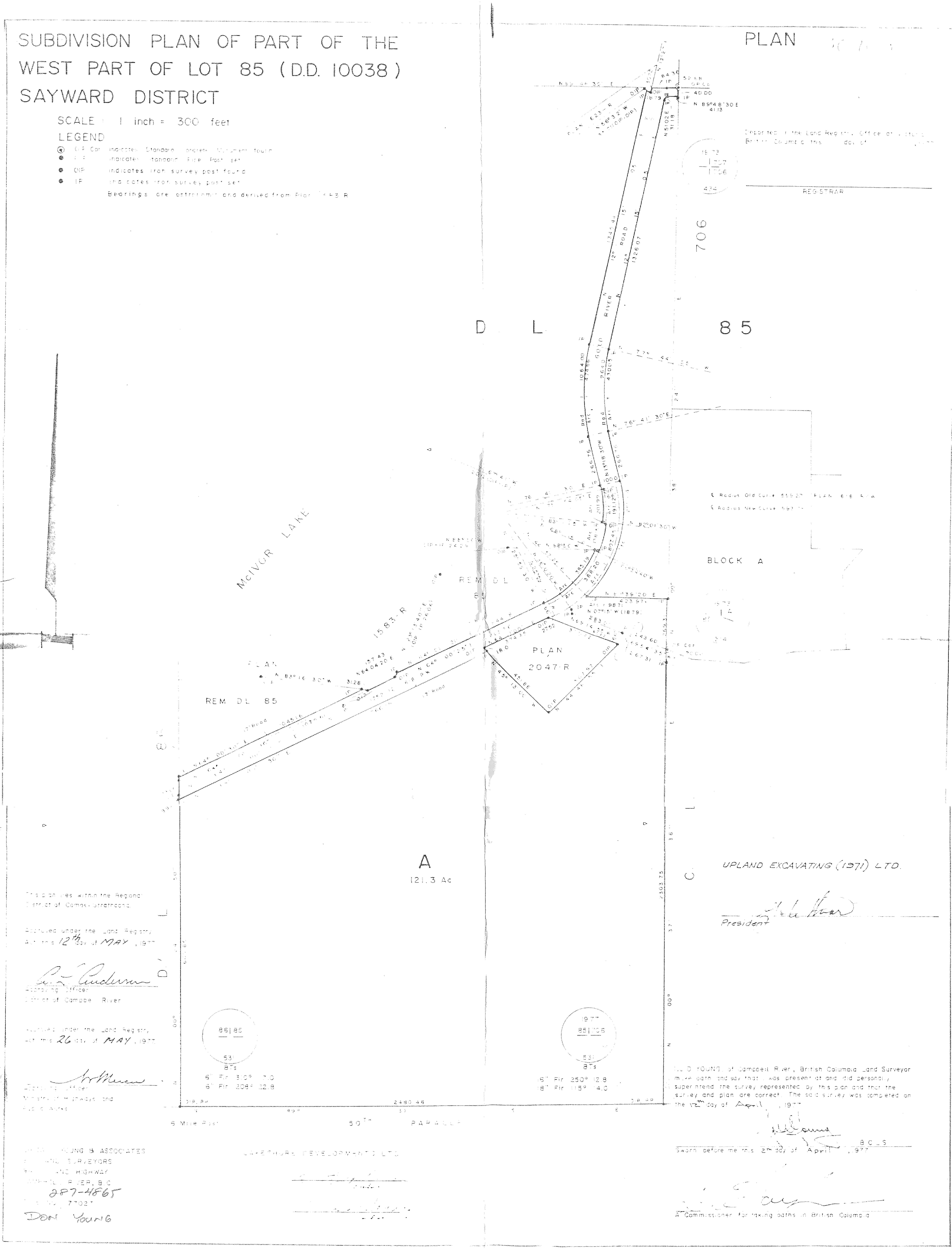
Title
PERIMETER TIE-IN DETAILS II

Sheet No.
C-14

Sheet 15 of 15

Appendices

Appendix A
Legal Survey Plan


SUBDIVISION PLAN OF PART OF THE
WEST PART OF LOT 85 (D.D. 10038)
SAYWARD DISTRICT
SCALE 1 inch = 300 feet
LEGEND
Bearings are astronomic and derived from Plan
PLAN
D L 85
McIVOR LAKE
GOLD RIVER ROAD
REM. D.L.
REM. D.L. 85
BLOCK A
PLAN 2047 R
A
121.3 Ac
706
50TH PARALLEL
6 Mile Post
2480.46
This plan lies within the Regional District of Comox-Strathcona
Approved under the Land Registry Act this 12th day of MAY, 1977
Approving Officer
District of Campbell River
Approved under the Land Registry Act this 26 day of MAY, 1977
Approving Officer
Ministry of Highways and Public Works
YOUNG & ASSOCIATES
LAND SURVEYORS
ISLAND HIGHWAY
CAMPBELL RIVER, B.C.
287-4865
DON YOUNG
UPLAND EXCAVATING (1971) LTD.
President
D. YOUNG of Campbell River, British Columbia Land Surveyor make oath and say that I was present at and did personally superintend the survey represented by this plan and that the survey and plan are correct. The said survey was completed on the 12th day of April, 1977
B.C.L.S.
Sworn before me this 2th day of April, 1977
A Commissioner for taking oaths in British Columbia
REGISTRAR

Appendix B
Existing Permit PR – 10807

Province of
British Columbia

Ministry of Environment,
Lands and Parks

BC Environment

Vancouver Island Region 1
Regional Headquarters
2569 Kenworth Road
Nanaimo
British Columbia
V9T 4P7
Telephone: (604) 751-3100

JUN 01 1992

File: PR-10807

REGISTERED MAIL

Upland Excavating Ltd.
480 - 10th Avenue
Campbell River, British Columbia
V9W 4E3

Gentlemen:

Enclosed is a copy of Permit No. PR-10807 issued under the provisions of the Waste Management Act, in the name of Upland Excavating Ltd. Your attention is respectfully directed to the terms and conditions outlined in the Permit.

The administration of this Permit will be carried out by staff from our Regional Office located at 2569 Kenworth Road, Nanaimo, British Columbia, V9T 4P7 (telephone 751-3100). Plans, data and reports pertinent to the Permit are to be submitted to the Regional Waste Manager at this address.

Yours truly,

G. E. Oldham

G.E. Oldham, P. Eng.
Regional Waste Manager

Enclosure

PROVINCE OF
BRITISH COLUMBIA

ENVIRONMENTAL PROTECTION
2569 Kenworth Road
Nanaimo, British Columbia
V9T 4P7
Telephone:(604) 751-3100

MINISTRY OF ENVIRONMENT,
LANDS AND PARKS

PERMIT

Under the Provisions of the Waste Management Act

Upland Excavating Ltd.

480 - 10th Avenue

Campbell River, British Columbia

V9W 4E3

is authorized to discharge refuse from Campbell River and the surrounding area to the land and air contaminants from a regulated open burning operation.

An annual fee will be determined on the basis of your industrial code and capacity in accordance with the Waste Management Fees Regulation.

This Permit does not authorize entry upon, crossing over, or use for any purpose of private or Crown lands or works, unless and except as authorized by the owner of such lands or works. The responsibility for obtaining such authority shall rest with the Permittee.

G. E. Oldham, P. Eng.
Regional Waste Manager

Date issued: JUN 01 1992

Date amended:
(most recent)

Permit No. PR-10807

1. AUTHORIZED DISCHARGES AND RELATED REQUIREMENTS

1.1 Refuse

1.1.1 The maximum rate at which refuse may be discharged is 3200 m^3/year.

1.1.2 The type of refuse which may be discharged is inert municipal.

1.1.3 The components of the refuse which may be discharged are stumps, trees, land clearing waste, selected building demolition debris, and residue of combustion from the open burning of woodwaste.

1.1.4 The works authorized are a landfill operation as directed, located approximately as shown on the attached Appendix A-1.

1.1.5 The works authorized must be complete and in operation on and from the date of this permit.

1.2 Emissions

1.2.1 The works authorized are a regulated open burning operation, as directed, located approximately as shown on the attached Appendix A-1.

1.2.2 The works authorized must be complete and in operation on and from the date of this permit.

2. LOCATION OF THE FACILITIES

Lot A, District Lot 85, Plan 30709, Sayward District.

G. E. Oldham, P. Eng.
Regional Waste Manager

3. **LANDFILL OPERATION**

The Permittee shall maintain the landfill as a Level E operation in accordance with the Pollution Control Objectives for Municipal Type Waste Discharges in British Columbia, dated September 1975, which, in normal conditions, requires that cover material be applied once per forty days of operation and at least once every two months. The Regional Waste Manager may vary the frequency of covering when freezing conditions or other circumstances affect normal operation.

4. **SITE PREPARATION AND RESTORATION**

Provision of fencing, site access, vehicle safety barriers, surface water diversionary works, firebreaks and site restoration as required, shall be carried out to the satisfaction of the Regional Waste Manager.

5. **PUTRESCIBLE WASTE**

No putrescible wastes shall be discharged at this site.

6. **OPERATIONAL REQUIREMENTS FOR REGULATED OPEN BURNING**

(a) Area

The operation shall be restricted to an area on the site which is satisfactory to the Regional Waste Manager. If required, this area shall be fenced to restrict access to the burn area stockpile.

G. E. Oldham

G. E. Oldham, P. Eng.
Regional Waste Manager

(b) Quantity and Frequency

The maximum quantity of wastes to be treated is 750 m^3 per burn at a frequency not to exceed four burns per year. Each burn shall comprise one continuous period necessary to reduce the stockpiled waste to ashes, and shall not exceed 48 hours.

(c) Nature of Wastes

Generally, no waste shall be burned which is unacceptable to the Regional Waste Manager. Acceptable materials may include stumps, trees and similar items, but exclude nuisance causing combustibles such as rubber, plastics, tars, insulation, etc. Demolition debris, excepting wood products, shall not be burned at this site. Burning of any antisapstain treated wood products is prohibited.

(d) Timing

Burning shall take place only when an attendant is on duty and when conditions promote rapid combustion and dispersion of combustion products with a wind direction that conveys the resulting gases away from McIvor Lake and Highway #28 (Gold River Highway). Burning shall take place only when the ventilation index for the Campbell River area is forecasted to exceed 33 for the period of the burn. The ventilation index is issued by the Pacific Weather Centre, Environment Canada, Vancouver, telephone 664-9032. Materials shall be charged to the facility in a manner to promote best combustion and restrict the uplift of lighter constituents. No burning shall take place during periods of fire hazard or when burning is prohibited by other government agencies.

G. E. Oldham, P. Eng.
Regional Waste Manager

Date issued: JUN 01 1992

Date amended:
(most recent)

(e) Fire Control

Suitable approved devices shall be available for extinguishing fires to prevent them from spreading to surrounding areas. Such devices may include a pressurized water supply, chemical type fire extinguishers, or an earth stockpile. If an earth stockpile is contemplated for fire control, earth moving equipment shall be available at the site during burning. A fireguard shall be cleared and maintained free of combustible materials.

(f) Residue of Combustion

As soon as the residue of combustion has cooled to ambient temperature, it shall be incorporated into the adjacent landfill.

(g) Other Requirements

The Ministry of Environment, Lands and Parks has established a Smoke Management Steering Committee to review the present practice of burning wood residue. A need for additional controls, such as auxiliary forced air, or other requirements, may result from the recommendations of the Steering Committee or following the observation of any burning episode, and the Permittee shall install such equipment or take measures as may be required by the Regional Waste Manager.

The Ministry is also in the process of revising the existing pollution control objectives for municipal landfills. Based on the provisions of the new criteria, the Permittee may be required to terminate open burning at this site.

7. GROUNDWATER MONITORING WELLS

The Permittee shall install not more than two groundwater monitoring wells. The number, locations and structural details of these facilities are subject to the approval of the Regional Waste Manager.

G. E. Oldham, P. Eng.
Regional Waste Manager

Date issued: JUN 01 1992

Date amended:
(most recent)

8. WASTE REDUCTION

The Ministry of Environment, Lands and Parks has developed a policy to reduce, recycle and reuse solid wastes. The Permittee is encouraged to segregate for recycling and reuse, where possible, materials destined for disposal at this site.

In certain landfill environments, some construction and demolition debris, may create air and water quality concerns. If problems arise at this site that are attributable to specific wastes, the Regional Waste Manager may require that alternate disposal procedures be implemented.

9. WASTE MANAGEMENT PLANNING

The Permittee is advised that the Regional District of Comox-Strathcona is developing a Solid Waste Management Plan which may have an impact on the discharge authorized by this Permit.

G. E. Oldham, P. Eng.
Regional Waste Manager

Date issued: JUN 01 1992

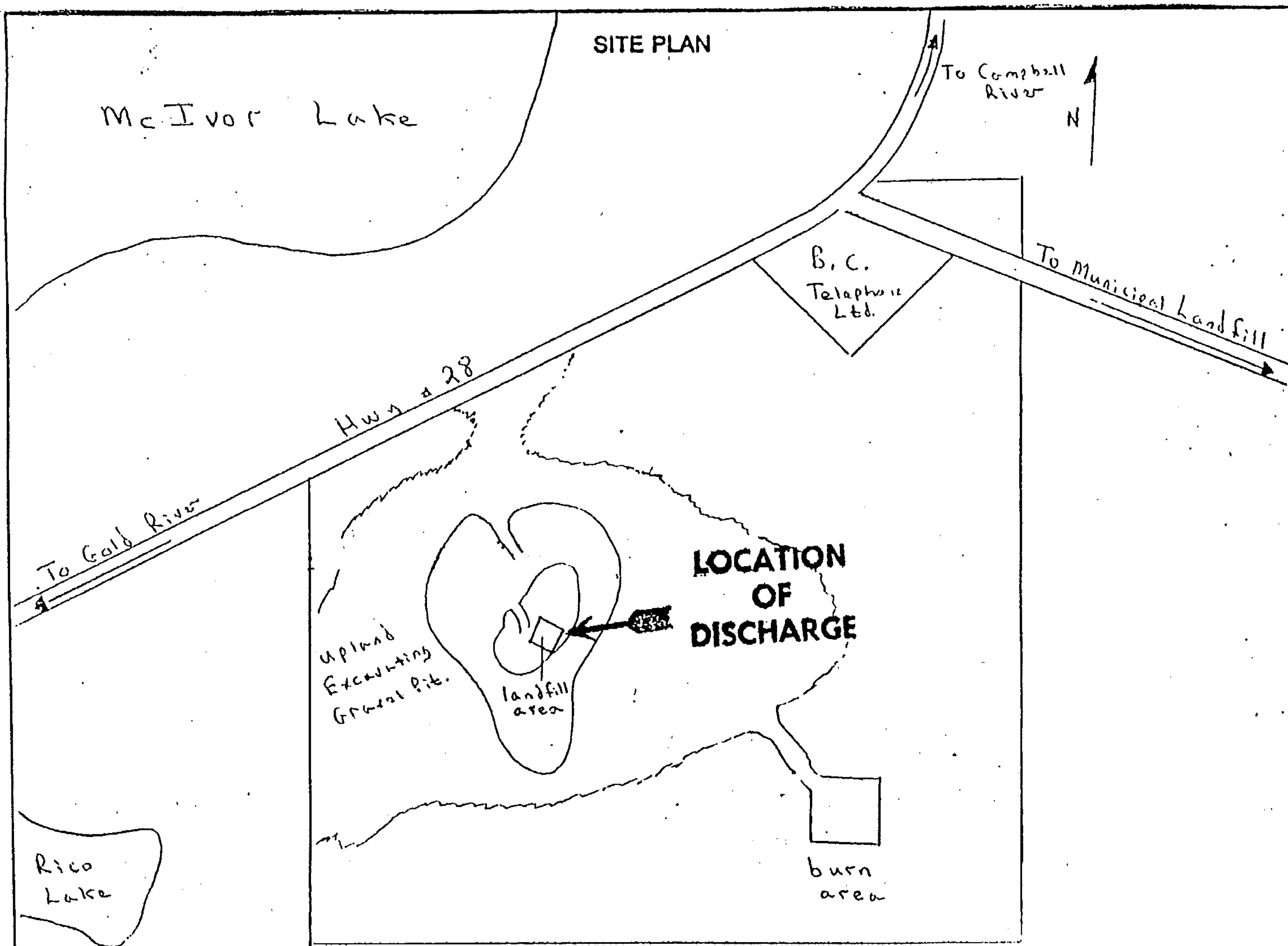
Date amended:
(most recent)

Province of British Columbia

Ministry of Environment Lands and Parks

ENVIRONMENTAL PROTECTION

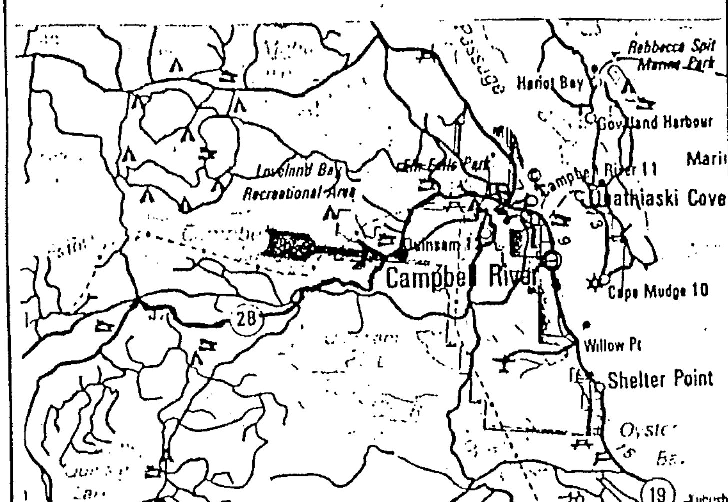
SITE PLAN



SCALE: ≃ 1 : 8,500

LEGAL DESCRIPTION: Lot A, District Lot 85, Plan 30709, Sayward District

LOCATION MAP



Upland Excavating Ltd.

Name of Permittee

Appendix A-1 to Permit No. PR-10807

Approval No.

Date Issued JUN 01 1992

Date Amended

Regional Waste Manager [signature]

Appendix C
Surface Water Management Plan Supporting Documents

Environment Canada/Environnement Canada

Short Duration Rainfall Intensity-Duration-Frequency Data
Données sur l'intensité, la durée et la fréquence des chutes de pluie de courte durée

Gumbel - Method of moments/Méthode des moments

2012/02/09

==

CAMPBELL RIVER A BC 1021261
(composite)
Latitude: 49 57'N Longitude: 125 16'W Elevation/Altitude: 108 m

Years/Années : 1970 - 2002 # Years/Années : 21

==

****

Table 1 : Annual Maximum (mm)/Maximum annuel (mm)

****

Year Année	5 min	10 min	15 min	30 min	1 h	2 h	6 h	12 h	24 h
1970	-99.9	-99.9	-99.9	-99.9	9.4	16.0	25.7	43.7	55.1
1971	-99.9	-99.9	-99.9	-99.9	9.1	15.5	29.2	46.0	57.7
1972	-99.9	-99.9	-99.9	-99.9	15.5	22.9	38.9	57.9	73.9
1973	-99.9	-99.9	-99.9	-99.9	9.1	14.0	26.2	39.4	53.3
1974	-99.9	-99.9	-99.9	-99.9	8.1	12.4	26.4	39.9	65.5
1975	-99.9	-99.9	-99.9	-99.9	18.3	20.6	41.9	44.2	59.7
1976	-99.9	-99.9	-99.9	-99.9	8.1	15.7	41.1	45.7	48.5
1981	-99.9	-99.9	-99.9	-99.9	12.4	18.6	33.4	39.8	63.2
1982	3.3	5.2	7.8	13.7	17.7	19.6	32.4	49.2	62.9
1983	2.8	3.9	4.7	7.4	10.9	17.7	33.6	53.1	79.6
1984	4.2	5.6	6.9	12.3	20.2	29.6	48.6	59.3	62.0
1985	2.6	2.9	3.6	6.3	9.0	12.0	21.4	24.7	36.8
1986	5.1	5.9	6.1	7.3	7.8	13.9	27.5	40.7	56.1
1987	2.4	3.2	3.7	4.6	8.5	16.4	39.0	43.6	65.7
1988	1.8	2.2	3.0	4.9	8.6	16.9	36.1	45.7	50.5
1989	4.6	7.1	9.0	13.0	14.5	14.6	18.5	29.2	39.2
1990	5.2	7.7	9.6	12.9	15.8	16.2	24.7	45.9	69.8
1991	1.7	2.8	3.9	5.9	9.6	16.9	42.5	64.1	72.3
1992	3.1	4.3	6.1	8.6	11.4	13.6	28.6	-99.9	61.6
1993	2.1	3.6	4.1	6.5	9.3	16.0	36.2	61.9	97.4
1994	3.6	4.8	5.3	6.8	9.7	15.3	31.9	49.6	58.3
1995	7.4	10.4	11.6	12.4	14.1	19.5	34.8	53.6	68.1
1996	5.5	5.9	6.1	8.0	11.5	14.9	27.6	39.9	50.9
1997	4.9	5.8	7.0	9.5	10.9	13.5	35.1	41.6	63.6
1998	5.5	8.8	10.3	13.1	15.3	18.8	32.5	-99.9	61.0
1999	2.2	3.6	4.5	6.0	9.1	17.2	33.2	63.6	81.0
2000	5.5	8.4	10.2	13.1	14.7	14.7	20.2	28.4	37.8
2001	3.5	4.8	5.4	8.9	13.5	18.1	32.3	38.3	46.8
2002	3.9	4.9	6.2	6.9	9.7	13.1	26.1	43.5	55.7
# Yrs. Années	21	21	21	21	29	29	29	27	29
Mean Moyenne	3.9	5.3	6.4	9.0	11.8	16.7	31.9	45.6	60.5
Std. Dev.	1.5	2.2	2.5	3.1	3.5	3.6	7.1	10.1	13.2

Écart-type Skew.	0.45	0.75	0.62	0.35	0.86	1.84	0.21	0.06	0.50
Dissymétrie Kurtosis	3.03	3.42	2.78	1.93	2.98	8.31	3.13	3.19	4.36

*-99.9 Indicates Missing Data/Données manquantes

Warning: annual maximum amount greater than 100-yr return period amount
Avertissement : la quantité maximale annuelle excède la quantité pour une période de retour de 100 ans

Year/Année	Duration/Durée	Data/Données	100-yr/ans
1984	2 h	29.6	27.8

****

Table 2a : Return Period Rainfall Amounts (mm)
Quantité de pluie (mm) par période de retour

****

Duration/Durée	2 yr/ans	5 yr/ans	10 yr/ans	25 yr/ans	50 yr/ans	100 yr/ans	#Years Années
5 min	3.6	4.9	5.8	7.0	7.8	8.6	21
10 min	5.0	6.9	8.1	9.7	10.9	12.1	21
15 min	6.0	8.2	9.7	11.5	12.9	14.2	21
30 min	8.4	11.2	13.0	15.3	17.0	18.7	21
1 h	11.2	14.3	16.3	18.9	20.8	22.6	29
2 h	16.1	19.3	21.3	24.0	25.9	27.8	29
6 h	30.8	37.0	41.2	46.4	50.3	54.2	29
12 h	44.0	52.9	58.9	66.3	71.9	77.4	27
24 h	58.3	70.0	77.7	87.5	94.7	101.9	29

****

Table 2b :

Return Period Rainfall Rates (mm/h) - 95% Confidence limits
Intensité de la pluie (mm/h) par période de retour - Limites de confiance de 95%

****

Duration/Durée	2 yr/ans	5 yr/ans	10 yr/ans	25 yr/ans	50 yr/ans	100 yr/ans	#Years Années
5 min	43.2	59.4	70.1	83.6	93.6	103.5	21
	+/- 7.2	+/- 12.1	+/- 16.3	+/- 22.0	+/- 26.3	+/- 30.7	21
10 min	29.8	41.3	48.9	58.4	65.5	72.6	21
	+/- 5.1	+/- 8.6	+/- 11.6	+/- 15.6	+/- 18.7	+/- 21.8	21
15 min	24.1	32.9	38.7	46.0	51.5	56.9	21
	+/- 3.9	+/- 6.6	+/- 8.9	+/- 12.0	+/- 14.3	+/- 16.7	21
30 min	16.9	22.4	26.0	30.6	34.1	37.4	21
	+/- 2.4	+/- 4.1	+/- 5.6	+/- 7.5	+/- 9.0	+/- 10.4	21
1 h	11.2	14.3	16.3	18.9	20.8	22.6	29
	+/- 1.2	+/- 1.9	+/- 2.6	+/- 3.5	+/- 4.2	+/- 4.9	29
2 h	8.1	9.6	10.7	12.0	13.0	13.9	29
	+/- 0.6	+/- 1.0	+/- 1.4	+/- 1.8	+/- 2.2	+/- 2.5	29
6 h	5.1	6.2	6.9	7.7	8.4	9.0	29
	+/- 0.4	+/- 0.7	+/- 0.9	+/- 1.2	+/- 1.4	+/- 1.7	29
12 h	3.7	4.4	4.9	5.5	6.0	6.5	27
	+/- 0.3	+/- 0.5	+/- 0.7	+/- 0.9	+/- 1.1	+/- 1.2	27
24 h	2.4	2.9	3.2	3.6	3.9	4.2	29
	+/- 0.2	+/- 0.3	+/- 0.4	+/- 0.6	+/- 0.7	+/- 0.8	29

****

Table 3 : Interpolation Equation / Équation d'interpolation: R = A*T^B

R = Interpolated Rainfall rate (mm/h)/Intensité interpolée de la pluie (mm/h)
RR = Rainfall rate (mm/h) / Intensité de la pluie (mm/h)
T = Rainfall duration (h) / Durée de la pluie (h)

****

Statistics/Statistiques	2 yr/ans	5 yr/ans	10 yr/ans	25 yr/ans	50 yr/ans	100 yr/ans
Mean of RR/Moyenne de RR	16.1	21.5	25.1	29.6	33.0	36.3
Std. Dev. /Écart-type (RR)	13.9	19.4	23.1	27.8	31.2	34.7
Std. Error/Erreur-type	0.7	1.1	1.4	1.7	2.0	2.3
Coefficient (A)	12.0	15.5	17.7	20.6	22.7	24.7
Exponent/Exposant (B)	-0.499	-0.529	-0.543	-0.556	-0.563	-0.569
Mean % Error/% erreur moyenne	3.3	4.2	4.9	5.5	5.8	6.1

Appendix C

Design Calculations - Forebay Desgin
Updated Design, Operations, and Closure Plan
Uplands Excavating Ltd.
Proposed Upland Landfill
Campbell River, British Columbia

Task: Design forebay for the inlet of Infiltration Areas

In accordance with "Best Management Practices Guide for Stormwater", Sedimentation forebay should provide 10% volume of total design storage volume for pond (infiltration area).

Infiltration Basin Volume=	3501	m^3
Sediment Forebay Volume=	10% of Infiltration Basin Volume	
Sediment Forebay Volume=	350	m^3
Forebay Length to width ratio=	2:1	
Forebay Depth=	1	m
Forebay Length=	26	m
Forebay Width=	13	m
Forebay Depth=	1	m

Reference: Allan Gibb, Harlan Kelly, and Thomas Schueler, 1999, Best Management Practices Guide for Stormwater, Prepared for Greater Vancouver Sewerage and Drainage District.

Appendix C

Design Calculations - Infiltration Area
Updated Design, Operations, and Closure Plan
Uplands Excavating Ltd.
Proposed Upland Landfill
Campbell River, British Columbia

East and West Infiltration Pond
Stage/Storage Relationship

Elevation		Area		Depth		Total Storage	
(m)	(ft)	(m^2)	(ft^2)	(m)	(ft)	(m^3)	(ft^3)
150	492.1	2682	28873	0			
150.20	492.8	2951	31760	0.2	0.7	563	19893
150.40	493.4	3246	34936	0.4	1.3	1186	41869
150.60	494.1	3570	38430	0.6	2.0	1876	66243
150.80	494.8	3927	42273	0.8	2.6	2644	93367
151.00	495.4	4320	46500	1	3.3	3501	123643

Note:

* Volume for an interval calculated by Average End Area Method.

EPA STORM WATER MANAGEMENT MODEL - VERSION 5.1 (Build 5.1.010)

****
Element Count
****

Number of rain gages 4
Number of subcatchments ... 15
Number of nodes 14
Number of links 12
Number of pollutants 0
Number of land uses 0

****
Raingage Summary
****

Name	Data Source	Data Type	Recording Interval
100yr_SCS_24h_Type_IA_118.2mm	100yr_SCS_24h_Type_IA_118.2mm	INTENSITY	15 min.
10yr_SCS_24h_Type_IA_90mm	10yr_SCS_24h_Type_IA_90mm	INTENSITY	15 min.
5yr_SCS_24h_Type_IA_81.2mm	5yr_SCS_24h_Type_IA_81.2mm	INTENSITY	15 min.
6month_SCS_24h_Type_IA_61.61mm	6month_SCS_24h_Type_IA_61.61mm	INTENSITY	15 min.

****
Subcatchment Summary
****

Name	Area	Width	%Imperv	%Slope	Rain Gage	Outlet
101	0.79	196.75	0.00	45.0000	5yr_SCS_24h_Type_IA_81.2mm	J5
102	0.08	21.05	0.00	45.0000	5yr_SCS_24h_Type_IA_81.2mm	J5
103	0.13	33.30	0.00	45.0000	5yr_SCS_24h_Type_IA_81.2mm	J4
104	1.35	245.89	0.00	35.0000	5yr_SCS_24h_Type_IA_81.2mm	J8
105	0.20	67.73	0.00	20.0000	5yr_SCS_24h_Type_IA_81.2mm	J7
106	0.95	146.54	0.00	22.0000	5yr_SCS_24h_Type_IA_81.2mm	J2
107	0.51	146.63	0.00	30.0000	5yr_SCS_24h_Type_IA_81.2mm	J5
108	0.53	150.14	0.00	30.0000	5yr_SCS_24h_Type_IA_81.2mm	J8
109	0.92	141.63	0.00	22.0000	5yr_SCS_24h_Type_IA_81.2mm	J3
110	0.18	40.56	0.00	22.0000	5yr_SCS_24h_Type_IA_81.2mm	J1
111	0.19	42.33	0.00	22.0000	5yr_SCS_24h_Type_IA_81.2mm	J1
112	0.46	185.00	100.00	15.0000	5yr_SCS_24h_Type_IA_81.2mm	POND_East
113	0.29	82.37	0.00	30.0000	5yr_SCS_24h_Type_IA_81.2mm	J9
114	0.50	200.56	100.00	15.0000	5yr_SCS_24h_Type_IA_81.2mm	POND_West
115	0.28	81.14	0.00	30.0000	5yr_SCS_24h_Type_IA_81.2mm	J6

****
Node Summary
****

Name	Type	Invert Elev.	Max. Depth	Ponded Area	External Inflow
J1	JUNCTION	164.50	0.50	0.0	
J10	JUNCTION	164.50	0.50	0.0	
J2	JUNCTION	164.30	0.50	0.0	
J3	JUNCTION	164.30	0.50	0.0	
J4	JUNCTION	164.00	0.50	0.0	
J5	JUNCTION	156.00	0.50	0.0	
J6	JUNCTION	153.00	0.50	0.0	
J7	JUNCTION	164.00	0.50	0.0	
J8	JUNCTION	156.00	0.50	0.0	
J9	JUNCTION	153.00	0.50	0.0	

OF1	OUTFALL	149.50	0.00	0.0
OF2	OUTFALL	149.50	0.00	0.0
POND_East	STORAGE	150.00	1.00	0.0
POND_West	STORAGE	150.00	1.00	0.0

****
Link Summary
****

Name	From Node	To Node	Type	Length	%Slope	Roughness
D101	J1	J2	CONDUIT	57.9	0.3454	0.0300
D102	J2	J4	CONDUIT	146.4	0.2050	0.0300
D103	J4	J5	CONDUIT	31.7	26.0720	0.0300
D104	J5	J6	CONDUIT	174.8	1.7166	0.0300
D105	J10	J3	CONDUIT	59.2	0.3376	0.0300
D106	J3	J7	CONDUIT	149.5	0.2006	0.0300
D107	J7	J8	CONDUIT	34.2	24.0519	0.0300
D108	J8	J9	CONDUIT	180.0	1.6664	0.0300
D109	J6	POND_West	CONDUIT	53.0	4.7258	0.0300
D110	J9	POND_East	CONDUIT	42.9	5.8374	0.0300
OL1	POND_West	OF1	OUTLET			
OL2	POND_East	OF2	OUTLET			

****
Cross Section Summary
****

Conduit	Shape	Full Depth	Full Area	Hyd. Rad.	Max. Width	No. of Barrels	Full Flow
D101	TRAPEZOIDAL	0.50	1.00	0.27	3.50	1	0.82
D102	TRAPEZOIDAL	0.50	1.00	0.27	3.50	1	0.64
D103	TRAPEZOIDAL	0.50	1.00	0.27	3.50	1	7.16
D104	TRAPEZOIDAL	0.50	1.00	0.27	3.50	1	1.84
D105	TRAPEZOIDAL	0.50	1.00	0.27	3.50	1	0.82
D106	TRAPEZOIDAL	0.50	1.00	0.27	3.50	1	0.63
D107	TRAPEZOIDAL	0.50	1.00	0.27	3.50	1	6.88
D108	TRAPEZOIDAL	0.50	1.00	0.27	3.50	1	1.81
D109	TRAPEZOIDAL	0.50	1.00	0.27	3.50	1	3.05
D110	TRAPEZOIDAL	0.50	1.00	0.27	3.50	1	3.39

****
NOTE: The summary statistics displayed in this report are
based on results found at every computational time step,
not just on results from each reporting time step.
****

****
Analysis Options
****

```
Flow Units ............... CMS
Process Models:
  Rainfall/Runoff ........ YES
  RDII ................... NO
  Snowmelt ............... NO
  Groundwater ............ NO
  Flow Routing ........... YES
  Ponding Allowed ........ NO
  Water Quality .......... NO
Infiltration Method ...... HORTON
Flow Routing Method ...... DYNWAVE
Starting Date ............ JAN-19-2016 00:00:00
Ending Date .............. JAN-25-2016 00:00:00
Antecedent Dry Days ...... 0.0
Report Time Step ......... 00:05:00
Wet Time Step ............ 00:00:01
Dry Time Step ............ 00:00:01
Routing Time Step ........ 1.00 sec
Variable Time Step ....... YES
Maximum Trials ........... 8
Number of Threads ........ 1
Head Tolerance ........... 0.001500 m
```

************************** Runoff Quantity Continuity **************************	Volume hectare-m	Depth mm
Total Precipitation	0.599	81.198
Evaporation Loss	0.000	0.000
Infiltration Loss	0.055	7.447
Surface Runoff	0.543	73.627

```
  Final Storage ...........         0.001           0.124
  Continuity Error (%) .....        0.000


  **************************        Volume         Volume
  Flow Routing Continuity        hectare-m      10^6 ltr
  **************************     ---------      ---------
  Dry Weather Inflow .......        0.000           0.000
  Wet Weather Inflow .......        0.543           5.434
  Groundwater Inflow .......        0.000           0.000
  RDII Inflow ..............        0.000           0.000
  External Inflow ..........        0.000           0.000
  External Outflow .........        0.551           5.509
  Flooding Loss ............        0.000           0.000
  Evaporation Loss .........        0.000           0.000
  Exfiltration Loss ........        0.000           0.000
  Initial Stored Volume ....        0.000           0.000
  Final Stored Volume ......        0.000           0.000
  Continuity Error (%) .....       -1.377


  *************************
  Highest Continuity Errors
  *************************
  Node POND_East (-1.39%)
  Node POND_West (-1.36%)


  ***************************
  Time-Step Critical Elements
  ***************************
  None


  ********************************
  Highest Flow Instability Indexes
  ********************************
  Link OL1 (4)
  Link OL2 (3)


  *************************
  Routing Time Step Summary
  *************************
  Minimum Time Step           :     0.50 sec
  Average Time Step           :     1.00 sec
  Maximum Time Step           :     1.00 sec
  Percent in Steady State     :     0.00
  Average Iterations per Step :     2.00
  Percent Not Converging      :     0.00


  ***************************
  Subcatchment Runoff Summary
  ***************************
```

Subcatchment	Total Precip mm	Total Runon mm	Total Evap mm	Total Infil mm	Total Runoff mm	Total Runoff 10^6 ltr	Peak Runoff CMS	Runoff Coeff
101	81.20	0.00	0.00	7.91	73.29	0.58	0.03	0.903
102	81.20	0.00	0.00	7.91	73.29	0.06	0.00	0.903
103	81.20	0.00	0.00	7.91	73.29	0.10	0.00	0.903
104	81.20	0.00	0.00	7.94	73.26	0.99	0.05	0.902
105	81.20	0.00	0.00	7.92	73.28	0.15	0.01	0.903
106	81.20	0.00	0.00	9.05	72.14	0.69	0.03	0.889
107	81.20	0.00	0.00	8.92	72.28	0.37	0.02	0.890
108	81.20	0.00	0.00	8.92	72.28	0.38	0.02	0.890

109	81.20	0.00	0.00	9.05	72.14	0.66	0.03 0.889
110	81.20	0.00	0.00	8.98	72.22	0.13	0.01 0.889
111	81.20	0.00	0.00	8.98	72.22	0.14	0.01 0.889
112	81.20	0.00	0.00	0.00	80.25	0.37	0.02 0.988
113	81.20	0.00	0.00	8.92	72.28	0.21	0.01 0.890
114	81.20	0.00	0.00	0.00	80.25	0.40	0.02 0.988
115	81.20	0.00	0.00	8.92	72.28	0.21	0.01 0.890

****
Node Depth Summary
****

Node	Type	Average Depth Meters	Maximum Depth Meters	Maximum HGL Meters	Time of Max Occurrence days hr:min	Reported Max Depth Meters
J1	JUNCTION	0.00	0.07	164.57	0 08:00	0.02
J10	JUNCTION	0.00	0.00	164.50	0 00:00	0.00
J2	JUNCTION	0.02	0.22	164.52	0 08:00	0.07
J3	JUNCTION	0.01	0.19	164.49	0 08:00	0.06
J4	JUNCTION	0.00	0.04	164.04	0 08:00	0.01
J5	JUNCTION	0.01	0.13	156.13	0 08:00	0.04
J6	JUNCTION	0.01	0.11	153.11	0 08:00	0.03
J7	JUNCTION	0.00	0.04	164.04	0 08:00	0.01
J8	JUNCTION	0.01	0.14	156.14	0 08:00	0.04
J9	JUNCTION	0.01	0.10	153.10	0 08:00	0.03
OF1	OUTFALL	0.00	0.00	149.50	0 00:00	0.00
OF2	OUTFALL	0.00	0.00	149.50	0 00:00	0.00
POND_East	STORAGE	0.01	0.17	150.17	0 10:03	0.05
POND_West	STORAGE	0.01	0.16	150.16	0 09:59	0.05

****
Node Inflow Summary
****

Node	Type	Maximum Lateral Inflow CMS	Maximum Total Inflow CMS	Time of Max Occurrence days hr:min	Lateral Inflow Volume 10^6 ltr	Total Inflow Volume 10^6 ltr	Flow Balance Error Percent
J1	JUNCTION	0.013	0.013	0 08:00	0.269	0.269	-0.027
J10	JUNCTION	0.000	0.000	0 00:00	0	0	0.000 ltr
J2	JUNCTION	0.033	0.046	0 08:00	0.687	0.957	0.010
J3	JUNCTION	0.032	0.032	0 08:00	0.664	0.664	0.006
J4	JUNCTION	0.005	0.051	0 08:00	0.0976	1.05	-0.001
J5	JUNCTION	0.049	0.099	0 08:00	1.01	2.06	-0.003
J6	JUNCTION	0.010	0.109	0 08:00	0.205	2.27	0.002
J7	JUNCTION	0.007	0.039	0 08:00	0.149	0.813	-0.003
J8	JUNCTION	0.066	0.105	0 08:00	1.37	2.18	-0.004
J9	JUNCTION	0.010	0.115	0 08:00	0.208	2.39	0.003
OF1	OUTFALL	0.000	0.044	0 04:04	0	2.71	0.000
OF2	OUTFALL	0.000	0.044	0 04:01	0	2.8	0.000
POND_East	STORAGE	0.016	0.131	0 08:00	0.371	2.76	-1.375
POND_West	STORAGE	0.018	0.127	0 08:00	0.402	2.67	

-1.342

****
Node Surcharge Summary
****

No nodes were surcharged.

****
Node Flooding Summary
****

No nodes were flooded.

****
Storage Volume Summary
****

Storage Unit	Average Volume 1000 m3	Avg Pcnt Full	Evap Pcnt Loss	Exfil Pcnt Loss	Maximum Volume 1000 m3	Max Pcnt Full	Time of Max Occurrence days hr:min	Maximum Outflow CMS
POND_East	0.024	1	0	0	0.475	14	0 10:03	0.044
POND_West	0.021	1	0	0	0.439	13	0 09:59	0.044

****
Outfall Loading Summary
****

Outfall Node	Flow Freq Pcnt	Avg Flow CMS	Max Flow CMS	Total Volume 10^6 ltr
OF1	14.95	0.035	0.044	2.708
OF2	15.17	0.036	0.044	2.802
System	15.06	0.071	0.088	5.509

****
Link Flow Summary
****

Link	Type	Maximum |Flow| CMS	Time of Max Occurrence days hr:min	Maximum |Veloc| m/sec	Max/ Full Flow	Max/ Full Depth
D101	CONDUIT	0.013	0 08:00	0.10	0.02	0.29
D102	CONDUIT	0.046	0 08:00	0.38	0.07	0.27
D103	CONDUIT	0.051	0 08:00	0.75	0.01	0.18
D104	CONDUIT	0.099	0 08:00	0.96	0.05	0.24
D105	CONDUIT	0.000	0 00:00	0.00	0.00	0.19
D106	CONDUIT	0.032	0 08:00	0.33	0.05	0.23
D107	CONDUIT	0.039	0 08:00	0.57	0.01	0.18
D108	CONDUIT	0.105	0 08:00	0.99	0.06	0.24
D109	CONDUIT	0.109	0 08:00	1.27	0.04	0.21
D110	CONDUIT	0.115	0 08:00	1.39	0.03	0.20
OL1	DUMMY	0.044	0 04:04			
OL2	DUMMY	0.044	0 04:01			

****
Flow Classification Summary
****

	Adjusted /Actual	---------- Fraction of Time in Flow Class ----------						
		Up	Down	Sub	Sup	Up	Down	Norm	Inlet

Conduit	Length	Dry	Dry	Dry	Crit	Crit	Crit	Crit	Ltd	Ctrl
D101	1.00	0.45	0.34	0.00	0.21	0.00	0.00	0.00	0.98	0.00
D102	1.00	0.45	0.01	0.00	0.55	0.00	0.00	0.00	0.00	0.00
D103	1.00	0.45	0.15	0.00	0.40	0.00	0.00	0.00	0.49	0.00
D104	1.00	0.45	0.00	0.00	0.54	0.02	0.00	0.00	0.09	0.00
D105	1.00	0.44	0.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D106	1.00	0.44	0.01	0.00	0.56	0.00	0.00	0.00	0.00	0.00
D107	1.00	0.44	0.16	0.00	0.41	0.00	0.00	0.00	0.50	0.00
D108	1.00	0.44	0.00	0.00	0.53	0.03	0.00	0.00	0.03	0.00
D109	1.00	0.67	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00
D110	1.00	0.68	0.00	0.00	0.00	0.00	0.00	0.32	0.00	0.00

****
Conduit Surcharge Summary
****

No conduits were surcharged.

Analysis begun on: Wed May 04 12:56:40 2016
Analysis ended on: Wed May 04 12:56:48 2016
Total elapsed time: 00:00:08

EPA STORM WATER MANAGEMENT MODEL - VERSION 5.1 (Build 5.1.010)

Element Count

Number of rain gages 4
Number of subcatchments ... 15
Number of nodes 14
Number of links 12
Number of pollutants 0
Number of land uses 0

Raingage Summary

Name	Data Source	Data Type	Recording Interval
100yr_SCS_24h_Type_IA_118.2mm	100yr_SCS_24h_Type_IA_118.2mm	INTENSITY	15 min.
10yr_SCS_24h_Type_IA_90mm	10yr_SCS_24h_Type_IA_90mm	INTENSITY	15 min.
5yr_SCS_24h_Type_IA_81.2mm	5yr_SCS_24h_Type_IA_81.2mm	INTENSITY	15 min.
6month_SCS_24h_Type_IA_61.61mm	6month_SCS_24h_Type_IA_61.61mm	INTENSITY	15 min.

Subcatchment Summary

Name	Area	Width	%Imperv	%Slope	Rain Gage	Outlet
101	0.79	196.75	0.00	45.0000	10yr_SCS_24h_Type_IA_90mm	J5
102	0.08	21.05	0.00	45.0000	10yr_SCS_24h_Type_IA_90mm	J5
103	0.13	33.30	0.00	45.0000	10yr_SCS_24h_Type_IA_90mm	J4
104	1.35	245.89	0.00	35.0000	10yr_SCS_24h_Type_IA_90mm	J8
105	0.20	67.73	0.00	20.0000	10yr_SCS_24h_Type_IA_90mm	J7
106	0.95	146.54	0.00	22.0000	10yr_SCS_24h_Type_IA_90mm	J2
107	0.51	146.63	0.00	30.0000	10yr_SCS_24h_Type_IA_90mm	J5
108	0.53	150.14	0.00	30.0000	10yr_SCS_24h_Type_IA_90mm	J8
109	0.92	141.63	0.00	22.0000	10yr_SCS_24h_Type_IA_90mm	J3
110	0.18	40.56	0.00	22.0000	10yr_SCS_24h_Type_IA_90mm	J1
111	0.19	42.33	0.00	22.0000	10yr_SCS_24h_Type_IA_90mm	J1
112	0.46	185.00	100.00	15.0000	10yr_SCS_24h_Type_IA_90mm	POND_East
113	0.29	82.37	0.00	30.0000	10yr_SCS_24h_Type_IA_90mm	J9
114	0.50	200.56	100.00	15.0000	10yr_SCS_24h_Type_IA_90mm	POND_West
115	0.28	81.14	0.00	30.0000	10yr_SCS_24h_Type_IA_90mm	J6

Node Summary

Name	Type	Invert Elev.	Max. Depth	Ponded Area	External Inflow
J1	JUNCTION	164.50	0.50	0.0	
J10	JUNCTION	164.50	0.50	0.0	
J2	JUNCTION	164.30	0.50	0.0	
J3	JUNCTION	164.30	0.50	0.0	
J4	JUNCTION	164.00	0.50	0.0	
J5	JUNCTION	156.00	0.50	0.0	
J6	JUNCTION	153.00	0.50	0.0	
J7	JUNCTION	164.00	0.50	0.0	
J8	JUNCTION	156.00	0.50	0.0	
J9	JUNCTION	153.00	0.50	0.0	

OF1	OUTFALL	149.50	0.00	0.0
OF2	OUTFALL	149.50	0.00	0.0
POND_East	STORAGE	150.00	1.00	0.0
POND_West	STORAGE	150.00	1.00	0.0

****
Link Summary
****

Name	From Node	To Node	Type	Length	%Slope	Roughness
D101	J1	J2	CONDUIT	57.9	0.3454	0.0300
D102	J2	J4	CONDUIT	146.4	0.2050	0.0300
D103	J4	J5	CONDUIT	31.7	26.0720	0.0300
D104	J5	J6	CONDUIT	174.8	1.7166	0.0300
D105	J10	J3	CONDUIT	59.2	0.3376	0.0300
D106	J3	J7	CONDUIT	149.5	0.2006	0.0300
D107	J7	J8	CONDUIT	34.2	24.0519	0.0300
D108	J8	J9	CONDUIT	180.0	1.6664	0.0300
D109	J6	POND_West	CONDUIT	53.0	4.7258	0.0300
D110	J9	POND_East	CONDUIT	42.9	5.8374	0.0300
OL1	POND_West	OF1	OUTLET			
OL2	POND_East	OF2	OUTLET			

****
Cross Section Summary
****

Conduit	Shape	Full Depth	Full Area	Hyd. Rad.	Max. Width	No. of Barrels	Full Flow
D101	TRAPEZOIDAL	0.50	1.00	0.27	3.50	1	0.82
D102	TRAPEZOIDAL	0.50	1.00	0.27	3.50	1	0.64
D103	TRAPEZOIDAL	0.50	1.00	0.27	3.50	1	7.16
D104	TRAPEZOIDAL	0.50	1.00	0.27	3.50	1	1.84
D105	TRAPEZOIDAL	0.50	1.00	0.27	3.50	1	0.82
D106	TRAPEZOIDAL	0.50	1.00	0.27	3.50	1	0.63
D107	TRAPEZOIDAL	0.50	1.00	0.27	3.50	1	6.88
D108	TRAPEZOIDAL	0.50	1.00	0.27	3.50	1	1.81
D109	TRAPEZOIDAL	0.50	1.00	0.27	3.50	1	3.05
D110	TRAPEZOIDAL	0.50	1.00	0.27	3.50	1	3.39

****
NOTE: The summary statistics displayed in this report are
based on results found at every computational time step,
not just on results from each reporting time step.
****

****
Analysis Options
****

```
Flow Units ............... CMS
Process Models:
  Rainfall/Runoff ........ YES
  RDII ................... NO
  Snowmelt ............... NO
  Groundwater ............ NO
  Flow Routing ........... YES
  Ponding Allowed ........ NO
  Water Quality .......... NO
Infiltration Method ...... HORTON
Flow Routing Method ...... DYNWAVE
Starting Date ............ JAN-19-2016 00:00:00
Ending Date .............. JAN-25-2016 00:00:00
Antecedent Dry Days ...... 0.0
Report Time Step ......... 00:05:00
Wet Time Step ............ 00:00:01
Dry Time Step ............ 00:00:01
Routing Time Step ........ 1.00 sec
Variable Time Step ....... YES
Maximum Trials ........... 8
Number of Threads ........ 1
Head Tolerance ........... 0.001500 m
```

Runoff Quantity Continuity	Volume hectare-m	Depth mm
Total Precipitation	0.664	89.999
Evaporation Loss	0.000	0.000
Infiltration Loss	0.055	7.455
Surface Runoff	0.608	82.420

Final Storage	0.001	0.124
Continuity Error (%)	0.000	

****

Flow Routing Continuity	Volume hectare-m	Volume 10^6 ltr
Dry Weather Inflow	0.000	0.000
Wet Weather Inflow	0.608	6.084
Groundwater Inflow	0.000	0.000
RDII Inflow	0.000	0.000
External Inflow	0.000	0.000
External Outflow	0.613	6.127
Flooding Loss	0.000	0.000
Evaporation Loss	0.000	0.000
Exfiltration Loss	0.000	0.000
Initial Stored Volume	0.000	0.000
Final Stored Volume	0.000	0.000
Continuity Error (%)	-0.714	

****
Time-Step Critical Elements
****

None

****
Highest Flow Instability Indexes
****

Link OL1 (3)
Link OL2 (2)

****
Routing Time Step Summary
****

Minimum Time Step :	0.50 sec
Average Time Step :	1.00 sec
Maximum Time Step :	1.00 sec
Percent in Steady State :	0.00
Average Iterations per Step :	2.00
Percent Not Converging :	0.00

****
Subcatchment Runoff Summary
****

Subcatchment	Total Precip mm	Total Runon mm	Total Evap mm	Total Infil mm	Total Runoff mm	Total Runoff 10^6 ltr	Peak Runoff CMS	Runoff Coeff
101	90.00	0.00	0.00	7.92	82.08	0.65	0.03	0.912
102	90.00	0.00	0.00	7.92	82.08	0.07	0.00	0.912
103	90.00	0.00	0.00	7.92	82.08	0.11	0.01	0.912
104	90.00	0.00	0.00	7.95	82.05	1.11	0.05	0.912
105	90.00	0.00	0.00	7.93	82.07	0.17	0.01	0.912
106	90.00	0.00	0.00	9.06	80.94	0.77	0.04	0.899
107	90.00	0.00	0.00	8.93	81.07	0.42	0.02	0.901
108	90.00	0.00	0.00	8.93	81.07	0.43	0.02	0.901
109	90.00	0.00	0.00	9.06	80.94	0.75	0.04	0.899
110	90.00	0.00	0.00	8.99	81.01	0.15	0.01	0.900
111	90.00	0.00	0.00	8.99	81.01	0.15	0.01	0.900
112	90.00	0.00	0.00	0.00	89.05	0.41		

							0.02	0.989
113	90.00	0.00	0.00	8.93	81.07	0.23	0.01	0.901
114	90.00	0.00	0.00	0.00	89.05	0.45	0.02	0.989
115	90.00	0.00	0.00	8.93	81.07	0.23	0.01	0.901

****
Node Depth Summary
****

Node	Type	Average Depth Meters	Maximum Depth Meters	Maximum HGL Meters	Time of Max Occurrence days	hr:min	Reported Max Depth Meters
J1	JUNCTION	0.01	0.07	164.57	0	08:00	0.02
J10	JUNCTION	0.00	0.00	164.50	0	00:00	0.00
J2	JUNCTION	0.02	0.23	164.53	0	08:00	0.07
J3	JUNCTION	0.02	0.20	164.50	0	08:00	0.06
J4	JUNCTION	0.00	0.05	164.05	0	08:00	0.01
J5	JUNCTION	0.01	0.14	156.14	0	08:00	0.04
J6	JUNCTION	0.01	0.11	153.11	0	08:00	0.03
J7	JUNCTION	0.00	0.04	164.04	0	08:00	0.01
J8	JUNCTION	0.01	0.15	156.15	0	08:00	0.05
J9	JUNCTION	0.01	0.11	153.11	0	08:00	0.03
OF1	OUTFALL	0.00	0.00	149.50	0	00:00	0.00
OF2	OUTFALL	0.00	0.00	149.50	0	00:00	0.00
POND_East	STORAGE	0.01	0.21	150.21	0	10:35	0.06
POND_West	STORAGE	0.01	0.20	150.20	0	10:24	0.06

****
Node Inflow Summary
****

Node	Type	Maximum Lateral Inflow CMS	Maximum Total Inflow CMS	Time of Max Occurrence days	hr:min	Lateral Inflow Volume 10^6 ltr	Total Inflow Volume 10^6 ltr	Flow Balance Error Percent
J1	JUNCTION	0.015	0.015	0	08:00	0.302	0.302	-0.026
J10	JUNCTION	0.000	0.000	0	00:00	0	0	0.000 ltr
J2	JUNCTION	0.037	0.051	0	08:00	0.771	1.07	0.010
J3	JUNCTION	0.036	0.036	0	08:00	0.745	0.745	0.006
J4	JUNCTION	0.005	0.056	0	08:00	0.109	1.18	-0.001
J5	JUNCTION	0.054	0.110	0	08:00	1.13	2.31	-0.003
J6	JUNCTION	0.011	0.121	0	08:00	0.23	2.54	0.002
J7	JUNCTION	0.008	0.043	0	08:00	0.167	0.912	-0.003
J8	JUNCTION	0.073	0.116	0	08:00	1.54	2.45	-0.004
J9	JUNCTION	0.011	0.127	0	08:00	0.234	2.68	0.003
OF1	OUTFALL	0.000	0.044	0	03:42	0	3.02	0.000
OF2	OUTFALL	0.000	0.044	0	03:31	0	3.11	0.000
POND_East	STORAGE	0.018	0.146	0	08:00	0.412	3.09	-0.528
POND_West	STORAGE	0.020	0.141	0	08:00	0.446	2.99	-0.895

****
Node Surcharge Summary
****

No nodes were surcharged.

****
Node Flooding Summary
****

No nodes were flooded.

****
Storage Volume Summary
****

Storage Unit	Average Volume 1000 m3	Avg Pcnt Full	Evap Pcnt Loss	Exfil Pcnt Loss	Maximum Volume 1000 m3	Max Pcnt Full	Time of Max Occurrence days hr:min	Maximum Outflow CMS
POND_East	0.038	1	0	0	0.600	17	0 10:35	0.044
POND_West	0.033	1	0	0	0.558	16	0 10:24	0.044

****
Outfall Loading Summary
****

Outfall Node	Flow Freq Pcnt	Avg Flow CMS	Max Flow CMS	Total Volume 10^6 ltr
OF1	15.48	0.038	0.044	3.017
OF2	15.57	0.039	0.044	3.110
System	15.52	0.076	0.088	6.127

****
Link Flow Summary
****

Link	Type	Maximum |Flow| CMS	Time of Max Occurrence days hr:min	Maximum |Veloc| m/sec	Max/ Full Flow	Max/ Full Depth
D101	CONDUIT	0.015	0 08:00	0.10	0.02	0.31
D102	CONDUIT	0.051	0 08:00	0.40	0.08	0.28
D103	CONDUIT	0.056	0 08:00	0.78	0.01	0.19
D104	CONDUIT	0.110	0 08:00	0.99	0.06	0.25
D105	CONDUIT	0.000	0 00:00	0.00	0.00	0.20
D106	CONDUIT	0.035	0 08:00	0.35	0.06	0.24
D107	CONDUIT	0.043	0 08:00	0.59	0.01	0.19
D108	CONDUIT	0.116	0 08:00	1.02	0.06	0.26
D109	CONDUIT	0.121	0 08:00	1.31	0.04	0.22
D110	CONDUIT	0.127	0 08:00	1.43	0.04	0.22
OL1	DUMMY	0.044	0 03:42			
OL2	DUMMY	0.044	0 03:31			

****
Flow Classification Summary
****

Conduit	Adjusted /Actual Length	Fraction of Time in Flow Class: Dry	Up Dry	Down Dry	Sub Crit	Sup Crit	Up Crit	Down Crit	Norm Ltd	Inlet Ctrl
D101	1.00	0.45	0.34	0.00	0.21	0.00	0.00	0.00	0.98	0.00
D102	1.00	0.44	0.00	0.00	0.55	0.00	0.00	0.00	0.00	0.00
D103	1.00	0.45	0.15	0.00	0.40	0.00	0.00	0.00	0.49	0.00
D104	1.00	0.45	0.00	0.00	0.54	0.02	0.00	0.00	0.09	0.00
D105	1.00	0.44	0.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00

D106	1.00	0.43	0.00	0.00	0.56	0.00	0.00	0.00	0.00	0.00
D107	1.00	0.44	0.16	0.00	0.41	0.00	0.00	0.00	0.50	0.00
D108	1.00	0.44	0.00	0.00	0.53	0.04	0.00	0.00	0.03	0.00
D109	1.00	0.67	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00
D110	1.00	0.68	0.00	0.00	0.00	0.00	0.00	0.32	0.00	0.00

****
Conduit Surcharge Summary
****

No conduits were surcharged.

Analysis begun on: Wed May 04 12:52:37 2016
Analysis ended on: Wed May 04 12:52:45 2016
Total elapsed time: 00:00:08

EPA STORM WATER MANAGEMENT MODEL - VERSION 5.1 (Build 5.1.010)

****
Element Count
****

Number of rain gages 4
Number of subcatchments ... 15
Number of nodes 14
Number of links 12
Number of pollutants 0
Number of land uses 0

****
Raingage Summary
****

Name	Data Source	Data Type	Recording Interval
100yr_SCS_24h_Type_IA_118.2mm	100yr_SCS_24h_Type_IA_118.2mm	INTENSITY	15 min.
10yr_SCS_24h_Type_IA_90mm	10yr_SCS_24h_Type_IA_90mm	INTENSITY	15 min.
5yr_SCS_24h_Type_IA_81.2mm	5yr_SCS_24h_Type_IA_81.2mm	INTENSITY	15 min.
6month_SCS_24h_Type_IA_61.61mm	6month_SCS_24h_Type_IA_61.61mm	INTENSITY	15 min.

****
Subcatchment Summary
****

Name	Area	Width	%Imperv	%Slope	Rain Gage	Outlet
101	0.79	196.75	0.00	45.0000	100yr_SCS_24h_Type_IA_118.2mm	J5
102	0.08	21.05	0.00	45.0000	100yr_SCS_24h_Type_IA_118.2mm	J5
103	0.13	33.30	0.00	45.0000	100yr_SCS_24h_Type_IA_118.2mm	J4
104	1.35	245.89	0.00	35.0000	100yr_SCS_24h_Type_IA_118.2mm	J8
105	0.20	67.73	0.00	20.0000	100yr_SCS_24h_Type_IA_118.2mm	J7
106	0.95	146.54	0.00	22.0000	100yr_SCS_24h_Type_IA_118.2mm	J2
107	0.51	146.63	0.00	30.0000	100yr_SCS_24h_Type_IA_118.2mm	J5
108	0.53	150.14	0.00	30.0000	100yr_SCS_24h_Type_IA_118.2mm	J8
109	0.92	141.63	0.00	22.0000	100yr_SCS_24h_Type_IA_118.2mm	J3
110	0.18	40.56	0.00	22.0000	100yr_SCS_24h_Type_IA_118.2mm	J1
111	0.19	42.33	0.00	22.0000	100yr_SCS_24h_Type_IA_118.2mm	J1
112	0.46	185.00	100.00	15.0000	100yr_SCS_24h_Type_IA_118.2mm	POND_East
113	0.29	82.37	0.00	30.0000	100yr_SCS_24h_Type_IA_118.2mm	J9
114	0.50	200.56	100.00	15.0000	100yr_SCS_24h_Type_IA_118.2mm	POND_West
115	0.28	81.14	0.00	30.0000	100yr_SCS_24h_Type_IA_118.2mm	J6

****
Node Summary
****

Name	Type	Invert Elev.	Max. Depth	Ponded Area	External Inflow
J1	JUNCTION	164.50	0.50	0.0	
J10	JUNCTION	164.50	0.50	0.0	
J2	JUNCTION	164.30	0.50	0.0	
J3	JUNCTION	164.30	0.50	0.0	
J4	JUNCTION	164.00	0.50	0.0	
J5	JUNCTION	156.00	0.50	0.0	
J6	JUNCTION	153.00	0.50	0.0	
J7	JUNCTION	164.00	0.50	0.0	
J8	JUNCTION	156.00	0.50	0.0	
J9	JUNCTION	153.00	0.50	0.0	

OF1	OUTFALL	149.50	0.00	0.0
OF2	OUTFALL	149.50	0.00	0.0
POND_East	STORAGE	150.00	1.00	0.0
POND_West	STORAGE	150.00	1.00	0.0

****
Link Summary
****

Name	From Node	To Node	Type	Length	%Slope	Roughness
D101	J1	J2	CONDUIT	57.9	0.3454	0.0300
D102	J2	J4	CONDUIT	146.4	0.2050	0.0300
D103	J4	J5	CONDUIT	31.7	26.0720	0.0300
D104	J5	J6	CONDUIT	174.8	1.7166	0.0300
D105	J10	J3	CONDUIT	59.2	0.3376	0.0300
D106	J3	J7	CONDUIT	149.5	0.2006	0.0300
D107	J7	J8	CONDUIT	34.2	24.0519	0.0300
D108	J8	J9	CONDUIT	180.0	1.6664	0.0300
D109	J6	POND_West	CONDUIT	53.0	4.7258	0.0300
D110	J9	POND_East	CONDUIT	42.9	5.8374	0.0300
OL1	POND_West	OF1	OUTLET			
OL2	POND_East	OF2	OUTLET			

****
Cross Section Summary
****

Conduit	Shape	Full Depth	Full Area	Hyd. Rad.	Max. Width	No. of Barrels	Full Flow
D101	TRAPEZOIDAL	0.50	1.00	0.27	3.50	1	0.82
D102	TRAPEZOIDAL	0.50	1.00	0.27	3.50	1	0.64
D103	TRAPEZOIDAL	0.50	1.00	0.27	3.50	1	7.16
D104	TRAPEZOIDAL	0.50	1.00	0.27	3.50	1	1.84
D105	TRAPEZOIDAL	0.50	1.00	0.27	3.50	1	0.82
D106	TRAPEZOIDAL	0.50	1.00	0.27	3.50	1	0.63
D107	TRAPEZOIDAL	0.50	1.00	0.27	3.50	1	6.88
D108	TRAPEZOIDAL	0.50	1.00	0.27	3.50	1	1.81
D109	TRAPEZOIDAL	0.50	1.00	0.27	3.50	1	3.05
D110	TRAPEZOIDAL	0.50	1.00	0.27	3.50	1	3.39

****
NOTE: The summary statistics displayed in this report are
based on results found at every computational time step,
not just on results from each reporting time step.
****

****
Analysis Options
****

```
Flow Units ............... CMS
Process Models:
  Rainfall/Runoff ........ YES
  RDII ................... NO
  Snowmelt ............... NO
  Groundwater ............ NO
  Flow Routing ........... YES
  Ponding Allowed ........ NO
  Water Quality .......... NO
Infiltration Method ...... HORTON
Flow Routing Method ...... DYNWAVE
Starting Date ............ JAN-19-2016 00:00:00
Ending Date .............. JAN-25-2016 00:00:00
Antecedent Dry Days ...... 0.0
Report Time Step ......... 00:05:00
Wet Time Step ............ 00:00:01
Dry Time Step ............ 00:00:01
Routing Time Step ........ 1.00 sec
Variable Time Step ....... YES
Maximum Trials ........... 8
Number of Threads ........ 1
Head Tolerance ........... 0.001500 m
```

Runoff Quantity Continuity	Volume hectare-m	Depth mm
Total Precipitation	0.872	118.198
Evaporation Loss	0.000	0.000
Infiltration Loss	0.055	7.471
Surface Runoff	0.816	110.603

Final Storage	0.001	0.124
Continuity Error (%)	0.000	

****
Flow Routing Continuity
****

	Volume hectare-m	Volume 10^6 ltr
Dry Weather Inflow	0.000	0.000
Wet Weather Inflow	0.816	8.164
Groundwater Inflow	0.000	0.000
RDII Inflow	0.000	0.000
External Inflow	0.000	0.000
External Outflow	0.817	8.168
Flooding Loss	0.000	0.000
Evaporation Loss	0.000	0.000
Exfiltration Loss	0.000	0.000
Initial Stored Volume	0.000	0.000
Final Stored Volume	0.000	0.000
Continuity Error (%)	-0.052	

****
Time-Step Critical Elements
****

None

****
Highest Flow Instability Indexes
****

Link OL1 (1)
Link OL2 (1)

****
Routing Time Step Summary
****

Minimum Time Step :	0.50 sec
Average Time Step :	1.00 sec
Maximum Time Step :	1.00 sec
Percent in Steady State :	0.00
Average Iterations per Step :	2.00
Percent Not Converging :	0.00

****
Subcatchment Runoff Summary
****

Subcatchment	Total Precip mm	Total Runon mm	Total Evap mm	Total Infil mm	Total Runoff mm	Total Runoff 10^6 ltr	Peak Runoff CMS	Runoff Coeff
101	118.20	0.00	0.00	7.94	110.26	0.87	0.04	0.933
102	118.20	0.00	0.00	7.94	110.26	0.09	0.00	0.933
103	118.20	0.00	0.00	7.94	110.26	0.15	0.01	0.933
104	118.20	0.00	0.00	7.97	110.22	1.49	0.07	0.933
105	118.20	0.00	0.00	7.95	110.25	0.22	0.01	0.933
106	118.20	0.00	0.00	9.08	109.12	1.04	0.05	0.923
107	118.20	0.00	0.00	8.94	109.26	0.56	0.03	0.924
108	118.20	0.00	0.00	8.94	109.26	0.57	0.03	0.924
109	118.20	0.00	0.00	9.08	109.12	1.00	0.05	0.923
110	118.20	0.00	0.00	9.00	109.19	0.20	0.01	0.924
111	118.20	0.00	0.00	9.00	109.19	0.21	0.01	0.924
112	118.20	0.00	0.00	0.00	117.25	0.54		

							0.02	0.992
113	118.20	0.00	0.00	8.94	109.26	0.31	0.01	0.924
114	118.20	0.00	0.00	0.00	117.25	0.59	0.03	0.992
115	118.20	0.00	0.00	8.94	109.26	0.31	0.01	0.924

****
Node Depth Summary
****

Node	Type	Average Depth Meters	Maximum Depth Meters	Maximum HGL Meters	Time of Max Occurrence days	hr:min	Reported Max Depth Meters
J1	JUNCTION	0.01	0.08	164.58	0	08:00	0.03
J10	JUNCTION	0.00	0.02	164.52	0	07:59	0.01
J2	JUNCTION	0.02	0.26	164.56	0	08:00	0.08
J3	JUNCTION	0.02	0.22	164.52	0	08:00	0.07
J4	JUNCTION	0.00	0.05	164.05	0	08:00	0.02
J5	JUNCTION	0.01	0.16	156.16	0	08:00	0.05
J6	JUNCTION	0.01	0.13	153.13	0	08:00	0.04
J7	JUNCTION	0.00	0.05	164.05	0	08:00	0.01
J8	JUNCTION	0.01	0.17	156.17	0	08:00	0.05
J9	JUNCTION	0.01	0.12	153.12	0	08:00	0.04
OF1	OUTFALL	0.00	0.00	149.50	0	00:00	0.00
OF2	OUTFALL	0.00	0.00	149.50	0	00:00	0.00
POND_East	STORAGE	0.04	0.38	150.38	0	12:46	0.12
POND_West	STORAGE	0.04	0.36	150.36	0	12:32	0.11

****
Node Inflow Summary
****

Node	Type	Maximum Lateral Inflow CMS	Maximum Total Inflow CMS	Time of Max Occurrence days	hr:min	Lateral Inflow Volume 10^6 ltr	Total Inflow Volume 10^6 ltr	Flow Balance Error Percent
J1	JUNCTION	0.019	0.019	0	08:00	0.407	0.407	-0.025
J10	JUNCTION	0.000	0.001	0	07:22	0	0.000649	0.867
J2	JUNCTION	0.049	0.068	0	08:00	1.04	1.45	0.009
J3	JUNCTION	0.047	0.047	0	08:00	1	1.01	0.005
J4	JUNCTION	0.007	0.074	0	08:00	0.147	1.59	-0.001
J5	JUNCTION	0.071	0.145	0	08:00	1.52	3.11	-0.003
J6	JUNCTION	0.015	0.160	0	08:00	0.31	3.43	0.002
J7	JUNCTION	0.010	0.057	0	08:00	0.224	1.23	-0.003
J8	JUNCTION	0.096	0.153	0	08:00	2.06	3.29	-0.003
J9	JUNCTION	0.015	0.168	0	08:00	0.315	3.61	0.002
OF1	OUTFALL	0.000	0.044	0	02:42	0	4.02	0.000
OF2	OUTFALL	0.000	0.044	0	02:27	0	4.15	0.000
POND_East	STORAGE	0.024	0.192	0	08:00	0.542	4.15	-0.007
POND_West	STORAGE	0.026	0.186	0	08:00	0.588	4.01	-0.098

****
Node Surcharge Summary
****

No nodes were surcharged.

****
Node Flooding Summary
****

No nodes were flooded.

****
Storage Volume Summary
****

Storage Unit	Average Volume 1000 m3	Avg Pcnt Full	Evap Pcnt Loss	Exfil Pcnt Loss	Maximum Volume 1000 m3	Max Pcnt Full	Time of Max Occurrence days hr:min	Maximum Outflow CMS
POND_East	0.124	4	0	0	1.130	33	0 12:46	0.044
POND_West	0.110	3	0	0	1.050	31	0 12:32	0.044

****
Outfall Loading Summary
****

Outfall Node	Flow Freq Pcnt	Avg Flow CMS	Max Flow CMS	Total Volume 10^6 ltr
OF1	18.21	0.043	0.044	4.017
OF2	18.77	0.043	0.044	4.151
System	18.49	0.085	0.088	8.168

****
Link Flow Summary
****

Link	Type	Maximum |Flow| CMS	Time of Max Occurrence days hr:min	Maximum |Veloc| m/sec	Max/ Full Flow	Max/ Full Depth
D101	CONDUIT	0.019	0 08:00	0.11	0.02	0.35
D102	CONDUIT	0.068	0 08:00	0.43	0.11	0.32
D103	CONDUIT	0.074	0 08:00	0.85	0.01	0.22
D104	CONDUIT	0.145	0 08:00	1.07	0.08	0.29
D105	CONDUIT	0.001	0 07:22	0.01	0.00	0.25
D106	CONDUIT	0.047	0 08:00	0.38	0.07	0.27
D107	CONDUIT	0.057	0 08:00	0.65	0.01	0.22
D108	CONDUIT	0.153	0 08:00	1.10	0.08	0.29
D109	CONDUIT	0.160	0 08:00	1.41	0.05	0.26
D110	CONDUIT	0.168	0 08:00	1.55	0.05	0.25
OL1	DUMMY	0.044	0 02:42			
OL2	DUMMY	0.044	0 02:27			

****
Flow Classification Summary
****

Conduit	Adjusted /Actual Length	Fraction of Time in Flow Class: Dry	Up Dry	Down Dry	Sub Crit	Sup Crit	Up Crit	Down Crit	Norm Ltd	Inlet Ctrl
D101	1.00	0.44	0.34	0.00	0.21	0.00	0.00	0.00	0.98	0.00
D102	1.00	0.44	0.00	0.00	0.56	0.00	0.00	0.00	0.00	0.00
D103	1.00	0.44	0.15	0.00	0.40	0.00	0.00	0.00	0.50	0.00
D104	1.00	0.44	0.00	0.00	0.53	0.03	0.00	0.00	0.09	0.00
D105	1.00	0.43	0.50	0.00	0.07	0.00	0.00	0.00	0.94	0.00

D106	1.00	0.43	0.00	0.00	0.57	0.00	0.00	0.00	0.00	0.00
D107	1.00	0.43	0.16	0.00	0.41	0.00	0.00	0.00	0.51	0.00
D108	1.00	0.43	0.00	0.00	0.50	0.07	0.00	0.00	0.03	0.00
D109	1.00	0.66	0.00	0.00	0.00	0.00	0.00	0.34	0.00	0.00
D110	1.00	0.67	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00

****
Conduit Surcharge Summary
****

No conduits were surcharged.

Analysis begun on: Wed May 04 12:46:54 2016
Analysis ended on: Wed May 04 12:47:03 2016
Total elapsed time: 00:00:09

Appendix D
HELP Model Inputs and Outputs

Table D-1

HELP Model Input Parameters
2017 Design, Operations, and Closure Plan
Upland Landfill
Campbell River, British Columbia

Description of Cover System	Layer Type	Layer Decription
Daily Cover		
	Vegetative Coverage	Bare (Leaf Area Index 0)
	Evaporative Zone Depth	150 mm
	Slope	10 % slope
Sand-Daily Cover	Vertical Percolation Layer	150 mm of Sand (Soil Texture No. 2), Hyd.Cond. 5.8x10^{-3}cm/sec
Municipal Waste	Vertical Percolation Layer	24 m if Municipal Solid Waste (Soil Texture No. 18), Hyd.Cond. 1x10^{-3}cm/sec
Geotextile	Flexible Membrane Liner	Drainage Net (model default, Soil Texture No. 20), Hyd.Cond. 10cm/sec Good placement quality, 2 pinholes/hectare, 6 installation defects/hectare
Drain Rock	Lateral Drainage Layer	300 mm of Gravel (Soil Texture No. 21), Hyd.Cond. 3x10^{-1}cm/sec
HDPE Base Liner	Flexible Membrane Liner	HDPE (model default, Soil Texture No. 35), Hyd.Cond. 2x10^{-13}cm/sec, Good placement quality, 2 pinholes/hectare, 6 installation defects/hectare
Geosynthetic Clay Liner	Barrier Soil Liner	Bentonite Mat (model default, Soil Texture No. 17), Hyd.Con. 3x10^{-9}cm/sec
Intermediate Cover		
	Vegetative Coverage	Bare (Leaf Area Index 1)
	Evaporative Zone Depth	300 mm
	Slope	10 % slope
Sand-Intermediate Cover	Vertical Percolation Layer	300 mm of Sand (Soil Texture No. 2), Hyd.Cond. 5.8x10^{-3}cm/sec
Municipal Waste	Vertical Percolation Layer	24 m if Municipal Solid Waste (Soil Texture No. 18), Hyd.Cond. 1x10^{-3}cm/sec
Geotextile	Flexible Membrane Liner	Drainage Net (model default, Soil Texture No. 20), Hyd.Cond. 10cm/sec Good placement quality, 2 pinholes/hectare, 6 installation defects/hectare
Drain Rock	Lateral Drainage Layer	300 mm of Gravel (Soil Texture No. 21), Hyd.Cond. 3x10^{-1}cm/sec
HDPE Base Liner	Flexible Membrane Liner	HDPE (model default, Soil Texture No. 35), Hyd.Cond. 2x10^{-13}cm/sec, Good placement quality, 2 pinholes/hectare, 6 installation defects/hectare
Geosynthetic Clay Liner	Barrier Soil Liner	Bentonite Mat (model default, Soil Texture No. 17), Hyd.Con. 3x10^{-9}cm/sec

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**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************


PRECIPITATION DATA FILE:    C:\HELP3\88877\PPT1.D4
TEMPERATURE DATA FILE:      C:\HELP3\88877\TEMP.D7
SOLAR RADIATION DATA FILE:  C:\HELP3\88877\SRAD.D13
EVAPOTRANSPIRATION DATA:    C:\HELP3\88877\EVAP.D11
SOIL AND DESIGN DATA FILE:  C:\HELP3\88877\DLYT.D10
OUTPUT DATA FILE:           C:\HELP3\88877\DLYTO.OUT


TIME:  13:53     DATE:   2/16/2016


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     TITLE:  Upland Landfill - Daily Cover Top

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     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
              COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                  LAYER  1
                                  --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER   2
           THICKNESS                 =    10.00   CM
           POROSITY                  =     0.4370 VOL/VOL
           FIELD CAPACITY            =     0.0620 VOL/VOL
           WILTING POINT             =     0.0240 VOL/VOL
           INITIAL SOIL WATER CONTENT  =     0.1380 VOL/VOL
           EFFECTIVE SAT. HYD. COND.   =  0.579999993000E-02 CM/SEC
```

NOTE: SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY 1.80
FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.

LAYER 2

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER   2

THICKNESS	=	5.00 CM
POROSITY	=	0.4370 VOL/VOL
FIELD CAPACITY	=	0.0620 VOL/VOL
WILTING POINT	=	0.0240 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4370 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.579999993000E-02 CM/SEC

LAYER 3

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 18

THICKNESS	=	2400.00 CM
POROSITY	=	0.6710 VOL/VOL
FIELD CAPACITY	=	0.2920 VOL/VOL
WILTING POINT	=	0.0770 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.3176 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.100000005000E-02 CM/SEC

LAYER 4

TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 20

THICKNESS	=	0.50 CM
POROSITY	=	0.0000 VOL/VOL
FIELD CAPACITY	=	0.0000 VOL/VOL
WILTING POINT	=	0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	10.0000000000 CM/SEC
FML PINHOLE DENSITY	=	2.00 HOLES/HECTARE
FML INSTALLATION DEFECTS	=	6.00 HOLES/HECTARE
FML PLACEMENT QUALITY	=	3 - GOOD

LAYER 5

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 21

```
THICKNESS                  =     30.00   CM
POROSITY                   =      0.3970 VOL/VOL
FIELD CAPACITY             =      0.0320 VOL/VOL
WILTING POINT              =      0.0130 VOL/VOL
INITIAL SOIL WATER CONTENT =      0.0366 VOL/VOL
EFFECTIVE SAT. HYD. COND.  =  0.300000012000     CM/SEC
SLOPE                      =      1.00   PERCENT
DRAINAGE LENGTH            =     80.0    METERS
```

LAYER 6

TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 35

```
THICKNESS                  =      0.15   CM
POROSITY                   =      0.0000 VOL/VOL
FIELD CAPACITY             =      0.0000 VOL/VOL
WILTING POINT              =      0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT =      0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.  =  0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY        =      2.00   HOLES/HECTARE
FML INSTALLATION DEFECTS   =      6.00   HOLES/HECTARE
FML PLACEMENT QUALITY      =  3 - GOOD
```

LAYER 7

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 17

```
THICKNESS                  =      0.60   CM
POROSITY                   =      0.7500 VOL/VOL
FIELD CAPACITY             =      0.7470 VOL/VOL
WILTING POINT              =      0.4000 VOL/VOL
INITIAL SOIL WATER CONTENT =      0.7500 VOL/VOL
EFFECTIVE SAT. HYD. COND.  =  0.300000003000E-08 CM/SEC
```

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE # 2 WITH BARE GROUND CONDITIONS, A SURFACE SLOPE OF 10.% AND A SLOPE LENGTH OF 35. METERS.

SCS RUNOFF CURVE NUMBER	=	81.70	
FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1.0000	HECTARES
EVAPORATIVE ZONE DEPTH	=	10.0	CM
INITIAL WATER IN EVAPORATIVE ZONE	=	1.380	CM
UPPER LIMIT OF EVAPORATIVE STORAGE	=	4.370	CM
LOWER LIMIT OF EVAPORATIVE STORAGE	=	0.240	CM
INITIAL SNOW WATER	=	0.000	CM
INITIAL WATER IN LAYER MATERIALS	=	767.418	CM
TOTAL INITIAL WATER	=	767.418	CM
TOTAL SUBSURFACE INFLOW	=	0.00	MM/YR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM Campbell River British Columbia

STATION LATITUDE	=	49.95	DEGREES
MAXIMUM LEAF AREA INDEX	=	1.00	
START OF GROWING SEASON (JULIAN DATE)	=	91	
END OF GROWING SEASON (JULIAN DATE)	=	305	
EVAPORATIVE ZONE DEPTH	=	10.0	CM
AVERAGE ANNUAL WIND SPEED	=	8.00	KPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	84.10	%
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	72.47	%
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	71.95	%
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	87.08	%

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR OLYMPIA WASHINGTON

NORMAL MEAN MONTHLY PRECIPITATION (MM)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
217.5	149.5	140.0	92.1	68.4	62.9
39.4	44.6	55.2	162.2	231.9	225.7

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR OLYMPIA WASHINGTON

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES CELSIUS)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
2.4	3.2	5.2	8.0	11.6	14.7
17.3	17.2	13.7	8.6	4.4	2.1

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR OLYMPIA WASHINGTON
AND STATION LATITUDE = 49.95 DEGREES

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AVERAGE MONTHLY VALUES (MM) FOR YEARS 1 THROUGH 100

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	216.01	144.89	142.48	102.27	67.19	62.06
	37.45	39.26	52.65	167.86	220.02	233.79
STD. DEVIATIONS	63.32	48.38	46.44	37.98	33.77	32.53
	28.36	30.28	30.04	68.74	74.24	69.47
RUNOFF						
TOTALS	12.660	20.060	2.466	0.416	0.328	0.233
	0.299	0.455	0.126	5.843	10.749	10.233
STD. DEVIATIONS	20.906	62.288	9.155	0.999	1.081	0.594
	0.916	2.784	0.580	7.616	13.502	9.764
EVAPOTRANSPIRATION						
TOTALS	7.957	13.239	35.662	52.059	38.419	35.466
	19.931	19.089	23.855	21.140	9.810	7.396
STD. DEVIATIONS	2.404	4.037	5.541	12.702	16.460	16.450
	13.694	13.506	11.262	4.414	1.406	1.741
PERCOLATION/LEAKAGE THROUGH LAYER 2						
TOTALS	192.0256	132.3064	107.2921	52.8757	29.9468	26.5194
	19.2414	18.7330	28.2144	134.6477	191.5514	204.7322

```
  STD. DEVIATIONS       63.5898  56.8081  43.3949  28.0032  20.9888  18.9106
                        18.2090  17.7337  20.4606  61.0302  63.7523  60.8738

PERCOLATION/LEAKAGE THROUGH LAYER  4
------------------------------------
  TOTALS                67.4621  89.1076 113.0098 134.5437 142.3553 125.1200
                       120.0066 108.1710  86.8786  55.0754  43.9157  49.8206

  STD. DEVIATIONS       21.6337  32.3856  32.5588  29.3513  25.6001  19.5805
                        16.4382  14.8682  13.8073  15.9821  15.0656  14.6495

LATERAL DRAINAGE COLLECTED FROM LAYER  5
----------------------------------------
  TOTALS                62.4320  85.4965 109.2216 130.5754 143.0746 127.6704
                       121.2699 110.6171  89.7698  62.5023  44.2309  48.5235

  STD. DEVIATIONS       18.8837  29.4818  29.8007  29.3624  25.4275  20.3398
                        15.9735  15.3262  13.1352  15.6702  14.7172  13.3482

PERCOLATION/LEAKAGE THROUGH LAYER  7
------------------------------------
  TOTALS                 0.0003   0.0004   0.0006   0.0007   0.0008   0.0007
                         0.0006   0.0006   0.0004   0.0003   0.0002   0.0002

  STD. DEVIATIONS        0.0001   0.0002   0.0002   0.0002   0.0002   0.0001
                         0.0001   0.0001   0.0001   0.0001   0.0001   0.0001


-------------------------------------------------------------------------------
                 AVERAGES OF MONTHLY AVERAGED DAILY HEADS (CM)
-------------------------------------------------------------------------------


DAILY AVERAGE HEAD ON TOP OF LAYER  2
-------------------------------------
  AVERAGES               0.1847   0.1400   0.1058   0.0572   0.0315   0.0293
                         0.0184   0.0195   0.0314   0.1352   0.1906   0.1933

  STD. DEVIATIONS        0.0651   0.0596   0.0448   0.0316   0.0229   0.0235
                         0.0189   0.0183   0.0243   0.0621   0.0670   0.0631

DAILY AVERAGE HEAD ON TOP OF LAYER  4
-------------------------------------
  AVERAGES               0.0728   0.1047   0.1207   0.1480   0.1515   0.1378
                         0.1278   0.1153   0.0957   0.0596   0.0497   0.0542

  STD. DEVIATIONS        0.0226   0.0374   0.0346   0.0321   0.0272   0.0215
                         0.0175   0.0158   0.0151   0.0167   0.0159   0.0153

DAILY AVERAGE HEAD ON TOP OF LAYER  6
-------------------------------------
  AVERAGES               3.1084   4.6701   5.4380   6.7179   7.1236   6.5685
                         6.0379   5.5075   4.6186   3.1119   2.2756   2.4159
```

STD. DEVIATIONS	0.9402	1.6024	1.4838	1.5107	1.2660	1.0465
	0.7953	0.7631	0.6758	0.7802	0.7572	0.6646

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 100

	MM		CU. METERS	PERCENT
PRECIPITATION	1485.94	(190.257)	14859.4	100.00
RUNOFF	63.869	(79.6342)	638.69	4.298
EVAPOTRANSPIRATION	284.022	(37.6888)	2840.22	19.114
PERCOLATION/LEAKAGE THROUGH LAYER 2	1138.08618	(171.59268)	11380.861	76.59047
AVERAGE HEAD ON TOP OF LAYER 2	0.947 (	0.154)		
PERCOLATION/LEAKAGE THROUGH LAYER 4	1135.46631	(133.15610)	11354.663	76.41415
AVERAGE HEAD ON TOP OF LAYER 4	1.031 (	0.120)		
LATERAL DRAINAGE COLLECTED FROM LAYER 5	1135.38354	(132.39745)	11353.836	76.40858
PERCOLATION/LEAKAGE THROUGH LAYER 7	0.00581	(0.00082)	0.058	0.00039
AVERAGE HEAD ON TOP OF LAYER 6	47.995 (	5.607)		
CHANGE IN WATER STORAGE	2.657	(7.4268)	26.57	0.179

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 100

	(MM)	(CU. METERS)
PRECIPITATION	128.90	1289.000
RUNOFF	78.302	783.0215
PERCOLATION/LEAKAGE THROUGH LAYER 2	67.475616	674.75616
AVERAGE HEAD ON TOP OF LAYER 2	24.195	
PERCOLATION/LEAKAGE THROUGH LAYER 4	9.021939	90.21939
AVERAGE HEAD ON TOP OF LAYER 4	2.979	
DRAINAGE COLLECTED FROM LAYER 5	7.94444	79.44437
PERCOLATION/LEAKAGE THROUGH LAYER 7	0.000050	0.00050
AVERAGE HEAD ON TOP OF LAYER 6	122.620	
MAXIMUM HEAD ON TOP OF LAYER 6	174.168	
LOCATION OF MAXIMUM HEAD IN LAYER 5 (DISTANCE FROM DRAIN)	23.2 METERS	
SNOW WATER	304.80	3048.0220

MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.3936
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.0240

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

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FINAL WATER STORAGE AT END OF YEAR 100

LAYER	(CM)	(VOL/VOL)
1	0.9824	0.0982
2	2.1850	0.4370
3	788.5034	0.3285
4	0.0000	0.0000
5	1.8657	0.0622
6	0.0000	0.0000
7	0.4500	0.7500
SNOW WATER	0.000	

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**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**             HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                   **
**               DEVELOPED BY ENVIRONMENTAL LABORATORY                      **
**                 USAE WATERWAYS EXPERIMENT STATION                        **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************


PRECIPITATION DATA FILE:    C:\HELP3\88877\PPT1.D4
TEMPERATURE DATA FILE:      C:\HELP3\88877\TEMP.D7
SOLAR RADIATION DATA FILE:  C:\HELP3\88877\SRAD.D13
EVAPOTRANSPIRATION DATA:    C:\HELP3\88877\EVAP.D11
SOIL AND DESIGN DATA FILE:  C:\HELP3\88877\INTT.D10
OUTPUT DATA FILE:           C:\HELP3\88877\INTTO.OUT


TIME:  13:23     DATE:   2/16/2016


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     TITLE:  Upland Landfill - Intermediate Cover Top

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     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
              COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                   LAYER  1
                                   --------

                    TYPE 1 - VERTICAL PERCOLATION LAYER
                        MATERIAL TEXTURE NUMBER   2
           THICKNESS                  =    25.00   CM
           POROSITY                   =     0.4370 VOL/VOL
           FIELD CAPACITY             =     0.0620 VOL/VOL
           WILTING POINT              =     0.0240 VOL/VOL
           INITIAL SOIL WATER CONTENT  =     0.1357 VOL/VOL
           EFFECTIVE SAT. HYD. COND.   =  0.579999993000E-02 CM/SEC
```

NOTE: SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY 1.80
FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.

LAYER 2

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 2

THICKNESS	=	5.00 CM
POROSITY	=	0.4370 VOL/VOL
FIELD CAPACITY	=	0.0620 VOL/VOL
WILTING POINT	=	0.0240 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4370 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.579999993000E-02 CM/SEC

LAYER 3

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 18

THICKNESS	=	2400.00 CM
POROSITY	=	0.6710 VOL/VOL
FIELD CAPACITY	=	0.2920 VOL/VOL
WILTING POINT	=	0.0770 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.3173 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.100000005000E-02 CM/SEC

LAYER 4

TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 20

THICKNESS	=	0.50 CM
POROSITY	=	0.0000 VOL/VOL
FIELD CAPACITY	=	0.0000 VOL/VOL
WILTING POINT	=	0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	10.0000000000 CM/SEC
FML PINHOLE DENSITY	=	2.00 HOLES/HECTARE
FML INSTALLATION DEFECTS	=	6.00 HOLES/HECTARE
FML PLACEMENT QUALITY	=	3 - GOOD

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                        LAYER  5
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            TYPE 2 - LATERAL DRAINAGE LAYER
              MATERIAL TEXTURE NUMBER  21
THICKNESS                   =     30.00   CM
POROSITY                    =      0.3970 VOL/VOL
FIELD CAPACITY              =      0.0320 VOL/VOL
WILTING POINT               =      0.0130 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0365 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.300000012000     CM/SEC
SLOPE                       =      1.00   PERCENT
DRAINAGE LENGTH             =     80.0    METERS


                        LAYER  6
                        --------

            TYPE 4 - FLEXIBLE MEMBRANE LINER
              MATERIAL TEXTURE NUMBER  35
THICKNESS                   =      0.15   CM
POROSITY                    =      0.0000 VOL/VOL
FIELD CAPACITY              =      0.0000 VOL/VOL
WILTING POINT               =      0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY         =      2.00   HOLES/HECTARE
FML INSTALLATION DEFECTS    =      6.00   HOLES/HECTARE
FML PLACEMENT QUALITY       =  3 - GOOD


                        LAYER  7
                        --------

              TYPE 3 - BARRIER SOIL LINER
              MATERIAL TEXTURE NUMBER  17
THICKNESS                   =      0.60   CM
POROSITY                    =      0.7500 VOL/VOL
FIELD CAPACITY              =      0.7470 VOL/VOL
WILTING POINT               =      0.4000 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.7500 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.300000003000E-08 CM/SEC


        GENERAL DESIGN AND EVAPORATIVE ZONE DATA
        ----------------------------------------
```

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE # 2 WITH BARE GROUND CONDITIONS, A SURFACE SLOPE OF 10.% AND A SLOPE LENGTH OF 35. METERS.

SCS RUNOFF CURVE NUMBER	=	81.70	
FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1.0000	HECTARES
EVAPORATIVE ZONE DEPTH	=	25.0	CM
INITIAL WATER IN EVAPORATIVE ZONE	=	3.393	CM
UPPER LIMIT OF EVAPORATIVE STORAGE	=	10.925	CM
LOWER LIMIT OF EVAPORATIVE STORAGE	=	0.600	CM
INITIAL SNOW WATER	=	0.000	CM
INITIAL WATER IN LAYER MATERIALS	=	768.748	CM
TOTAL INITIAL WATER	=	768.748	CM
TOTAL SUBSURFACE INFLOW	=	0.00	MM/YR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM Campbell River British Columbia

STATION LATITUDE	=	49.95	DEGREES
MAXIMUM LEAF AREA INDEX	=	1.00	
START OF GROWING SEASON (JULIAN DATE)	=	91	
END OF GROWING SEASON (JULIAN DATE)	=	305	
EVAPORATIVE ZONE DEPTH	=	25.0	CM
AVERAGE ANNUAL WIND SPEED	=	8.00	KPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	84.10	%
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	72.47	%
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	71.95	%
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	87.08	%

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR OLYMPIA WASHINGTON

NORMAL MEAN MONTHLY PRECIPITATION (MM)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
217.5	149.5	140.0	92.1	68.4	62.9
39.4	44.6	55.2	162.2	231.9	225.7

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR OLYMPIA WASHINGTON

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES CELSIUS)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
2.4	3.2	5.2	8.0	11.6	14.7
17.3	17.2	13.7	8.6	4.4	2.1

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR OLYMPIA WASHINGTON
AND STATION LATITUDE = 49.95 DEGREES

****

AVERAGE MONTHLY VALUES (MM) FOR YEARS 1 THROUGH 100

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	216.01	144.89	142.48	102.27	67.19	62.06
	37.45	39.26	52.65	167.86	220.02	233.79
STD. DEVIATIONS	63.32	48.38	46.44	37.98	33.77	32.53
	28.36	30.28	30.04	68.74	74.24	69.47
RUNOFF						
TOTALS	11.574	18.198	2.272	0.361	0.245	0.168
	0.181	0.355	0.090	5.606	10.318	9.448
STD. DEVIATIONS	19.223	57.911	8.408	0.813	0.823	0.470
	0.653	2.106	0.455	7.529	12.881	9.076
EVAPOTRANSPIRATION						
TOTALS	7.839	13.211	40.185	68.052	57.834	51.460
	33.136	29.011	34.211	23.100	9.498	7.224
STD. DEVIATIONS	2.333	3.950	4.776	12.918	21.465	22.204
	21.304	19.806	17.068	4.939	1.334	1.683
PERCOLATION/LEAKAGE THROUGH LAYER 2						
TOTALS	194.2538	134.2317	105.0295	43.2416	15.1362	11.1932
	8.2510	6.4076	15.2898	122.9946	191.3676	205.0231

STD. DEVIATIONS	63.5373	55.0831	44.4712	28.1301	15.5597	13.6235
	12.5512	11.6952	16.4097	61.0493	64.1833	60.0784

PERCOLATION/LEAKAGE THROUGH LAYER 4

TOTALS	54.1586	77.1800	102.0399	130.6695	143.5367	123.6345
	114.5949	102.9147	82.3963	48.5532	32.8072	38.0974
STD. DEVIATIONS	18.9922	29.9075	32.6631	29.7576	24.0855	19.2459
	16.7116	17.2591	16.5870	16.0111	12.8274	12.1295

LATERAL DRAINAGE COLLECTED FROM LAYER 5

TOTALS	49.7162	73.3875	97.7029	124.7242	143.9364	126.5635
	117.0358	104.8597	85.6843	56.8653	33.3237	36.7255
STD. DEVIATIONS	16.2902	27.1451	29.6063	29.6055	24.7124	20.3401
	15.8836	17.3139	16.4285	16.3566	12.3817	11.1638

PERCOLATION/LEAKAGE THROUGH LAYER 7

TOTALS	0.0002	0.0004	0.0005	0.0007	0.0008	0.0007
	0.0006	0.0005	0.0004	0.0003	0.0001	0.0002
STD. DEVIATIONS	0.0001	0.0002	0.0002	0.0002	0.0002	0.0001
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (CM)

DAILY AVERAGE HEAD ON TOP OF LAYER 2

AVERAGES	0.2005	0.1563	0.1128	0.0482	0.0159	0.0122
	0.0087	0.0070	0.0165	0.1245	0.2085	0.2126
STD. DEVIATIONS	0.0670	0.0645	0.0480	0.0312	0.0166	0.0147
	0.0134	0.0151	0.0184	0.0652	0.0723	0.0631

DAILY AVERAGE HEAD ON TOP OF LAYER 4

AVERAGES	0.0586	0.0908	0.1088	0.1439	0.1528	0.1361
	0.1220	0.1095	0.0907	0.0525	0.0374	0.0417
STD. DEVIATIONS	0.0198	0.0342	0.0346	0.0328	0.0256	0.0211
	0.0178	0.0184	0.0183	0.0168	0.0137	0.0124

DAILY AVERAGE HEAD ON TOP OF LAYER 6

AVERAGES	2.4753	4.0083	4.8645	6.4169	7.1665	6.5115
	5.8271	5.2209	4.4084	2.8313	1.7145	1.8285

STD. DEVIATIONS	0.8111	1.4739	1.4741	1.5232	1.2304	1.0465
	0.7908	0.8621	0.8452	0.8144	0.6370	0.5558

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 100

	MM		CU. METERS	PERCENT
PRECIPITATION	1485.94	(190.257)	14859.4	100.00
RUNOFF	58.816	(74.0490)	588.16	3.958
EVAPOTRANSPIRATION	374.760	(52.5743)	3747.60	25.220
PERCOLATION/LEAKAGE THROUGH LAYER 2	1052.41980	(167.61417)	10524.198	70.82533
AVERAGE HEAD ON TOP OF LAYER 2	0.936	(0.146)		
PERCOLATION/LEAKAGE THROUGH LAYER 4	1050.58301	(131.30502)	10505.830	70.70171
AVERAGE HEAD ON TOP OF LAYER 4	0.954	(0.119)		
LATERAL DRAINAGE COLLECTED FROM LAYER 5	1050.52466	(130.58589)	10505.246	70.69778
PERCOLATION/LEAKAGE THROUGH LAYER 7	0.00534	(0.00078)	0.053	0.00036
AVERAGE HEAD ON TOP OF LAYER 6	44.395	(5.518)		
CHANGE IN WATER STORAGE	1.830	(7.3837)	18.30	0.123

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           PEAK DAILY VALUES FOR YEARS    1 THROUGH  100
   ------------------------------------------------------------------------
                                                (MM)      (CU. METERS)
                                             ----------   ------------
      PRECIPITATION                          128.90         1289.000

      RUNOFF                                  77.348         773.4814

      PERCOLATION/LEAKAGE THROUGH LAYER  2    65.043274      650.43274

      AVERAGE HEAD ON TOP OF LAYER  2         49.208

      PERCOLATION/LEAKAGE THROUGH LAYER  4     8.488104       84.88104

      AVERAGE HEAD ON TOP OF LAYER  4          2.803

      DRAINAGE COLLECTED FROM LAYER  5         7.54004        75.40035

      PERCOLATION/LEAKAGE THROUGH LAYER  7     0.000047        0.00047

      AVERAGE HEAD ON TOP OF LAYER  6        116.378

      MAXIMUM HEAD ON TOP OF LAYER  6        166.852

      LOCATION OF MAXIMUM HEAD IN LAYER  5
            (DISTANCE FROM DRAIN)             22.6 METERS

      SNOW WATER                             304.80         3048.0220


      MAXIMUM VEG. SOIL WATER (VOL/VOL)                0.3446

      MINIMUM VEG. SOIL WATER (VOL/VOL)                0.0240

       ***  Maximum heads are computed using McEnroe's equations.  ***

            Reference:  Maximum Saturated Depth over Landfill Liner
                        by Bruce M. McEnroe, University of Kansas
                        ASCE Journal of Environmental Engineering
                        Vol. 119, No. 2, March 1993, pp. 262-270.

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FINAL WATER STORAGE AT END OF YEAR 100

LAYER	(CM)	(VOL/VOL)
1	2.8031	0.1121
2	2.1850	0.4370
3	779.9935	0.3250
4	0.0000	0.0000
5	1.6204	0.0540
6	0.0000	0.0000
7	0.4500	0.7500
SNOW WATER	0.000	

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**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************


PRECIPITATION DATA FILE:    C:\HELP3\88877\PPT1.D4
TEMPERATURE DATA FILE:      C:\HELP3\88877\TEMP.D7
SOLAR RADIATION DATA FILE:  C:\HELP3\88877\SRAD.D13
EVAPOTRANSPIRATION DATA:    C:\HELP3\88877\EVAP.D11
SOIL AND DESIGN DATA FILE:  C:\HELP3\88877\OP2T.D10
OUTPUT DATA FILE:           C:\HELP3\88877\OP2TO.OUT


TIME:  14:13     DATE:   2/16/2016


******************************************************************************

     TITLE:  Upland Landfill - Option 2 Top

******************************************************************************


     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
              COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                  LAYER  1
                                  --------

                      TYPE 1 - VERTICAL PERCOLATION LAYER
                          MATERIAL TEXTURE NUMBER   4
           THICKNESS                  =    15.00   CM
           POROSITY                   =     0.4370 VOL/VOL
           FIELD CAPACITY             =     0.1050 VOL/VOL
           WILTING POINT              =     0.0470 VOL/VOL
           INITIAL SOIL WATER CONTENT =     0.1961 VOL/VOL
           EFFECTIVE SAT. HYD. COND.  =  0.170000002000E-02 CM/SEC
```

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NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  1.80
         FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.


                          LAYER  2
                          --------

                TYPE 2 - LATERAL DRAINAGE LAYER
                  MATERIAL TEXTURE NUMBER   2
  THICKNESS                   =     60.00   CM
  POROSITY                    =      0.4370 VOL/VOL
  FIELD CAPACITY              =      0.0620 VOL/VOL
  WILTING POINT               =      0.0240 VOL/VOL
  INITIAL SOIL WATER CONTENT  =      0.3198 VOL/VOL
  EFFECTIVE SAT. HYD. COND.   =  0.579999993000E-02 CM/SEC
  SLOPE                       =     10.00   PERCENT
  DRAINAGE LENGTH             =     35.0    METERS


                          LAYER  3
                          --------

                  TYPE 3 - BARRIER SOIL LINER
                  MATERIAL TEXTURE NUMBER  17
  THICKNESS                   =      0.60   CM
  POROSITY                    =      0.7500 VOL/VOL
  FIELD CAPACITY              =      0.7470 VOL/VOL
  WILTING POINT               =      0.4000 VOL/VOL
  INITIAL SOIL WATER CONTENT  =      0.7500 VOL/VOL
  EFFECTIVE SAT. HYD. COND.   =  0.300000003000E-08 CM/SEC


                          LAYER  4
                          --------

              TYPE 1 - VERTICAL PERCOLATION LAYER
                  MATERIAL TEXTURE NUMBER   2
  THICKNESS                   =     15.00   CM
  POROSITY                    =      0.4370 VOL/VOL
  FIELD CAPACITY              =      0.0620 VOL/VOL
  WILTING POINT               =      0.0240 VOL/VOL
  INITIAL SOIL WATER CONTENT  =      0.1248 VOL/VOL
  EFFECTIVE SAT. HYD. COND.   =  0.579999993000E-02 CM/SEC


                          LAYER  5
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                         --------

           TYPE 1 - VERTICAL PERCOLATION LAYER
               MATERIAL TEXTURE NUMBER  18
THICKNESS                  =   2400.00   CM
POROSITY                   =      0.6710 VOL/VOL
FIELD CAPACITY             =      0.2920 VOL/VOL
WILTING POINT              =      0.0770 VOL/VOL
INITIAL SOIL WATER CONTENT =      0.2920 VOL/VOL
EFFECTIVE SAT. HYD. COND.  =  0.100000005000E-02 CM/SEC


                         LAYER  6
                         --------

             TYPE 4 - FLEXIBLE MEMBRANE LINER
               MATERIAL TEXTURE NUMBER  20
THICKNESS                  =      0.50   CM
POROSITY                   =      0.0000 VOL/VOL
FIELD CAPACITY             =      0.0000 VOL/VOL
WILTING POINT              =      0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT =      0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.  =   10.0000000000     CM/SEC
FML PINHOLE DENSITY        =      2.00   HOLES/HECTARE
FML INSTALLATION DEFECTS   =      6.00   HOLES/HECTARE
FML PLACEMENT QUALITY      =  3 - GOOD


                         LAYER  7
                         --------

             TYPE 2 - LATERAL DRAINAGE LAYER
               MATERIAL TEXTURE NUMBER  21
THICKNESS                  =     30.00   CM
POROSITY                   =      0.3970 VOL/VOL
FIELD CAPACITY             =      0.0320 VOL/VOL
WILTING POINT              =      0.0130 VOL/VOL
INITIAL SOIL WATER CONTENT =      0.0337 VOL/VOL
EFFECTIVE SAT. HYD. COND.  =  0.300000012000     CM/SEC
SLOPE                      =      1.00   PERCENT
DRAINAGE LENGTH            =     80.0    METERS


                         LAYER  8
                         --------

             TYPE 4 - FLEXIBLE MEMBRANE LINER
               MATERIAL TEXTURE NUMBER  35
```

```
   THICKNESS                    =      0.15   CM
   POROSITY                     =      0.0000 VOL/VOL
   FIELD CAPACITY               =      0.0000 VOL/VOL
   WILTING POINT                =      0.0000 VOL/VOL
   INITIAL SOIL WATER CONTENT   =      0.0000 VOL/VOL
   EFFECTIVE SAT. HYD. COND.    =  0.199999996000E-12 CM/SEC
   FML PINHOLE DENSITY          =      2.00   HOLES/HECTARE
   FML INSTALLATION DEFECTS     =      6.00   HOLES/HECTARE
   FML PLACEMENT QUALITY        =  3 - GOOD


                           LAYER  9
                           --------

                 TYPE 3 - BARRIER SOIL LINER
                 MATERIAL TEXTURE NUMBER  17
   THICKNESS                    =      0.60   CM
   POROSITY                     =      0.7500 VOL/VOL
   FIELD CAPACITY               =      0.7470 VOL/VOL
   WILTING POINT                =      0.4000 VOL/VOL
   INITIAL SOIL WATER CONTENT   =      0.7500 VOL/VOL
   EFFECTIVE SAT. HYD. COND.    =  0.300000003000E-08 CM/SEC


             GENERAL DESIGN AND EVAPORATIVE ZONE DATA
             ----------------------------------------

  NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
           SOIL DATA BASE USING SOIL TEXTURE # 4 WITH A
           GOOD STAND OF GRASS, A SURFACE SLOPE OF 10.%
           AND A SLOPE LENGTH OF   35. METERS.

SCS RUNOFF CURVE NUMBER             =     56.00
FRACTION OF AREA ALLOWING RUNOFF    =    100.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE  =      1.0000 HECTARES
EVAPORATIVE ZONE DEPTH              =     30.0    CM
INITIAL WATER IN EVAPORATIVE ZONE   =      5.349  CM
UPPER LIMIT OF EVAPORATIVE STORAGE  =     13.110  CM
LOWER LIMIT OF EVAPORATIVE STORAGE  =      1.065  CM
INITIAL SNOW WATER                  =      0.000  CM
INITIAL WATER IN LAYER MATERIALS    =    726.712  CM
TOTAL INITIAL WATER                 =    726.712  CM
TOTAL SUBSURFACE INFLOW             =      0.00   MM/YR


              EVAPOTRANSPIRATION AND WEATHER DATA
              -----------------------------------
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NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
Campbell River British Columbia

STATION LATITUDE	=	49.95 DEGREES
MAXIMUM LEAF AREA INDEX	=	1.00
START OF GROWING SEASON (JULIAN DATE)	=	91
END OF GROWING SEASON (JULIAN DATE)	=	305
EVAPORATIVE ZONE DEPTH	=	30.0 CM
AVERAGE ANNUAL WIND SPEED	=	8.00 KPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	84.10 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	72.47 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	71.95 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	87.08 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR OLYMPIA WASHINGTON

NORMAL MEAN MONTHLY PRECIPITATION (MM)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
217.5	149.5	140.0	92.1	68.4	62.9
39.4	44.6	55.2	162.2	231.9	225.7

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR OLYMPIA WASHINGTON

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES CELSIUS)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
2.4	3.2	5.2	8.0	11.6	14.7
17.3	17.2	13.7	8.6	4.4	2.1

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR OLYMPIA WASHINGTON
AND STATION LATITUDE = 49.95 DEGREES

****

AVERAGE MONTHLY VALUES (MM) FOR YEARS 1 THROUGH 100

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	216.01	144.89	142.48	102.27	67.19	62.06
	37.45	39.26	52.65	167.86	220.02	233.79
STD. DEVIATIONS	63.32	48.38	46.44	37.98	33.77	32.53
	28.36	30.28	30.04	68.74	74.24	69.47
RUNOFF						
TOTALS	3.023	14.326	1.112	0.000	0.000	0.000
	0.000	0.000	0.000	0.004	0.187	0.083
STD. DEVIATIONS	14.285	56.396	8.204	0.000	0.000	0.000
	0.000	0.000	0.000	0.024	1.005	0.549
EVAPOTRANSPIRATION						
TOTALS	7.766	13.095	40.089	69.854	63.253	57.535
	37.501	30.032	34.741	23.416	9.256	7.128
STD. DEVIATIONS	2.300	3.857	4.513	11.371	20.360	23.171
	24.850	20.964	17.630	4.444	1.325	1.653
LATERAL DRAINAGE COLLECTED FROM LAYER 2						
TOTALS	208.8775	152.6560	126.3396	68.4861	26.0513	11.7623
	6.8537	4.5603	7.2992	69.9399	170.0754	204.2333
STD. DEVIATIONS	55.0937	54.4171	40.7682	28.3134	14.7437	11.4592
	7.9709	8.9878	11.3421	41.8334	60.3282	52.8479
PERCOLATION/LEAKAGE THROUGH LAYER 3						
TOTALS	3.2637	2.3996	2.0055	1.1213	0.4773	0.2570
	0.1848	0.1497	0.1888	1.1461	2.6695	3.1925
STD. DEVIATIONS	0.8402	0.8297	0.6212	0.4314	0.2247	0.1746
	0.1215	0.1370	0.1730	0.6375	0.9196	0.8054
PERCOLATION/LEAKAGE THROUGH LAYER 6						
TOTALS	3.2174	2.8545	2.5191	1.9535	1.4044	0.8755
	0.6480	0.4966	0.3453	0.1309	0.3817	2.2334
STD. DEVIATIONS	0.8987	0.7407	0.7315	0.4757	0.3160	0.1823
	0.1322	0.1053	0.1073	0.1103	0.4791	1.0848
LATERAL DRAINAGE COLLECTED FROM LAYER 7						
TOTALS	3.1041	2.9213	2.6231	2.0436	1.5197	0.9493

	0.6875	0.5199	0.3711	0.1792	0.2378	1.9007
STD. DEVIATIONS	0.8970	0.7042	0.7303	0.5095	0.3373	0.2020
	0.1382	0.1057	0.1030	0.1080	0.3185	1.0535

PERCOLATION/LEAKAGE THROUGH LAYER 9

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (CM)

DAILY AVERAGE HEAD ON TOP OF LAYER 3

AVERAGES	23.7706	19.0715	14.3755	8.0524	2.9642	1.3830
	0.7799	0.5189	0.8582	7.9581	19.9984	23.2390
STD. DEVIATIONS	6.2740	6.8228	4.6388	3.3290	1.6776	1.3473
	0.9070	1.0227	1.3336	4.7600	7.0955	6.0140

DAILY AVERAGE HEAD ON TOP OF LAYER 6

AVERAGES	0.0032	0.0031	0.0025	0.0020	0.0014	0.0009
	0.0006	0.0005	0.0004	0.0001	0.0004	0.0022
STD. DEVIATIONS	0.0009	0.0008	0.0007	0.0005	0.0003	0.0002
	0.0001	0.0001	0.0001	0.0001	0.0005	0.0011

DAILY AVERAGE HEAD ON TOP OF LAYER 8

AVERAGES	0.1545	0.1596	0.1306	0.1051	0.0757	0.0488
	0.0342	0.0259	0.0191	0.0089	0.0122	0.0946
STD. DEVIATIONS	0.0447	0.0387	0.0364	0.0262	0.0168	0.0104
	0.0069	0.0053	0.0053	0.0054	0.0164	0.0525

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 100

	MM		CU. METERS	PERCENT
PRECIPITATION	1485.94	(190.257)	14859.4	100.00

RUNOFF	18.735	(67.9096)	187.35	1.261
EVAPOTRANSPIRATION	393.665	(55.5687)	3936.65	26.493
LATERAL DRAINAGE COLLECTED FROM LAYER 2	1057.13489	(173.09804)	10571.349	71.14264
PERCOLATION/LEAKAGE THROUGH LAYER 3	17.05568	(2.63860)	170.557	1.14781
AVERAGE HEAD ON TOP OF LAYER 3	102.475	(16.885)		
PERCOLATION/LEAKAGE THROUGH LAYER 6	17.06026	(2.57652)	170.603	1.14811
AVERAGE HEAD ON TOP OF LAYER 6	0.014	(0.002)		
LATERAL DRAINAGE COLLECTED FROM LAYER 7	17.05735	(2.53267)	170.573	1.14792
PERCOLATION/LEAKAGE THROUGH LAYER 9	0.00011	(0.00001)	0.001	0.00001
AVERAGE HEAD ON TOP OF LAYER 8	0.725	(0.108)		
CHANGE IN WATER STORAGE	-0.655	(2.1752)	-6.55	-0.044

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 100

	(MM)	(CU. METERS)
PRECIPITATION	128.90	1289.000
RUNOFF	77.176	771.7640
DRAINAGE COLLECTED FROM LAYER 2	18.08482	180.84816
PERCOLATION/LEAKAGE THROUGH LAYER 3	0.292863	2.92863
AVERAGE HEAD ON TOP OF LAYER 3	671.935	
MAXIMUM HEAD ON TOP OF LAYER 3	916.679	
LOCATION OF MAXIMUM HEAD IN LAYER 2 (DISTANCE FROM DRAIN)	10.9 METERS	
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.296422	2.96422
AVERAGE HEAD ON TOP OF LAYER 6	0.079	
DRAINAGE COLLECTED FROM LAYER 7	0.20740	2.07401
PERCOLATION/LEAKAGE THROUGH LAYER 9	0.000001	0.00001
AVERAGE HEAD ON TOP OF LAYER 8	3.201	
MAXIMUM HEAD ON TOP OF LAYER 8	6.205	
LOCATION OF MAXIMUM HEAD IN LAYER 7 (DISTANCE FROM DRAIN)	2.5 METERS	
SNOW WATER	304.80	3048.0220

MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.3998

MINIMUM VEG. SOIL WATER (VOL/VOL) 0.0355

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

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FINAL WATER STORAGE AT END OF YEAR 100

LAYER	(CM)	(VOL/VOL)
1	2.4238	0.1616
2	13.1710	0.2195
3	0.4500	0.7500
4	1.8267	0.1218
5	700.8000	0.2920
6	0.0000	0.0000
7	1.0401	0.0347
8	0.0000	0.0000
9	0.4500	0.7500
SNOW WATER	0.000	

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Appendix E
Contaminating Lifespan Assessment Calculations

Chloride (1st Order)

British Columbia CSR Contaminating Life Span of Chloride

Drinking Water Land Use

Maximum Anticipated Concentration

C_t	250	mg/L	
C_B	1500	mg/L	
λ	0.065	y^{-1}	
t	27.57	y	Time to reduce below Criteria
t	28	y	Time, rounded up
C_o	243.04	mg/L	Check at t (rounded up)

Note: This calculation uses the average concentration from the investigated Sites listed in the Leachate Profile tab.

Note: First order decay rate obtained from Lu et al., 1981, Leachate Production and Management from Municipal Landfill: Summary and Assessment, Land Disposal: Municipal Solid Waste – Proceedings of the Seventh Annual Research Symposium, EPA 600/9 81, pp. 1 17, 1981

Chloride - Rowe Model

British Columbia CSR Contaminating Life Span of Chloride

Drinking Water Land Use

	Scenario 1	Scenario 2	Units	Comments
C_t	250	250	mg/L	Target concentration
C_t	0.25	0.25	kg/m^3	Target concentration
q_o	0.017	0.017	m/y	Average rate of infiltration
p	0.0004	0.00064	-	Proportion of total waste mass that is chloride
A_o	36,000	36,000	m^2	Unit area[2]
V_o	506,000	506,000	m^3	Volume of landfill
C_o	1500	1500	mg/L	Chloride concentration (peak or average)
C_o	1.5	1.5	kg/m^3	Chloride concentration (peak or average)
r_{dw}	1300	1300	kg/m^3	Dry density of waste
M_o	657,800,000	657,800,000	kg	
H_r	4.87	7.80	m	Reference height of leachate
λ	0.065	0.065	y^{-1}	First Order decay constant
k	0.0685	0.0672	y^{-1}	
k	0.0035	0.0022	y^{-1}	
t	**26.16**	**26.67**	**years**	
t			years	
q_o			m/y	Infiltration rate required to achieve CLS = 30 years

Scenario 1	Maximum chloride concentration, average proportion of chloride in waste
Scenario 2	Maximum chloride concentration, maximum proportion of chloride in waste

Notes

1. The Modified Rowe Model calculates the contaminating life span using a unit area of 1 sq. m. at the highest point of the landfill.

2. The Rowe Model, utilizes the total area of the landfill, as described in "*Rowe, 1995, Leachate characteristics for MSW landfills, R.K. Rowe, Geotechnical Research Centre Report, GEOT 8 95*".

3. The proportion of total waste mass that is chloride was determined for Brooks Road Landfill, based on analytical studies.

4. First order decay rate obtained from *Lu et al., 1981, Leachate Production and Management from Municipal Landfill: Summary and Assessment, Land Disposal: Municipal Solid Waste – Proceedings of the Seventh Annual Research Symposium, EPA 600/9 81, pp. 1 17, 1981*

Sulphate 1st Order
British Columbia CSR Contaminating Life Span of Sulphate

Drinking Water Land Use
Maximum Anticipated Concentration

C_t	500	mg/L	
C_B	1000	mg/L	
λ	0.079	y^{-1}	
t	8.77	y	Time to reduce below Criteria
t	9	y	Time, rounded up
C_o	491.15	mg/L	Check at t (rounded up)

Note: This calculation uses the average concentration from the investigated Sites listed in the Leachate Profile tab.

Note: First order decay rate obtained from Lu et al., 1981, Leachate Production and Management from Municipal Landfill: Summary and Assessment, Land Disposal: Municipal Solid Waste – Proceedings of the Seventh Annual Research Symposium, EPA 600/9 81, pp. 1 17, 1981

Copper - 1st Order
<u>British Columbia CSR Contaminating Life Span of Copper</u>

<u>Drinking Water Land Use</u>
Maximum Anticipated Concentration

C_t	1	mg/L	
C_B	0.05	mg/L	
λ	0.2	y^{-1}	
t	-14.98	y	Time to reduce below Criteria
t	-15	y	Time, rounded up
C_o	1.00	mg/L	Check at t (rounded up)

From Column AI

C_t	0.5	mg/L	
C_B	0.05	mg/L	
λ	0.2	y^{-1}	
t	-11.51	y	Time to reduce below Criteria
t	-12	y	Time, rounded up
C_o	0.55	mg/L	Check at t (rounded up)

Note: This calculation uses the average concentration from the investigated Sites listed in the Leachate Profile tab.
Note: First order decay rate obtained from Lu et al., 1981, Leachate Production and Management from Municipal Landfill: Summary and Assessment, Land Disposal: Municipal Solid Waste – Proceedings of the Seventh Annual Research Symposium, EPA 600/9 81, pp. 1 17, 1981

Appendix F
Downgradient HELP Model Results

```
******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************


PRECIPITATION DATA FILE:    C:\HELP3\88877\PPT1.D4
TEMPERATURE DATA FILE:      C:\HELP3\88877\TEMP.D7
SOLAR RADIATION DATA FILE:  C:\HELP3\88877\SRAD.D13
EVAPOTRANSPIRATION DATA:    C:\HELP3\88877\EVAP.D11
SOIL AND DESIGN DATA FILE:  C:\HELP3\88877\DWNGR.D10
OUTPUT DATA FILE:           C:\HELP3\88877\DWNGRO.OUT


TIME:  16:36     DATE:   5/30/2017


******************************************************************************

     TITLE:  Upland Landfill - DOWNGRADIENT

******************************************************************************


     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
                COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                   LAYER  1
                                   --------

                      TYPE 1 - VERTICAL PERCOLATION LAYER
                          MATERIAL TEXTURE NUMBER   1
           THICKNESS                  =   3500.00   CM
           POROSITY                   =      0.4170 VOL/VOL
           FIELD CAPACITY             =      0.0450 VOL/VOL
           WILTING POINT              =      0.0180 VOL/VOL
           INITIAL SOIL WATER CONTENT =      0.0757 VOL/VOL
           EFFECTIVE SAT. HYD. COND.  =  0.999999978000E-02 CM/SEC
```

NOTE: SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY 1.80
FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
SOIL DATA BASE USING SOIL TEXTURE # 1 WITH BARE
GROUND CONDITIONS, A SURFACE SLOPE OF 3.% AND
A SLOPE LENGTH OF 200. METERS.

SCS RUNOFF CURVE NUMBER	=	71.90	
FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1.0000	HECTARES
EVAPORATIVE ZONE DEPTH	=	30.0	CM
INITIAL WATER IN EVAPORATIVE ZONE	=	3.597	CM
UPPER LIMIT OF EVAPORATIVE STORAGE	=	12.510	CM
LOWER LIMIT OF EVAPORATIVE STORAGE	=	0.540	CM
INITIAL SNOW WATER	=	0.000	CM
INITIAL WATER IN LAYER MATERIALS	=	264.820	CM
TOTAL INITIAL WATER	=	264.820	CM
TOTAL SUBSURFACE INFLOW	=	0.00	MM/YR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
Campbell River British Columbia

STATION LATITUDE	=	49.95	DEGREES
MAXIMUM LEAF AREA INDEX	=	1.00	
START OF GROWING SEASON (JULIAN DATE)	=	91	
END OF GROWING SEASON (JULIAN DATE)	=	305	
EVAPORATIVE ZONE DEPTH	=	30.0	CM
AVERAGE ANNUAL WIND SPEED	=	8.00	KPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	84.10	%
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	72.47	%
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	71.95	%
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	87.08	%

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR OLYMPIA WASHINGTON

NORMAL MEAN MONTHLY PRECIPITATION (MM)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
217.5	149.5	140.0	92.1	68.4	62.9
39.4	44.6	55.2	162.2	231.9	225.7

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR OLYMPIA WASHINGTON

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES CELSIUS)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
2.4	3.2	5.2	8.0	11.6	14.7
17.3	17.2	13.7	8.6	4.4	2.1

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR OLYMPIA WASHINGTON
AND STATION LATITUDE = 49.95 DEGREES

****

AVERAGE MONTHLY VALUES (MM) FOR YEARS 1 THROUGH 100

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	216.01	144.89	142.48	102.27	67.19	62.06
	37.45	39.26	52.65	167.86	220.02	233.79
STD. DEVIATIONS	63.32	48.38	46.44	37.98	33.77	32.53
	28.36	30.28	30.04	68.74	74.24	69.47
RUNOFF						
TOTALS	3.934	14.270	1.151	0.004	0.004	0.000
	0.001	0.065	0.001	0.883	1.951	1.639
STD. DEVIATIONS	13.587	54.972	8.056	0.036	0.032	0.000
	0.014	0.626	0.008	1.913	4.537	2.905
EVAPOTRANSPIRATION						
TOTALS	7.840	13.199	40.143	67.513	56.813	50.345

	32.543	28.117	33.634	22.952	9.510	7.228
STD. DEVIATIONS	2.334	3.971	4.979	12.991	21.388	22.293
	21.697	19.702	17.191	5.052	1.334	1.686

PERCOLATION/LEAKAGE THROUGH LAYER 1

TOTALS	71.9297	98.2503	122.8276	137.1311	137.3340	113.6443
	100.3723	88.5671	71.0573	46.5177	33.3858	47.1655
STD. DEVIATIONS	26.3691	35.3745	38.3219	35.3850	29.2549	22.0743
	17.4402	14.6448	13.3432	13.2981	12.2372	15.9583

****

****

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 100

	MM		CU. METERS	PERCENT
PRECIPITATION	1485.94	(190.257)	14859.4	100.00
RUNOFF	23.902	(65.8864)	239.02	1.609
EVAPOTRANSPIRATION	369.840	(52.3562)	3698.40	24.889
PERCOLATION/LEAKAGE THROUGH LAYER 1	1068.18250	(190.94087)	10681.825	71.88612
CHANGE IN WATER STORAGE	24.012	(9.0187)	240.12	1.616

****

****

PEAK DAILY VALUES FOR YEARS 1 THROUGH 100

	(MM)	(CU. METERS)
PRECIPITATION	128.90	1289.000
RUNOFF	76.924	769.2419
PERCOLATION/LEAKAGE THROUGH LAYER 1	10.355275	103.55275
SNOW WATER	304.80	3048.0220
MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.3769	
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.0180	

****

****

FINAL WATER STORAGE AT END OF YEAR 100

LAYER	(CM)	(VOL/VOL)
1	504.9421	0.1443

SNOW WATER 0.000

****
****

Appendix G
Fire Safety and Emergency Contingency Plan

FIRE SAFETY AND EMERGENCY CONTINGENCY PLAN

UPLAND LANDFILL
CAMPBELL RIVER, BRITISH COLUMBIA

Prepared For: **Upland Excavating Ltd.**
Gold River Highway
Campbell River, British Columbia

MAY 12, 2016
REF. NO. 088877 (10) APPG

TABLE OF CONTENTS

<u>LIST OF FIGURES</u>

REVISIONS

DATE	REVISION NO.	AUTHOR/COMPANY	

1.0 INTRODUCTION

The operators of the proposed Upland Landfill, in compliance with British Columbia Occupational Health and Safety (B.C. OH&S) Regulation 296/97 Part 4, s.4.13-4.18 (Emergency Preparedness and Response) and Part 5, s.5.97-5.102 (Emergency Procedures) and Section 2.8 of the British Columbia Fire Code, have developed the following Fire Safety and Emergency Contingency Plan based on an assessment of the risks identified on-site. This plan documents the potential hazards and sets out the safety measures, roles, responsibilities, procedures, and parties to be contacted in the event of a medical or environmental emergency, or the occurrence of any of the identified hazardous situations.

The Upland Landfill is located on an approximately 10 hectare parcel of land located in the City of Campbell River, British Columbia, within Lot A, District Lot 85, Plan 30709, Sayward District, approximately 10 km west of the city centre of Campbell River. The Site fronts onto Gold River Highway and is situated west of the Island Highway and south of McIvor Lake. The Upland Landfill is owned and operated by Upland Excavating Ltd. (UEL).

The Upland Landfill currently operates under Permit PR-10807. The current landfill operation predominantly receives land clearing waste. The wood waste loads are sorted to remove isolated quantities of metal, white goods, tires, plastics, and other materials which are recycled. The demolition and construction wood waste, excluding clean wood wastes, are shredded on-site and stockpiled for subsequent use as “hog fuel” for energy fuel for off Site market purposes.

The proposed operations include the acceptance of construction, demolition waste, land clearing debris, and contaminated soil. The contaminated soil will predominately be composed of metals and hydrocarbon impacted soil

The following sections detail the Fire Safety and Emergency Contingency Plan for waste disposal operations at the Upland Landfill. It is essential that site personnel be prepared in the event of an emergency. Emergencies can take many forms. The potential health and safety concerns identified in this plan include illnesses or injuries, chemical exposure, fires, explosions, spills, leaks, releases of harmful contaminants, or sudden changes in the weather. The following sections outline the general procedures for dealing with emergency situations that may potentially be experienced at the Upland Landfill

This Plan will be reviewed by all on-Site personnel and kept at the Upland Landfill. Emergency information presented herein, will be posted at the Site in locations where it can readily be seen. This Plan will be reviewed at least once annually by the owner/operator of the landfill, in consultation with the employee health and safety representative, to ensure that it remains effective and accurate as a Fire Safety and Emergency Contingency Plan.

2.0 EMERGENCY CONTACTS

This page is to be posted with the hospital road map in conspicuous workplace locations.

Fire:	911
Police:	911
Ambulance:	911
Poison Control Center:	1-800-567-8911
Hospital:	250-850-2141 Campbell River Hospital 375 2nd Ave. Campbell River, BC V9W 3V1

Directions to Campbell River Hospital (see Figure 2.1):

- Head northeast on Gold River Hwy/BC-28 E toward Argonaut Rd
- Turn right onto Inland Island Hwy/BC-19 S (signs for Nanaimo)
- Turn left onto 14 Ave
- Continue onto Homewood Road
- Continue onto 9 Ave
- Slight right onto Alder St
- Turn right onto 2 Ave, Destination will be on the left

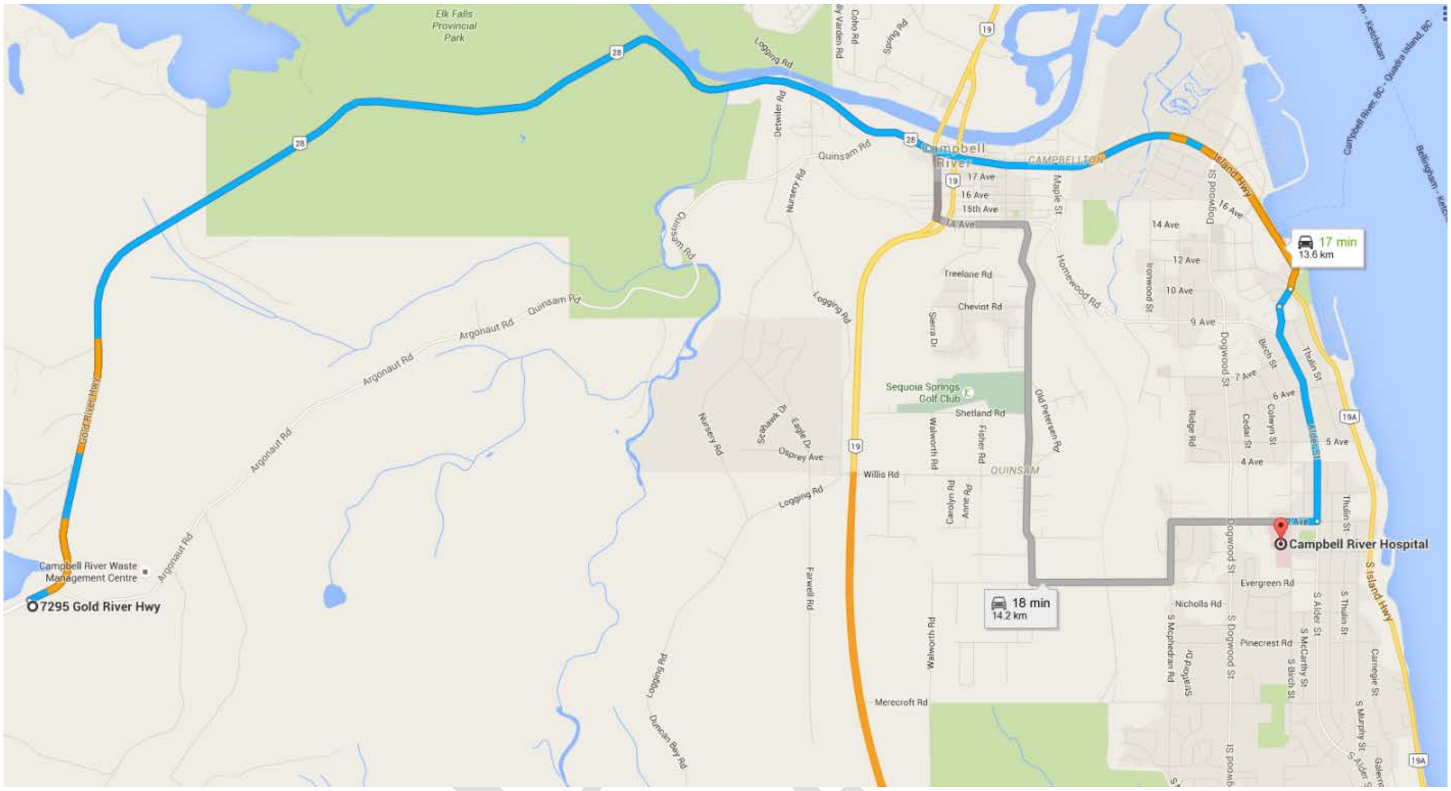
Provincial Emergency Program (PEP), 24 hour Spill Reporting:	1-800-663-3456
MOE Regional Waste Manager (Allan Leuschen)	250-751-3199
Ministry of Forest, Lands and Natural Resources	250-286-9300
Fire Department	250-286-6266
Forest Fire Reporting	1-800-633-5555 *5555 Cellular

Upland Excavating Ltd. (Upland Landfill Operator)

- Site Managers(Mark Stuart) 250-287-0738 (Cell)
- Site Manager (Terry Stuart) 250-286-1148 (Cell)

FIGURE 2.1
EMERGENCY HOSPITAL ROUTE

TO BE POSTED IN CONSPICUOUS AREAS OF THE WORKPLACE



Map Data/Image Source: Google Maps, 2016

<u>Hospital:</u>	250-850-2141
	Campbell River Hospital
	375 2nd Ave.
	Campbell River, BC
	V9W 3V1

Directions to Campbell River Hospital (see Figure 2.1):

- Head northeast on Gold River Hwy/BC-28 E toward Argonaut Rd
- Turn right onto Inland Island Hwy/BC-19 S (signs for Nanaimo)
- Turn left onto 14 Ave
- Continue onto Homewood Road
- Continue onto 9 Ave
- Slight right onto Alder St
- Turn right onto 2 Ave, Destination will be on the left

3.0 EMERGENCY EQUIPMENT AVAILABLE ON SITE

The following emergency equipment is available at the Front Desk of the Site Office:

- First aid kit (Level 1 Kit)
- 20 pound Class A, B, and C dry chemical fire extinguisher
- Petroleum spill containment kit
- Telephone
- Portable air horn alarm

All Site vehicles and equipment, including excavators, loaders, rock-trucks, and pick-up trucks, are all equipped with Class A, B, and C dry chemical fire extinguishers.

A suitable pump with appropriate length of hose will be kept available on-site at all time to pump water from the wash plant pond for emergency use.

4.0 EMERGENCY ROUTES AND ASSEMBLY POINTS

The Upland Landfill Operator will ensure that emergency exit routes and assembly points are marked on Site by clear signage and in accordance with municipal and provincial requirements.

5.0 MEDICAL EMERGENCIES

The Upland Landfill Operator will employ, and assign to the Site, a competent and authorized representative, herein referred to as the HSO. A Site Health & Safety Representative will also be selected. The Site Supervisor will be present at the Upland Landfill during normal operating hours.

The Upland Landfill Operator will ensure that all on-Site personnel, as a minimum, are equipped with the appropriate first aid materials and supplies and personnel protective equipment (PPE), and clothing required by municipal and provincial regulations. Safety and emergency equipment and PPE and clothing will be stored in a readily accessible location when not in use and kept clean and well maintained. The location of the equipment will be marked by clear signage.

Emergency and first-aid equipment will be placed at or near the active work area of the Upland Landfill during normal operating hours. A list of the emergency and first aid equipment available at the Site and where this equipment is located is provided in Section 3.0 of this Plan.

As a minimum, the Upland Landfill Operator will designate at least one person who is trained in basic first aid and CPR as the First Aid Attendant, to be on-Site at all times. This person may perform other duties, but will be immediately available to render first aid when required.

In the event of injury requiring immediate first-aid / medical attention to on-Site personnel, the following procedures will be implemented:

- Notify the First Aid Attendant and administer initial first aid services
- Notify the HSO/Site Supervisor
- Phone the hospital and/or medical service provider closest to the Upland Landfill (see Section 2.0) and describe the nature of the injury or event
- As directed by the hospital, administer additional on-going first aid or CPR
- As directed by the hospital, either wait for an ambulance to arrive or transport personnel to the specified hospital along the most direct route
- If the injured person will be transported by ambulance and it is safe to leave them (when only two workers are on Site) meet the ambulance at the gate and direct them to the injured person, otherwise, give the ambulance/hospital complete and accurate directions to your exact location at the Site

Note: Any person transporting an injured/exposed person to the designated hospital for treatment, should take directions to the hospital with them (Figure 2.1). Details of the injury and a list of the compounds of concern, animal or insect bites, or other injurious circumstances to which the worker may have been exposed should also accompany the injured person.

6.0 FIRE OR EXPLOSION

All fire fighting equipment present at the Site shall be regularly inspected (monthly minimum) and maintained in accordance with manufacturer's recommendation and a record of these inspections will be kept on Site.

In the event of an uncontrolled fire, explosion, release of hazardous material, or the need for emergency evacuation, the following procedures will be followed:

- Notify all workers on Site by sounding the air horn alarm
- Site personnel will report immediately to the upwind safe assembly area and the Site Supervisor will confirm the safe evacuation of all workers from the hazardous area
- Notify the Fire Department / emergency services immediately
- Notify the HSO
- Notify any adjacent workplaces or residences which may be affected by exposure (**Note:** notification of the public must be in conformity with the requirements of municipal and provincial agencies (BC Reg. 296/97, s.5.100))
- Site personnel will position themselves at the entrance gate and such other safe locations as to effectively direct the Fire Department to the location of the uncontrolled fire or hazardous circumstances
- Site personnel will advise the Fire Commander of the location, nature, and identification of any hazardous materials at the Site as per the Inventory of Hazardous Substances maintained at the Site (see Section 10.0)
- If the Site Supervisor determines that it is safe to do so, before the Fire Department arrives, site personnel may:
    - Use fire equipment available on Site
    - Remove or isolate flammable or other hazardous materials that may contribute to the fire
- If the Fire Commander determines that it is safe to do so, Site personnel may assist the Fire Department

7.0 SPILLS OR LEAKS

The Upland Landfill operator will ensure that all on-Site personnel have received the appropriate Work Place Hazardous Materials Information System (WHMIS) training as required by provincial regulations. The Upland Landfill operator will ensure that personnel assigned to spill clean-up and re-entry duties have been trained in the safe procedures and use of personal protective equipment appropriate to the spill conditions. Written procedures for clean up and record of training will be maintained on Site. The Upland Landfill operator will ensure that PPE and related clean-up equipment is readily available on Site and maintained in good condition.

In the event of a spill or leak, site personnel will follow the following procedures:

- Notify the Site Supervisor and/or HSO of the accidental release
- Report off-Site spills and releases of hydrocarbon contaminated soils or contaminated water to PEP and the B.C. Ministry of Environment in accordance with the B.C. Spill Reporting Regulation
    - **B.C. Emergency Management: 800-663-3456**
- Locate the source of the spillage, determine the degree of hazard associated with the clean-up activities, and if it can be done safely, stop the flow or release of the contaminant
- Contain and recover the spilled materials, in a safe manner as appropriate

If the spill is not reportable, under the B.C. Spill Reporting Regulation a Notification of Independent Remediation Initiation form, Site Risk Classification Report Form, and Exposure Pathway Questionnaire is required and the independent remediation may be initiated.

If the spill is reportable, under the B.C. Spill Reporting Regulation, a B.C. Ministry of Environment case manager will be appointed to guide remediation requirements.

Note: Any spillage of demolition and construction wood waste or land clearing waste received at the Upland Landfill will be collected and transported to the waste segregation and sorting area.

8.0 INCLEMENT WEATHER

The following special procedures will be implemented during periods of severe weather, such as high winds, rain, electrical storms, thermal inversions, and winter conditions.

High Winds

If winds become excessive, the following control measures will be implemented at the Upland Landfill to ensure that dust and litter does not become problematic or hazardous:

- Low speed limits will be enforced
- All vehicle traffic transporting waste to and around the Upland Landfill will be appropriately loaded to prevent debris from blowing out of the vehicle
- Landfilling activities will be reduced
- Soil handling operations will be suspended
- If dry conditions warrant, water (dust suppressant) will be applied to roadways and borrow areas, and if required, to the active disposal area
- Personnel will wear appropriate respiratory protection if total dust particulates exceed provincial exposure limits

Rain and Electrical Storms

Rain: is not expected to adversely affect operations; therefore the Upland Landfill will be operated during all but extremely excessive rain periods. If access roads become impassable due to heavy rain, they will be graded and granular material will be added as necessary to maintain and improve operating conditions.

Electrical Storms: In the event of an electrical storm, all operations will be suspended until the storm subsides and personnel will take safe shelter in the Site Office. All electrical powered equipment will be immediately shut down in a manner that will not endanger personnel.

Winter Conditions

During winter operations, the Upland Landfill Operator will undertake advanced planning for site preparation/access, snow removal, and the stockpiling and storage of waste cover material.

The following procedures will be taken during winter weather conditions:

- The Upland Landfill operator will ensure that all on-Site personnel are suitably clothed for working in winter conditions and monitor ongoing conditions to minimize the potential for cold related stress/hypothermia
- During severe winter conditions the HSO will provide appropriate direction to on-site personnel, regarding the continuance or curtailing of Upland Landfill operations
- Site equipment will be cleaned and maintained on a daily basis to ensure safe operation during periods of cold or extreme weather
- Snow accumulation will be removed from the access roads and working areas prior to and during each day's landfilling activities, as required to maintain safe working conditions
- Frozen fill materials will not be placed in the landfill
- All runoff from snow, which has contacted waste or soil in the Landfill will be managed as leachate and controlled accordingly

9.0 EMERGENCY PROCEDURES TRAINING & DRILLS

The following training requirements will be followed as written in the B.C. OH&S Reg. 296/97 Part 4, s.4.16:

- All workers must be given adequate instruction in fire prevention and emergency evacuation procedures applicable to their workplace
- Workers assigned firefighting duties must be given adequate training by a qualified instructor in suppression methods, fire prevention, emergency procedures, company organization and chain of command, and firefighting crew safety and communications applicable to their workplace
- Retraining must occur once per year
- A worker not covered by B.C. OH&S Reg. 296/97 Part 31 (Firefighting), who is assigned firefighting duties, must be physically capable of performing the duties assigned safely and effectively, before being permitted to do them
- At least once per year, emergency drills must be conducted to ensure worker awareness and effectiveness of the exit routes and procedures
- A record of the drills is to be kept at the Site Office

10.0 HAZARDOUS SUBSTANCE INVENTORY & NOTIFICATION OF FIRE DEPARTMENT

The Upland Landfill Operator will maintain a Hazardous Substance Inventory (Inventory) at the Site. The Inventory will include safe handling methods for all hazardous substances that are stored at the Site in quantities that may endanger workers in an emergency. The Inventory will include such materials as WHMIS controlled products, explosives, pesticides, radioactive materials, hazardous wastes, and will provide the nature, location, quantity and Material Safety Data Sheets (MSDS) for the material.

As part of Site operations, the Upland Landfill Operator performs visual inspections of all waste loads received at the Site and any material that is not authorized for discharge at the Site, including hazardous substances, is rejected by the operator and sent off Site for disposal. As such, the Inventory is limited to materials that are stored on Site for use by the Upland Landfill only and not for landfilled materials.

The Inventory is to be kept up to date and located in an area readily accessible by personnel during an emergency. The Fire Department shall be notified of any significant changes to the Inventory.

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