Minto Creek Constructed Wetland: Physical Infrastructure Preliminary Design

Prepared for

Minto Explorations Ltd.

Prepared by

SRK Consulting (Canada) Inc.
1CM002.044
August 2016

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August 2016

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Project No: 1CM002.044

File Name: Minto_WetlandDesign_DRAFT_Report_1CM002-044_20160805_sdm_VM_dbm

srk consulting

Table of Contents

1 Introduction

Minto Explorations Ltd. (Minto) asked SRK develop designs for the necessary physical infrastructure to support a Constructed Wetland Treatment System (CWTS) proposed to be constructed within the footprint currently occupied by the Water Storage Pond (WSP) as part of mine closure works at Minto Mine, central Yukon Territory. This report describes the design basis and the accompanying drawings provide the preliminary design details.

This physical infrastructure preliminary design report was developed to support Contango Strategies' design of the treatment wetland (Minto Mine Reclamation and Closure Plan – Preliminary Design Report for Treatment Wetland (Contango 2016)). Details related to wetland establishment, monitoring, and maintenance are provided in Contango's design report, along with a thorough discussion of treatment mechanisms, on-site wetland trials (completed, in-progress, and planned), and performance expectations.

2 Background

Water Licence QZ14-031 was issued to Minto in 2015. The licence included a condition requiring Minto to submit a revised reclamation and closure plan (RCP), and the submission date for the revised RCP was extended to August 5, 2016 via a December 2015 amendment to QZ14-031. Minto's 2016 Reclamation and Closure Plan will be the sixth major revision of the site closure plan, and will be referred to as 'RCP 2016-01' in this document.

The CWTS preliminary infrastructure design is one component of RCP 2016-01.

2.1 Current Layout of Site

The Water Storage Dam was constructed during initial mine construction in 2006. It was constructed across the Minto Creek valley at a narrow point near the eastern limit of Minto's quartz claims and represents the eastern-most major infrastructure facility at Minto Mine. The dam construction formed the WSP reservoir, which was initially used for mill water supply and later as a clean water reservoir for storing water prior to discharge to Minto Creek. The outline of the WSP and the Water Storage Dam are shown in Drawing WC-01.

2.2 Closure Phases

For the closure and post closure periods, planning and management of site activities are guided by the Minto RCP. This includes the identification of distinct closure phases with defined activities and performance expectations:

1. Active Closure;
2. Post Closure I (transition to passive treatment); and
3. Post Closure II (passive treatment only).

3 Design

3.1 Overview

During Active Closure, the Water Storage Dam will be decommissioned and the footprint of the WSP will receive fill and be graded to allow the subsequent construction of a Constructed Wetland Treatment System (CWTS), which is also referred to as the Minto Creek Constructed Wetland. The CWTS will receive water from E3 Conveyance Channel in the closure conveyance system, which receives surface water from nearly all of the disturbed areas of the mine site that lie within the Minto Creek catchment. Flows up to 3000 m^3/day[1] will route through the CWTS, with inflows controlled by inlet control structures. To protect the CWTS from high flows, the inlet control structures are designed to convey higher flows through a spillway system to discharge into a high flow bypass channel. Details are presented in Drawings CW-03 in Appendix A.

During Post-Closure 1, commissioning of the CWTS will take place and CWTS effluent will be managed by a combination of reservoir and pumping-and-piping system, with water that meets discharge standards discharged off site and water that does not meet discharge standards pumped to one of the open pits for storage. As discussed in the Section 7.7.1 of the RCP the water treatment plant used during operations will remain in operational until WUL criteria can be achieved consistently without its utilization. Transition from Post-closure 1 to Post-closure 2 will occur when the CWTS effluent adequately meets performance objectives, at which time the effluent reservoir will be connected to the high flow bypass channel and the system will transition to being passively managed

Drawings WC-01 through WC-04 provide the preliminary designs for the physical infrastructure of the CWTS and bring in relevant conveyance design details from other components of the Minto Mine RCP for reference, including details from Appendix G2, *Closure Water Conveyance System Design Update Report, Minto Mine, Yukon* (SRK 2016a).

The following sections generally are organized sequentially by order in which the various components will be constructed.

3.2 Design Objectives, Considerations and Criteria

Summarized in this section are the objectives, considerations, and criteria for the preliminary CWTS design. Physical design elements are illustrated in the appended preliminary drawing package. Design criteria that are critical to the biological efficiency of the wetland system to sequester soluble metals were developed by Contango. These design elements are included in the physical wetland design and the water conveyance dynamics.

3.2.1 Head Pond and Wetland Intake Structure:

- Design flow rate for the passive treatment wetland system is based on a typical average monthly summer flow experienced in June, July and August. The maximum targeted flow rate

[1] Range of flows received by CWTS is expected to range from zero (during summer dry periods) to a maximum of 3000 m^3/day (under extreme high runoff conditions).

to be diverted into the wetland system is 3000 m^3/day or approximately 0.035 m^3/s. 3000 m^3/day is the upper limit of the flow rate that the CWTS is intended to handle.

3.2.2 Wetland Cell and Conveyance Channel Geometry:

- A 3:1 aspect ratio (Length to Width) is used to site the location of the passive treatment wetland cells. The cells are typically 15 m wide and 45 m long. Due to the limited width of the valley, space was limited in some areas- the cells were designed as typical 15 m wide and in some cases it was necessary to shorten the length of the cells to fit the site configuration.
- Substrate depth within the cells is designed to be a minimum of 0.5 m, substrate depths are illustrated in the design drawings to be 1 m thick and submerged by 0.3 m for a total of 1.3 m of initial design height above liner to the water surface in each cell. The substrate material will consist of sand with 2 to 7% by volume as organic matter (e.g. wood chips, straw).

3.2.3 Seepage Management:

- Seepage losses from the wetland cells and groundwater ingress into the cells is managed by inclusion of a low hydraulic conductivity geomembrane liner. The liner will prevent both groundwater from entering and seepage from leaving the CWTS and will avoid the performance uncertainty that would accompany unquantified inputs and losses of both flow and geochemical load.

3.2.4 Erosion Management:

- Internal erosion protection of the wetland pond system is limited to rip-rap channel protection because the CWTS inlet control structure is to be designed to limit inflows to a maximum flow rate of 3000 m^3/day.
- Distinct from limits on daily volumes, considerations around wetland plant establishment and propagation patterns require limits on water velocity as follows: maximum velocity 0.35 m/s, and typical velocities of <0.15m/s (Contango 2016).

3.2.5 Restrict Dam Classification for Designed Infrastructure:

- Design intentions have been focused on precluding the classification of any design infrastructure as a dam as defined by the Canadian Dam Safety Guidelines (CDA 2007) and dam classification guidelines in the Yukon Territory. CDA defines a dam as a constructed barrier that is at least 2.5 m tall and retains at least 30,000 m^3 of water. The Yukon Territory's definition of a constructed dam without a licence for a Schedule 7 Quartz Mining Undertaking as having a height greater than 3 m and less than 10,000 m^3 of water storage (Yukon Government 2012).

3.2.6 Exclusions

The following elements are outside of the limits of the preliminary physical infrastructure design:

- Establishment and success of wetland vegetation in the CWTS,
- Treatment performance of the CWTS,

- Revegetation of disturbed surfaces associated with the construction of the CWTS, and
- Construction compaction specifications of fill materials are not specified for this preliminary level of design. An assessment of available material properties is required at future stages of design to determine compaction requirements.

3.3 Constructability and Sequencing

The overall wetland layout and the configuration of the cells and intake structures have considered a long-term closure of the Minto site and the future needs of this site beyond the Post Closure 1 timeline. Intake and conveyance structure designs to the wetland ponds have been considered for their ability to be adaptive (i.e. allowance for the modification of conveyance elevations and flow rates to allow vegetation to establish).

In future stages of closure design it is recommended that a staged construction and decommissioning plan be developed to optimize water management resource needs and material handling. Additionally, a phased commissioning plan for a constructed closure conveyance system and wetlands must be developed.

Decommissioning of the Water Storage Pond Dam is required to construct the wetland and diversion channels. Initial decommissioning efforts require that the reservoir be drawn down and incoming flows routed around the construction area to allow for the partial excavation of the dam. Flow routing is expected to include excavating a water retention sump and back pumping water to the Main Pit to manage sedimentation and through pumping water from the Main Pit to Minto Creek. Retention sump locations details are provided in Drawing CW-02 in Appendix A.

Final decommissioning of the WSP dam will include the construction of the High Flow Bypass Channel that will convey flow around the wetlands. Additionally, it will require the removal of the sump and pumping diversion systems to allow flows to enter the wetland pond system. The infrastructure design, alignments, and specifications are located in the drawings in Appendix A.

Access for post-closure monitoring and maintenance at the CWTS is to be maintained after construction. The pond system is designed with a wide berm access of 4 m around the perimeters of each wetland cell to accommodate a vehicle or small excavator.

3.4 Foundation Preparation and Base Construction

To construct the passive treatment wetlands and provide a graded profile to the wetland area the existing WSP Dam will be decommissioned. Decommissioning of the WSP dam is illustrated in Drawing CW-02 located in Appendix A. The Dam is constructed of coarse waste rock and fine grained materials as segregated zones. During the decommissioning of the dam the segregated materials are repurposed in the construction of the wetland system. Coarse rock will be used to build up the basal area of the pond system, fine grained materials are to be used as separation layering between geomembranes and coarse materials.

During the decommissioning of the WSP Dam an existing access road will potentially require upgrades for haul truck access within the former ponded area. Material stockpiles, load and haul routes within the wetland area should be constructed as dam decommissioning advances.

3.5 Wetland Intake Flow Control Structure

A Primary Head Pond is designed to buffer turbulent flows exiting the E3 conveyance channel stilling basin. The pond elevation (715 masl) will be controlled by two hydraulic control structures: High Flow Discharge Channel and the Wetland Intake Structure. The Secondary Head Pond Intake Structure will convey 1% of the total flow entering the Primary Head Pond into the Secondary Head Pond the remainder of flows enter the High Flow Bypass Channel. Water entering the Secondary Head Pond will then be moderated where the design flow for the wetland system is conveyed in the wetland intake structure and the remainder of flow is conveyed through a spillway into the High Flow Bypass Channel.

The Secondary Head Pond and Wetland Intake structure are designed to reduce the intake flows and convey the expected design flows from the Primary Head Pond to the wetland cells. Flows exceeding this rate will be diverted to the High Flow Bypass Channel. Discharge flow from the wetland system is discharged to the High Flow Bypass Channel down gradient of the wetland system. Surface water quality monitoring station W50 is located approximately 50 m downstream of the confluence of these two flows.

At this stage of design the wetland intake structure has not been designed in detail. Conceptually, hydraulic principles that govern open channel flow have been considered to confirm that the system of ponds, inlet structures, and high flow spillways can reduce peak flows adequately to limit CWTS inflows to the design peak flow rate. The wetland infrastructure design is capable of separating a maximum of 3000 m^3/day from the mine closure conveyance system and conveying the flow through the wetland cells. It should be noted that this design peak flow rate is based on treatment performance limitations, and not on limitations of the hydraulic system to pass substantially greater flow volumes.

Future stages of design should consider an options analysis for common hydraulic structures such as weirs, flumes, and orifice flow control structures. Options to consider include orienting the inlet structure to be south facing to maximize early spring thaw, and applying a coating to the inlet structure to maximize solar heat absorption to melt and shed ice buildup.

3.6 Passive Treatment Wetland Cells and Conveyance Channels

Water depth within the wetland cells is designed to a targeted 0.15-0.4 m depth. After vegetation planting and during the initial growing seasons the water level in the cells will be controlled to be 0.2 m. Once the vegetation is rooted and acclimatized the wetland cells, water depth will be increased to 0.3-0.4 m. Section and plan details illustrating the CWTS designs are provided in Drawing CW-02 and CW-04 in Appendix A.

Internal cell-to-cell conveyance channels are designed as an excavated 4 m wide swale with 2:1 side slopes and a 1% slope. The mild channel slope is designed to have a 350 mm layer of rock

rip-rap with an average diameter of 200 mm. Flow velocities through the cell spillway sections are measured as 0.3 m/s and a water depth of 30 mm.

Underlying the passive treatment wetland cells and the cell-to-cell conveyance channels is a geomembrane to manage seepage loss and ingress. It is recommended that all exposed geomembranes be covered with a minimum of 0.3 m of fine grained material to reduce its exposure to radiation from the sun.

4 Physical Monitoring and Maintenance

The construction, commissioning, and operation of the passive treatment wetland is expected to have a variable management requirements for the physical monitoring and maintenance. This section discusses what physical attention is needed for the wetland infrastructure. Effective implementation of the *Closure Adaptive Management Plan* (SRK 2016b) will mitigate conditions beyond those expected during closure and post closure care and maintenance programs.

During construction and dam decommissioning water within the footprint of the CWTS construction will require ongoing and active monitoring and maintenance. The commissioning phase will require a site presence to monitor flow rates at the wetland intake structure to confirm that the wetland system is receiving the design flow rates. During this phase it may be required to make alterations to the flow regulating structure. After the commissioning phase it is expected that the frequency of inspection and maintenance decrease over time. However, long-term physical monitoring and maintenance will be required for this wetland system.

Monitoring frequency and maintenance requirements should be re-assessed and adapted based on the judgement of a qualified person as the site transitions through Active Closure, Post-Closure I and Post-Closure II periods. The proposed schedule for the monitoring programs is provided in Section 7.12 of the RCP. The following subsections suggest some of basic monitoring and maintenance needs for the structure of the wetland system.

4.1 Active Closure

Physical monitoring and maintenance requirements during the construction period include:

- Routine water quality sampling for sediment and metal composition at the intake and discharge of the pond system.
- Assessing the grading of the channels between ponds to assess the flow paths. Flow through the channels should be unobstructed and non-eroding.
- During initial rooting stages of pond vegetation commissioning the water depth in the ponds are expected to be lower than the final operational elevation. Once advised that the rooting is sufficient the elevation in the ponds can be increased to the final elevation.
- Routine removal of vegetation and debris that may block channels.

- Assessment of initial signs of settlement and erosion of surfaces adjacent to the wetland system. If settlement within the conveyance network is observed then remedial construction activities should be initiated as described in the closure adaptive management plan.
- Ground water seepage assessments of the surrounding area to determine if there will be exposed seeps in the former WSP area that may affect the pond system. If seepage volumes are considerable and are leading to erosion of soils then remedial construction activities should be initiated as described in the closure adaptive management plan.

4.2 Post-Closure I

The closure monitoring and maintenance requirements will be developed at the end of the active construction phase as the site transitions to passive treatment. Typically the monitoring will assess the following geotechnical and hydraulic conditions:

- Measure the flow rates into the wetland system and determine if the flow rates are appropriate and if there are meeting objectives. Field samples should be collected to determine the water quality at the intake and discharge of the pond system.
- Assess the flow profile through and in between each wetland cell to document the development or extent of erosion or blockages.
- The intake flow structures should be assessed for operation and integrity.
- Surface erosion and settlement deformations.

4.3 Post-Closure II

An assessment of the existing state of the wetland system is required to identify the needs of monitoring and maintenance as the site transitions to the Post Closure II phase.

5 Recommendations

This section summarizes design requirement to advance the design of the wetland system from preliminary to a feasibility level.

- Limnology study of sediments in WSP to quantify chemistry and thickness to determine if additional design and management allowance is needed for the wetland pond system.
- Geotechnical investigation of the wetland foundation area and the High Flow Bypass Channel for the existence of permafrost and other geotechnical considerations which may have a potential for thaw consolidation and settlement.
- Site wide definition of material sources including defining dam materials and potential opportunity to use local soils and local quarries near the existing WSP Dam. The site-wide materials assessment should define the volumes and material types that are needed for the wetland construction.

- Evaluation of merit of routing the High Flow Bypass Channel through a purpose built rock quarry located in south abutment of dam.
- Assessment of the suitability of rip-rap in the current WSP dam spillway for use as riprap in the long term. Evaluation of the existing spillway rip-rap covering is needed to determine if the condition of the armouring is suitable for reuse for closure activities as foundation fill material for the wetland area.
- Excavation optimization for the materials removed from the WSP Dam which can be reused as foundation fill material for the wetland area.
- Hydrologic assessment of the transition of the High Flow Bypass Channel from the former WSP Dam area downstream to the Minto Creek basin.
- Evaluation and design of the hydraulic intake structure that moderated flow from the head ponds into the wetland system at the specified rate of 3000 m^3/day or the rate required during the final engineering and design stages.
- Reassessment of the need for a geomembrane to line the ponds and conveyance channels between ponds.
- Future assessment to the efficiency of the wetland pond dynamics may redefine the cell geometry needs and peak flow rate requirements defined by Contango.
- Head Pond: design requires further optimization such that the final design (excessive storage water volume or height of impounded water) does not become defined as a dam.
- Tailings Diversion Ditch: energy dissipation area requires additional design consideration to transition flow exiting the Tailings Diversion Ditch into the High Flow Bypass Channel. Additional design should focus on managing flow hydraulics and erosion.

This report, Preliminary Design: Physical Infrastructure for the Water Storage Pond Constructed Wetland Treatment SystemPreliminary Design: Physical Infrastructure for the Water Storage Pond Constructed Wetland Treatment System, was prepared by

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Dylan MacGregor, MASc, PGeo

All data used as source material plus the text, tables, figures, and attachments of this document have been reviewed and prepared in accordance with generally accepted professional engineering and environmental practices.

6 References

CDA 2007. Canadian Dam Association Dam Safety Guidelines 2007 (2013 Edition). Prepared by the Canadian Dam Association.

Yukon Government 2012. Dam Guide: Design Expectations and Required Information. Prepared by the Yukon Government and Yukon Environmental and Socio-economic Assessment Branch. February 2012.

Contango Strategies Ltd. 2016. Minto Mine Reclamation and Closure Plan – Preliminary Design Report for Treatment Wetland. Prepared for Minto Explorations Ltd. July 2016.

SRK Consulting (Canada) Inc. 2016a. Closure Water Conveyance System Design Update Report, Minto Mine, Yukon. August 2016.SRK Consulting (Canada) Inc. 2016a. Closure Adaptive Management Plan. August 2016.

Appendix A: Drawings

Engineering Drawings for the Minto Creek Constructed Wetlands Minto Mine, Yukon, Canada

ACTIVE DRAWING STATUS

DWG NUMBER	DRAWING TITLE	REVISION	DATE	STATUS
CW-00	Engineering Drawings for the WSP Constructed Wetlands, Minto Mine, Yukon, Canada	A	July 29, 2016	Issued For Review
CW-01	General Arrangement	A	July 29, 2016	Issued For Review
CW-02	Wetland Cell Configuration	A	July 29, 2016	Issued For Review
CW-03	Primary Head Pond Area Layout	A	July 29, 2016	Issued For Review
CW-04	Typical Cell and Cell Spillway Layout	A	July 29, 2016	Issued For Review

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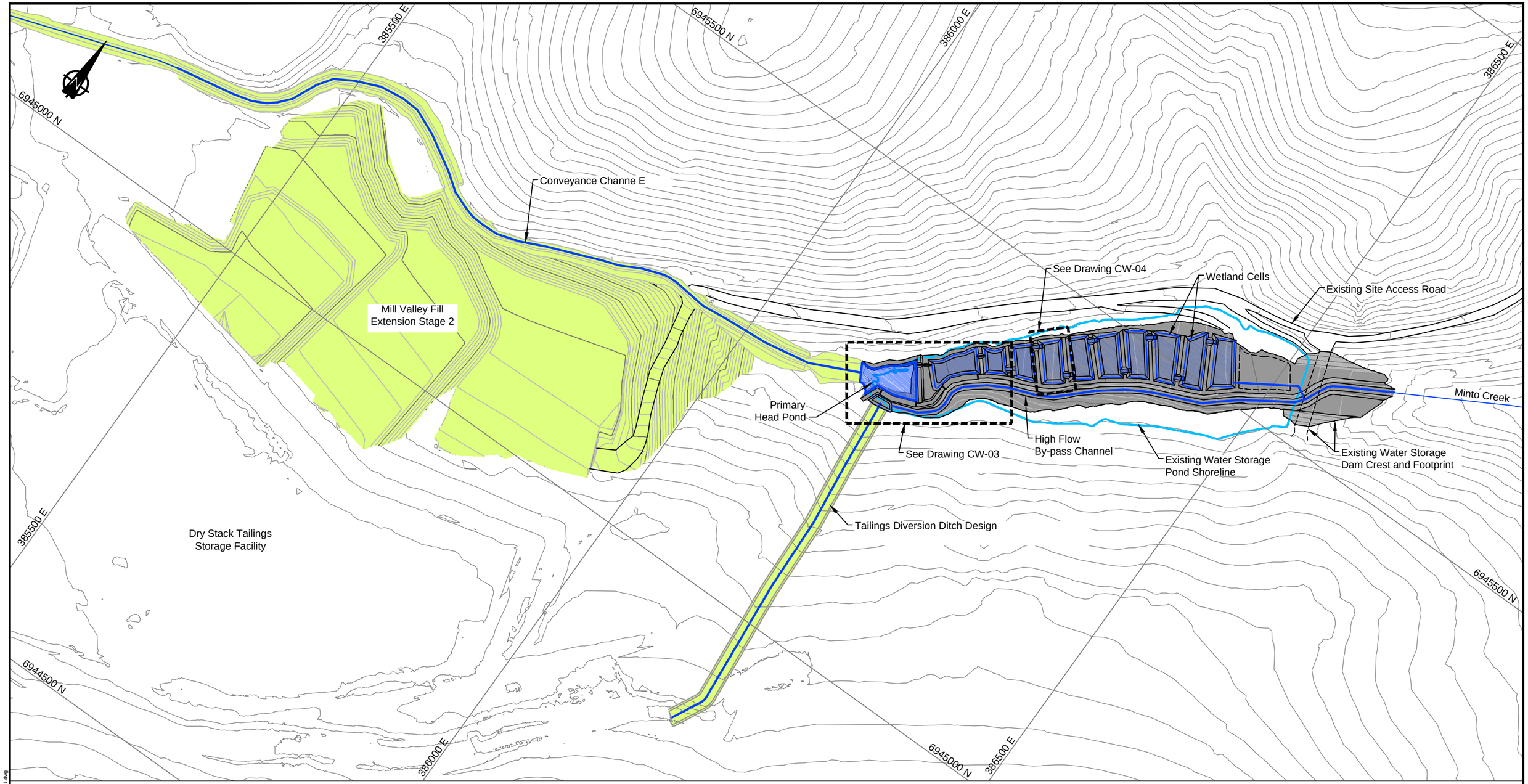
PROJECT NO: 1CM002.044
Revision A - Issued for Review
July 29, 2016
Drawing CC-00



NOTES

1. Contour Interval 1m typical though drawing package.
2. Coordinate system is in NAD83 UTM Zone 8
3. Digital topographic surface has been provided by Minto Exploration ltd.
4. Notes on this drawing apply to all other drawings within this drawing package unless otherwise advised.

LEGEND

- Constructed Wetlands Design
- Designed Infrastructure (Not Constructed)
- Design Toes & Crests
- Flow Direction

NOT FOR CONSTRUCTION

0 40 80 120 160 200

Scale in Metres

DRAWING NO.	DRAWING TITLE	DRAWING NO.	DRAWING TITLE

REFERENCE DRAWINGS

NO.	DESCRIPTION	CHK'D	APP'D	DATE
A	Issued for Review	SM	–	15Jul16

REVISIONS

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SM	NV	SM
CHECKED:	APPROVED:	DATE:
SM	DM	July 2016

FILE NAME: 1CM002_044–Wetland–1.dwg

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SRK JOB NO.: 1CM002.042

Preliminary Infrastructure Minto Creek Constructed Wetlands

DRAWING TITLE: General Arrangement

DRAWING NO.	SHEET	REVISION NO.
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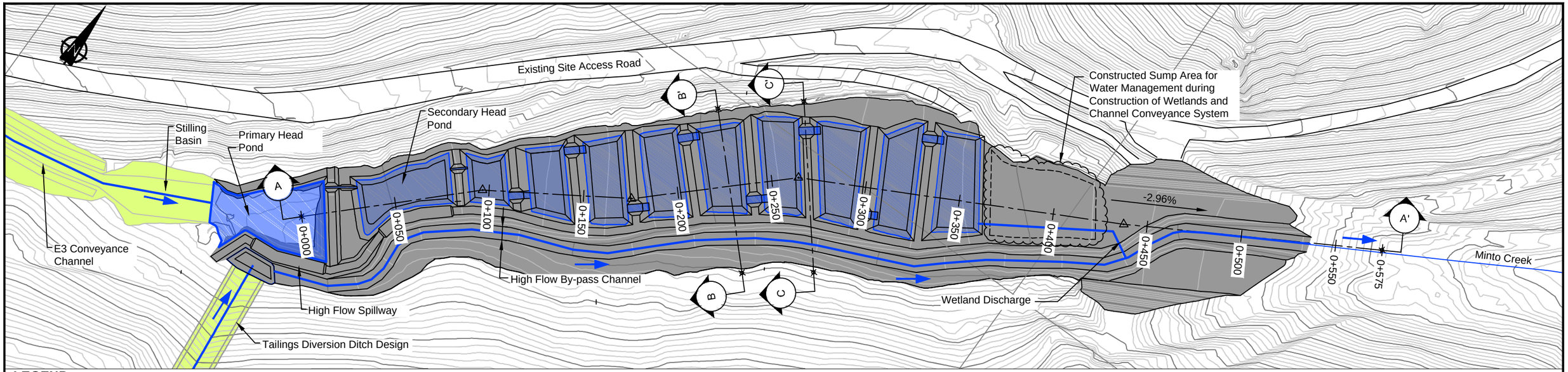

LEGEND

- Wetland Foundation Fill Material
- Rip Rap
- Constructed Wetlands Design
- Designed Infrastructure (Not Constructed)
- Geomembrane
- Flow Direction

NOTES

1. During the decommissioning of the dam the segregated materials are repurposed in the construction of the wetland system
2. Road access within WSP footprint will be required for construction.
3. Material stockpiles, load and haul routes within the wetland area should be constructed as dam decommissioning advances.
4. Decommissioning of the WSP dam will include the construction of the High Flow By-pass Channel that will convey flow around the wetlands as per SRK Closure Conveyance Channel Design 2016.
5. Supporting features: E3 Stilling Basin, Energy dissipation pond, and the High Flow By-pass Channel are designed by SRK in the Closure Conveyance Design Report 2016.
6. Notes on this drawing apply to all other drawings within this drawing package unless otherwise advised.

CONSTRUCTED WETLANDS PLAN VIEW

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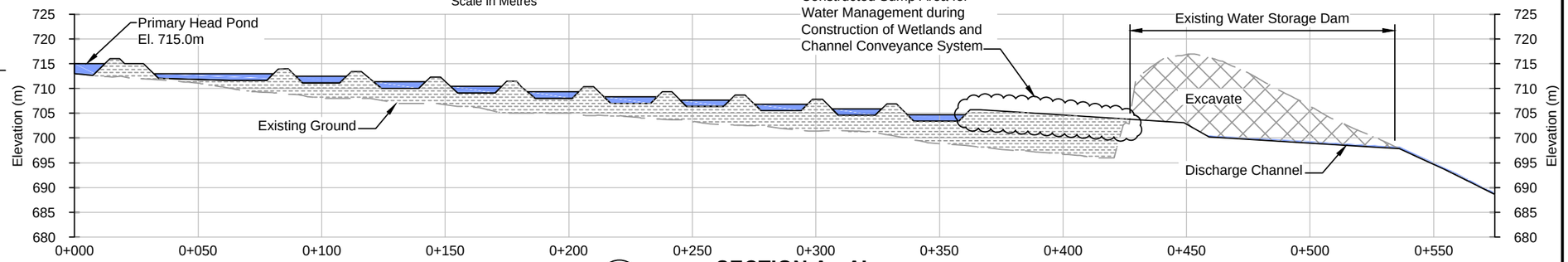
Scale in Metres



SECTION A - A'

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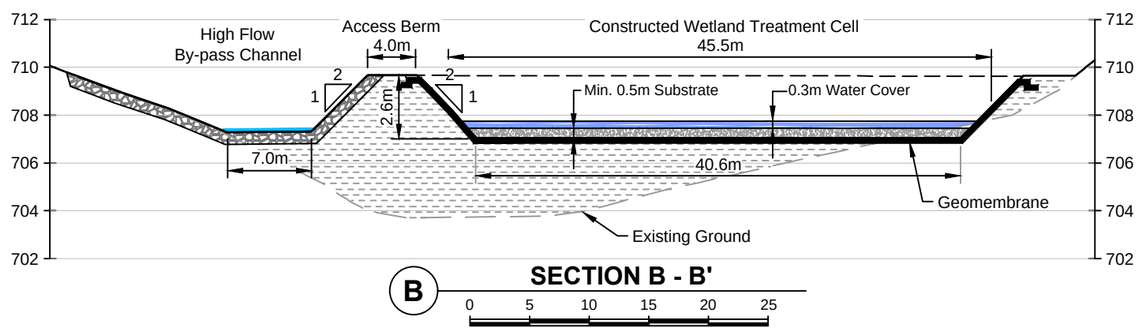
Vertical Exaggeration 2X



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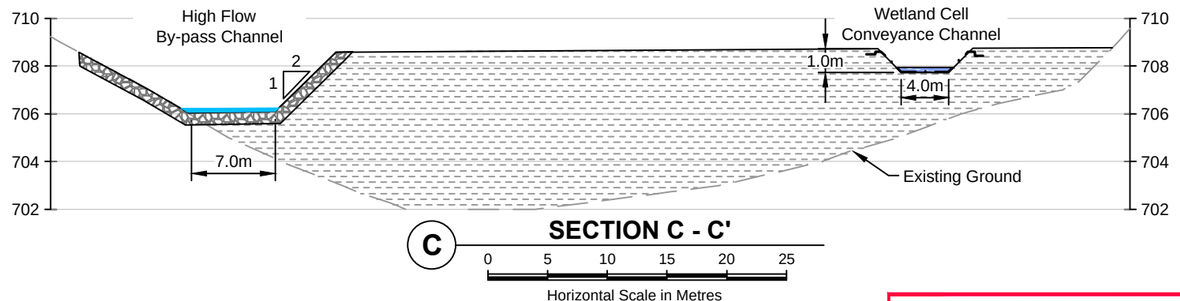
Vertical Exaggeration 2X



SECTION C - C'

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Horizontal Scale in Metres
Vertical Exaggeration 2X

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Preliminary Infrastructure Minto Creek Constructed Wetlands

DRAWING TITLE: Wetland Cell Configuration

DRAWING NO.	SHEET	REVISION NO.
CW-02	3 OF 5	A

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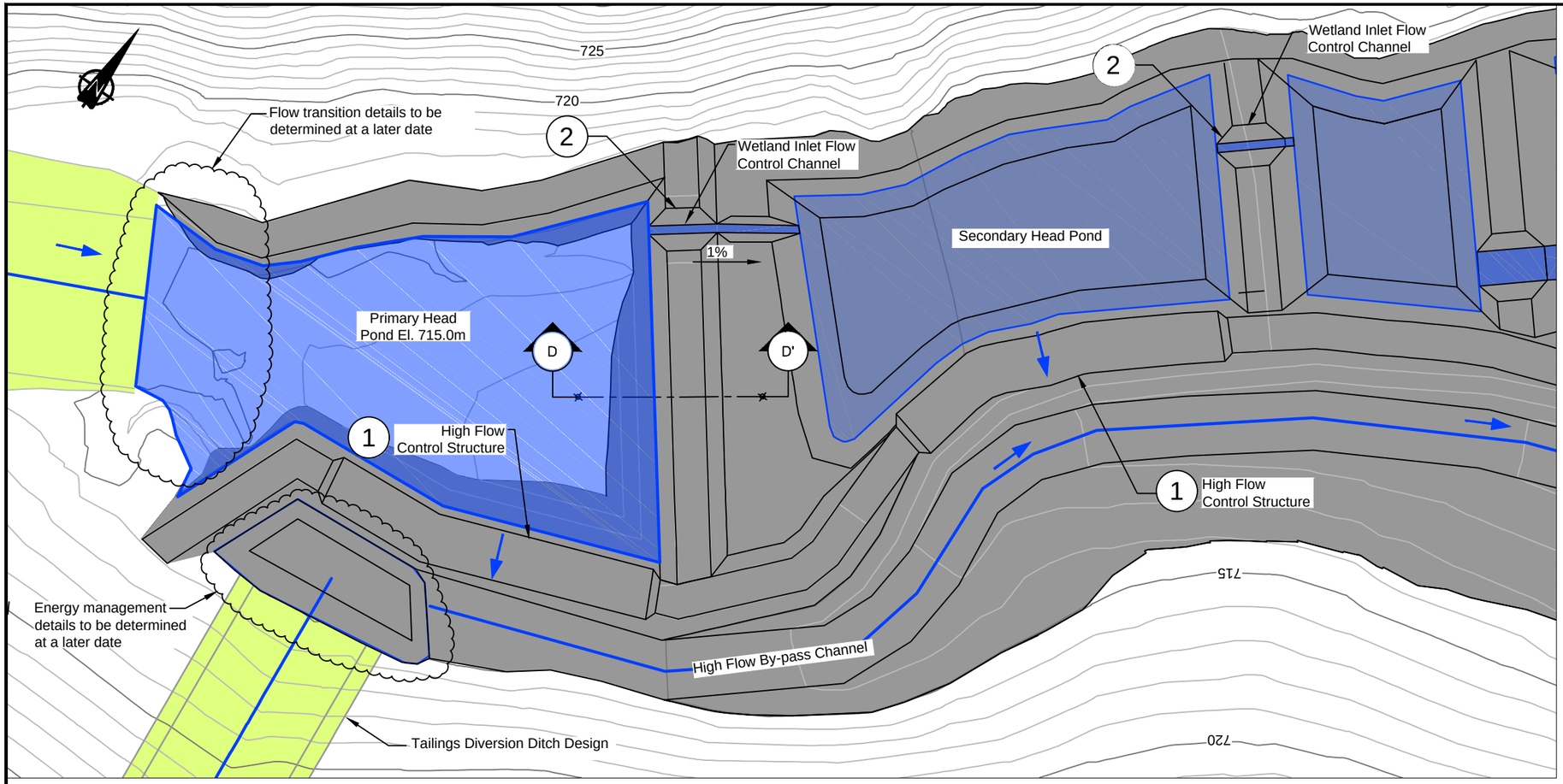

LEGEND

- Wetland Foundation Fill Material
- Rip Rap
- Constructed Wetlands Design
- Designed Infrastructure (Not Constructed)
- Geomembrane
- Flow Direction

NOTES

1. The Wetland Intake structure is designed to convey the design flow rate from the Primary Head Pond to the Secondary Head Pond. Flows exceeding this rate enter the high-flow bypass channel.
2. Wetland intake structure to be designed at later stages of design to convey 3000 m3/day into the wetland.
3. High Flow By-Pass flow control structure to be designed at later stages of design.
4. High Flow By-Pass Channel and Stilling Basin designed by SRK Closure Conveyance Channel Design Report 2016.
5. Pond to be filled to avoid structures classified as dams

PRIMARY AND SECONDARY HEAD POND PLAN VIEW

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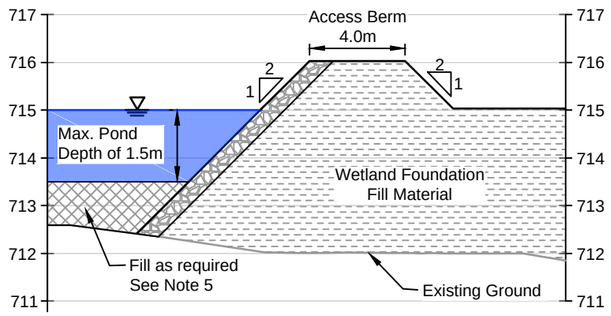
Scale in Metres



SECTION D - D'

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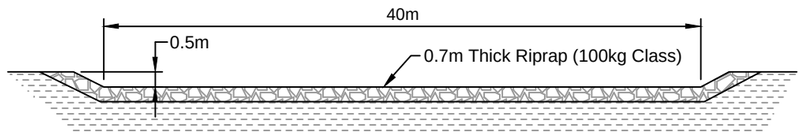
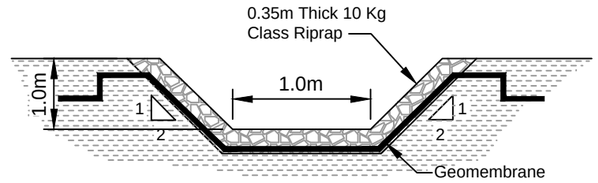
Vertical Exaggeration 2X



DETAIL 1 - TYPICAL HIGH FLOW CONTROL STRUCTURE

1

NTS



DETAIL 2 - TYPICAL WETLAND INLET FLOW CONTROL CHANNEL

2

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SM	DM	July 2016

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Preliminary Infrastructure Minto Creek Constructed Wetlands

DRAWING TITLE: Head Pond Area Layout

DRAWING NO.	SHEET	REVISION NO.
CW-03	4 OF 5	A

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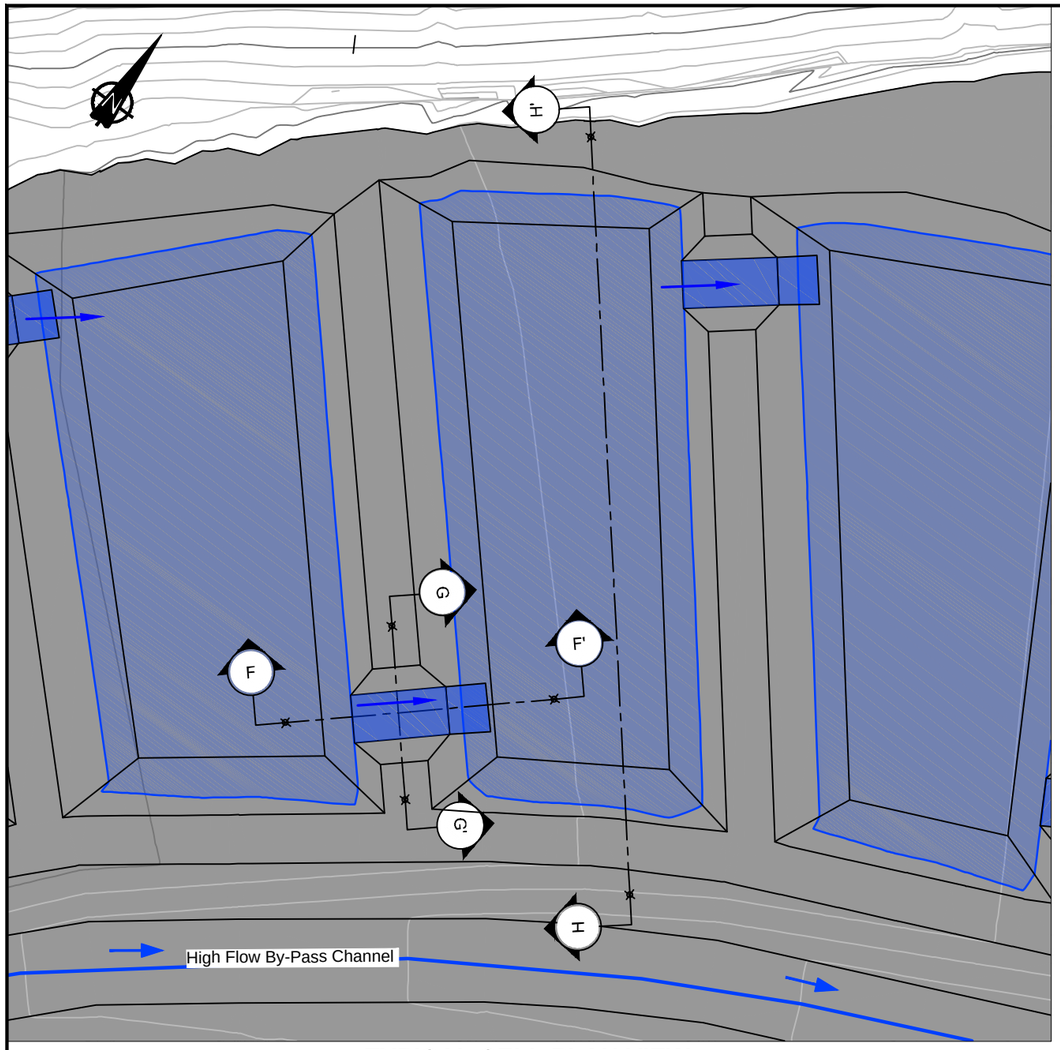
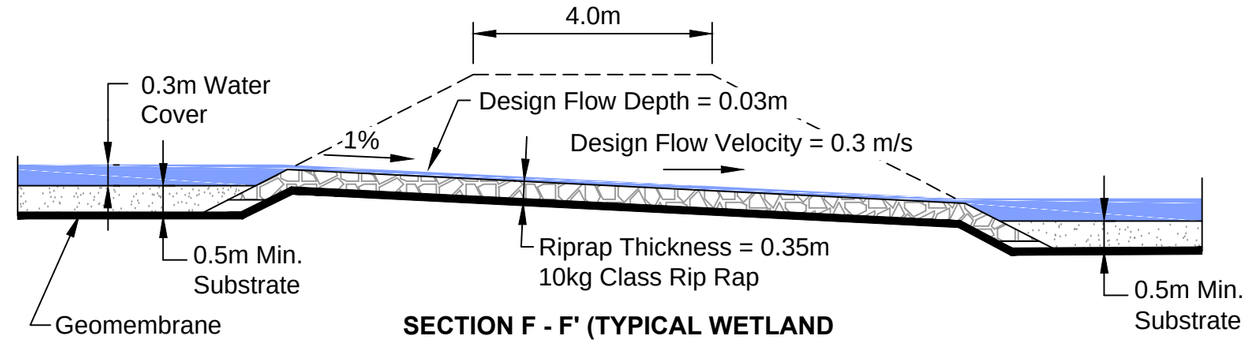


TYPICAL CELL PLAN VIEW

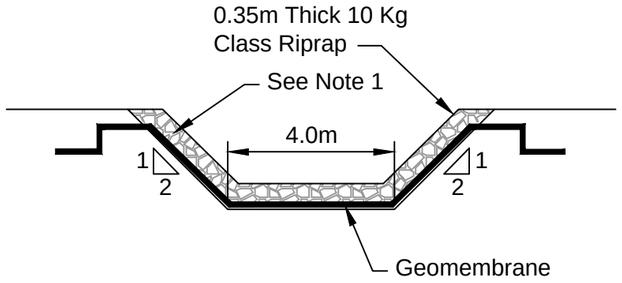
0 5 10 15 20 25

Scale in Metres



SECTION F - F' (TYPICAL WETLAND CELL CONVEYANCE CHANNEL)

F — NTS



SECTION G - G' (TYPICAL WETLAND CELL CONVEYANCE CHANNEL)

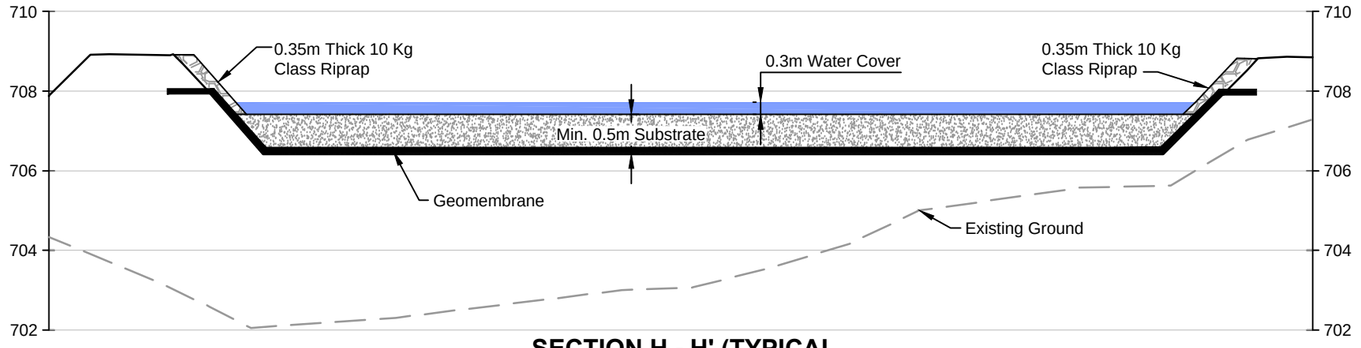
G — NTS

10kg CLASS - RIP RAP

Material Type	Rip Rap Dia. (mm)
D_{100}	300
D_{85}	280
D_{50}	200
D_{15}	90
Layer Thickness	350

100 kg CLASS - RIP RAP

Material Type	Rip Rap Dia. (mm)
D_{100}	680
D_{85}	610
D_{50}	450
D_{15}	200
Layer Thickness	700



SECTION H - H' (TYPICAL CONSTRUCTED WETLAND)

H

0 2 4 6 8 10

Horizontal Scale in Metres
Vertical Exaggeration 2X

LEGEND

- Rip Rap
- Constructed Wetlands Design
- Geomembrane
- Flow Direction

NOTES

1. Cell Conveyance Channel requires a minimum 350 mm layer of rock rip-rap having an average diameter of greater than 200 mm to mitigate erosion.
2. Typical 4.0 m wide berms to be constructed to provide access for Construction and monitoring and maintenance.

NOT FOR CONSTRUCTION

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DRAWING NO.	DRAWING TITLE	DRAWING NO.	DRAWING TITLE

REFERENCE DRAWINGS

NO.	DESCRIPTION	CHK'D	APP'D	DATE
A	Issued for Review	SM	–	15Jul16

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SRK JOB NO.: 1CM002.042

Preliminary Infrastructure Minto Creek Constructed Wetlands

DRAWING TITLE: Typical Cell and Cell Spillway Layout

DRAWING NO.	SHEET	REVISION NO.
CW-04	5 OF 5	A