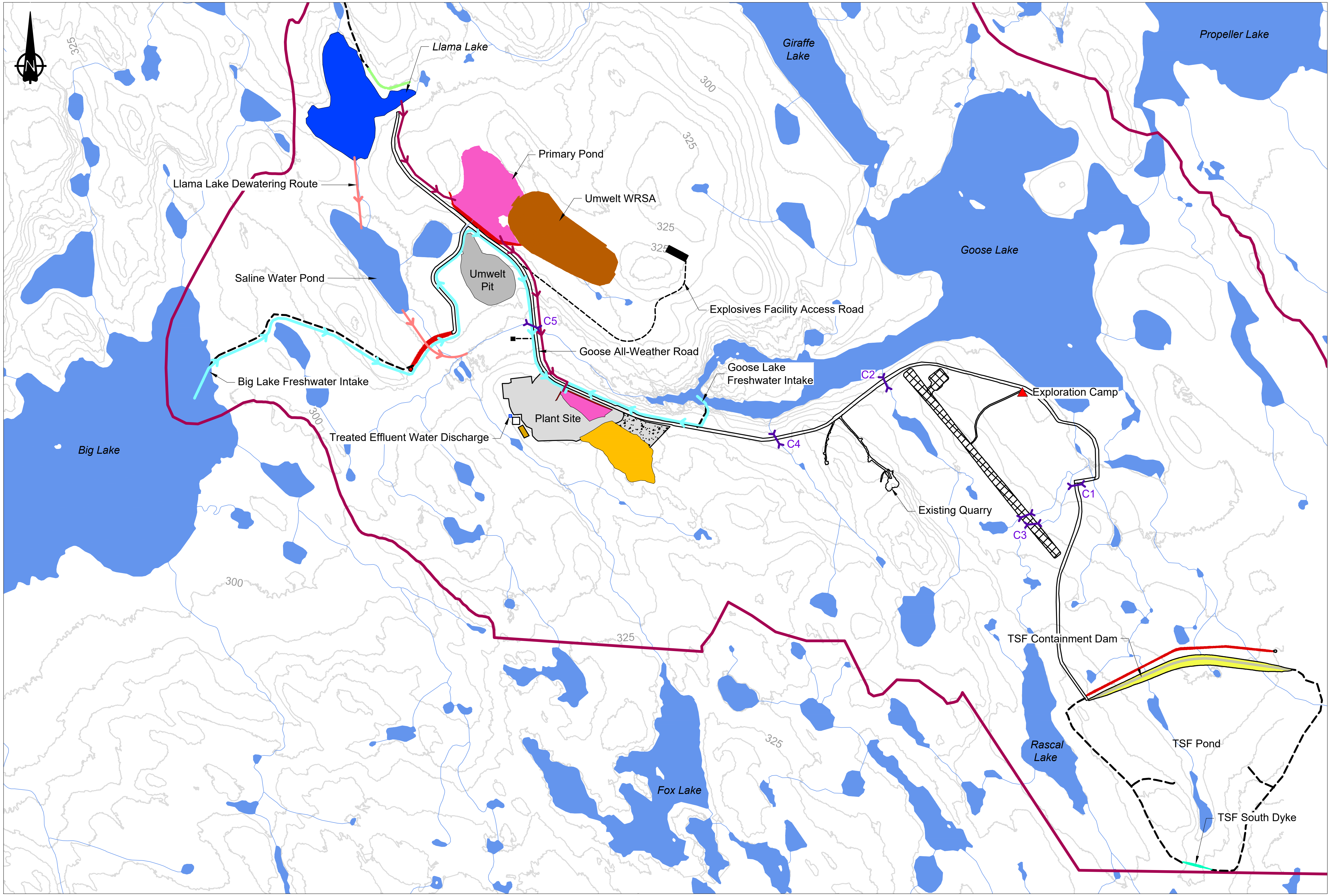

LEGEND

- Culvert
- Service Road
- Water Intake Pipeline
- Pumped Contact Water Pipeline
- Dewatering Pathway
- Site Infrastructure
- Watercourse
- Contact Water Containment Dam (Lined)
- Non-contact Water Diversion Berm (Unlined)

GOOSE LAYOUT

- Airstrip
- U/G Laydown Area
- Other Infrastructure
- Resource Pit
- Camp / Plant Site
- TSF Containment Dam Embankment
- TSF South Dyke
- Contact Water Event Pond
- Haul Road
- Landfarm
- Potential Development Area
- Waste Rock Storage Area
- Ore Stockpile
- Waterbody

NOTES

1. Contours are shown at 5.0m intervals.
2. All units are in meters unless otherwise specified.

REFERENCES

1. NAD83 UTM Zone 13.
2. Footprint obtained from client.
3. Hydrography data obtained from Geogratis, © Department of Natural Resources Canada. All rights reserved.

0m 300 600 900 1200

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Back River Project

SRK JOB NO.: 1CS020.018

Water Licence Phase

DRAWING TITLE: Phase 1: Construction (Year -3 to-1)

DRAWING NO.: A-04
SHEET 4 OF 26
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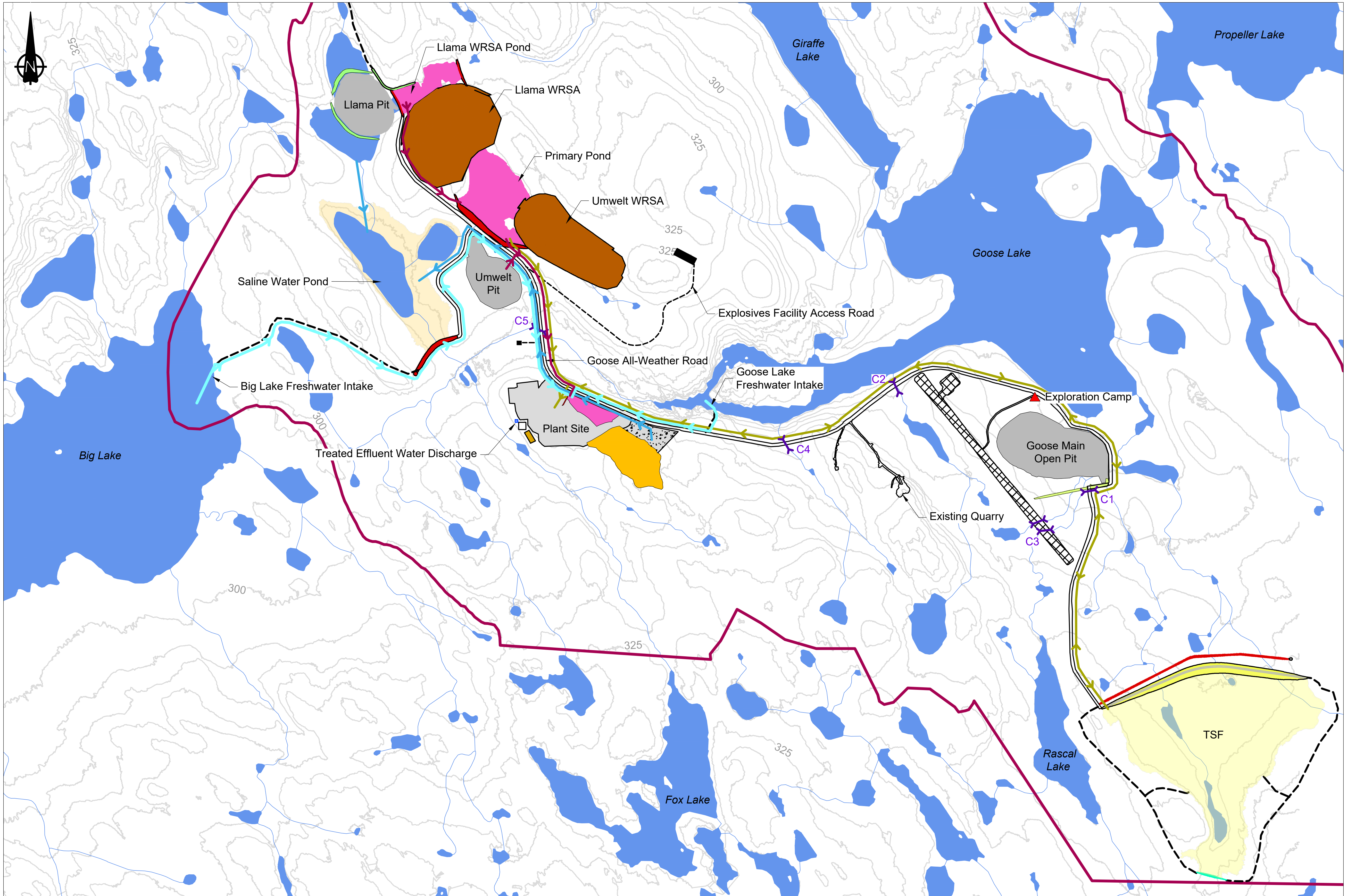

LEGEND

- Culvert
- Contact Water Pipeline
- Saline Water Flow
- Reclaim Water / Slurry Pipeline
- Site Infrastructure
- Service Road
- Water Intake Pipeline
- Watercourse
- Water Treatment Plant
- Contact Water Containment Dam (Lined)
- Non-contact Water Diversion Berm (Unlined)

GOOSE LAYOUT

- Airstrip
- U/G Laydown Area
- Other Infrastructure
- Resource Pit
- Camp / Plant Site
- Waste Rock Storage Area
- TSF Containment Dam Embankment
- TSF South Dyke
- Contact Water Event Pond
- Haul Road
- Landfarm
- Potential Development Area
- Active TSF
- Saline Water Pond
- Waterbody

NOTES

1. Contours are shown at 5.0m intervals.
2. All units are in meters unless otherwise specified.

REFERENCES

1. NAD83 UTM Zone 13.
2. Footprint obtained from client.
3. Hydrography data obtained from Geogratis, © Department of Natural Resources Canada. All rights reserved.

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SRK JOB NO.: 1CS020.018

Water Licence Phase

DRAWING TITLE: Phase 2, Stage 1 (TSF): Operations Year 1 to 5

DRAWING NO.: A-05 — SHEET 5 OF 26 — REVISION NO. A

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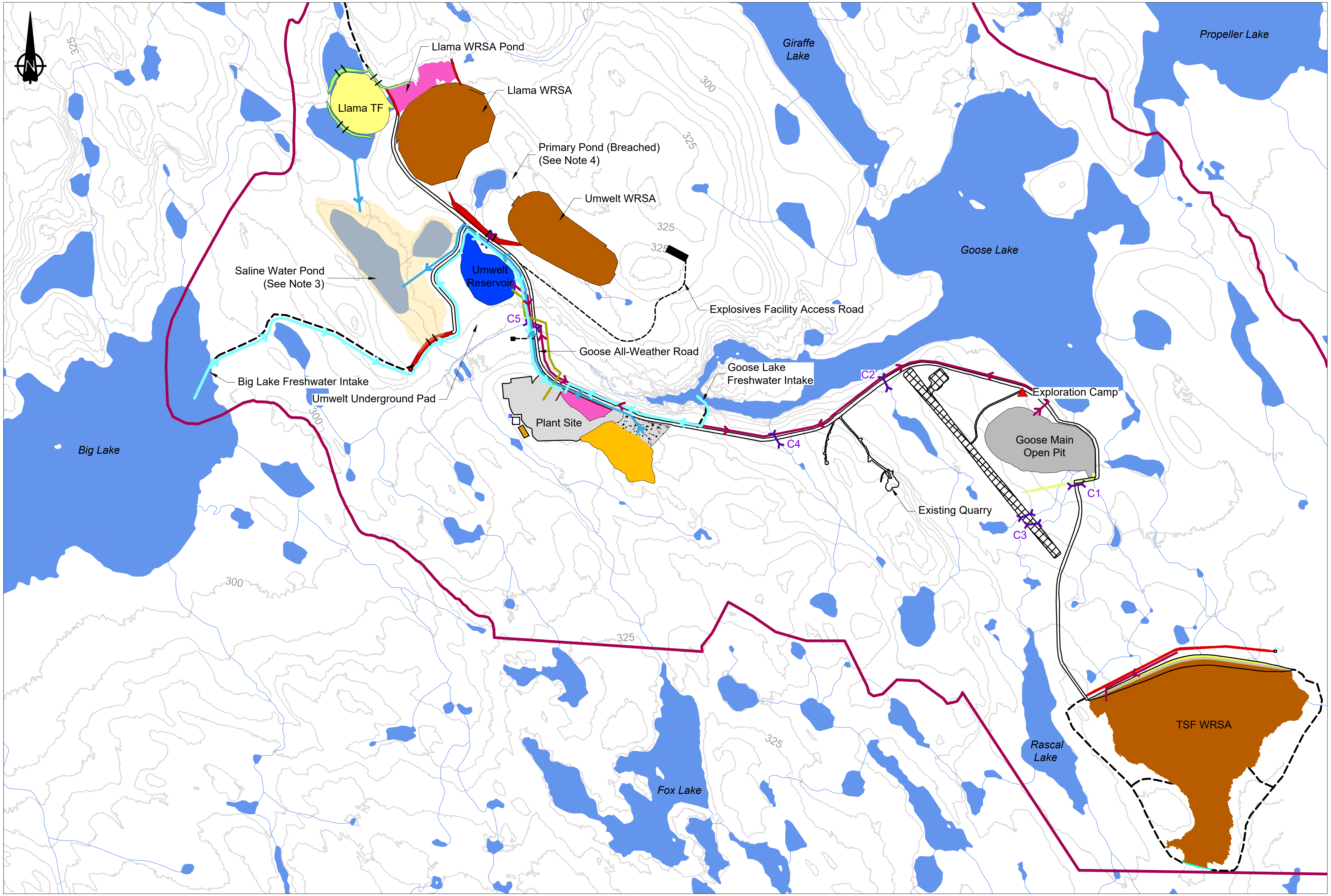

LEGEND

- Breach Berm Location
- Culvert
- Contact Water Pipeline
- Non-Contact Water Pipeline
- Saline Water Flow
- Reclaim Water / Slurry Pipeline
- Site Infrastructure
- Service Road
- Water Intake Pipeline
- Watercourse
- Active TF
- Contact Water Containment Dam (Lined)
- Non-contact Water Diversion Berm (Unlined)

GOOSE LAYOUT

- Airstrip
- U/G Laydown Area
- Other Infrastructure
- Resource Pit
- Camp / Plant Site
- Waste Rock Storage Area
- TSF Containment Dam Embankment
- TSF South Dyke
- Contact Water Event Pond
- Haul Road
- Landfarm
- Potential Development Area
- Saline Water Pond
- Waterbody

NOTES

1. Contours are shown at 5.0m intervals.
2. All units are in meters unless otherwise specified.
3. When Saline Water Pond is breached flow discharges to Goose Lake through natural drainage.
4. The Primary Pond is dewatered and breached via culverts beneath the haul road, allowing contact water to drain by gravity to Umwelt Reservoir.

REFERENCES

1. NAD83 UTM Zone 13.
2. Footprint obtained from client.
3. Hydrography data obtained from Geogratis, © Department of Natural Resources Canada. All rights reserved.

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Water Licence Phase

DRAWING TITLE:
Phase 2, Stage 2 (Llama TF): Operations - Year 5 to 12

DRAWING NO. A-06 | SHEET 6 OF 26 | REVISION NO. A

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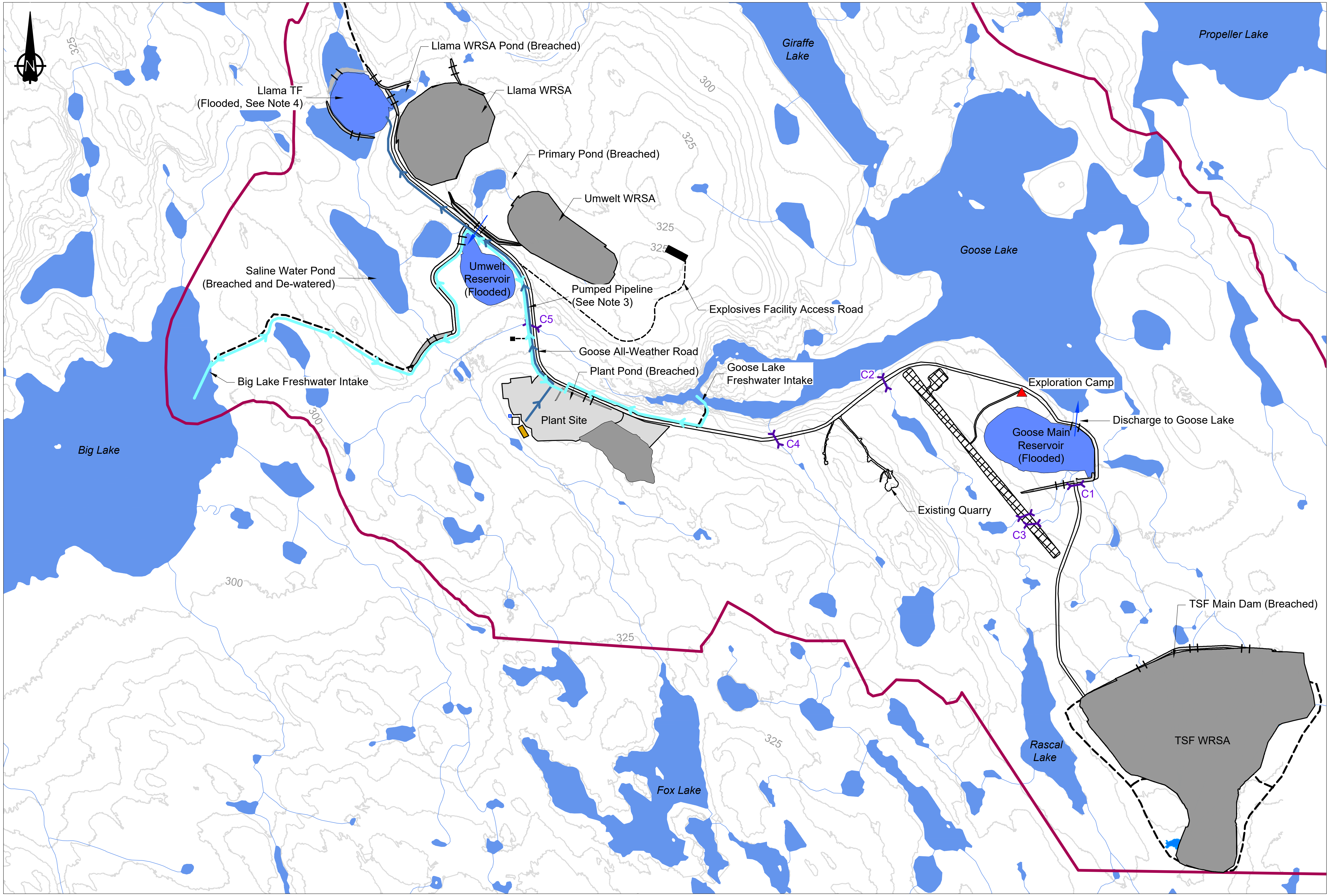

LEGEND

- Breach Berm Location
- Culvert
- Water Treatment Pipeline
- Service Road
- Water Intake Pipeline
- Watercourse
- Berm
- Proposed Airstrip
- Decommissioned Pads
- Other Infrastructure
- Potential Development Area
- Haul Road
- Inactive Waste Rock Storage Area
- Landfarm
- Pit Lake (Closed)
- Waterbody

NOTES

1. Contours are shown at 5.0m intervals.
2. All units are in meters unless otherwise specified.
3. Treated water from Llama TF is pumped back to Llama TF in parallel pipeline.
4. Treated water flow from Llama TF travels to the breached Saline Water Pond area then through Goose Creek / Goose Neck into Goose Lake.

REFERENCES

1. NAD83 UTM Zone 13.
2. Footprint obtained from client.
3. Hydrography data obtained from Geogratis, © Department of Natural Resources Canada. All rights reserved.

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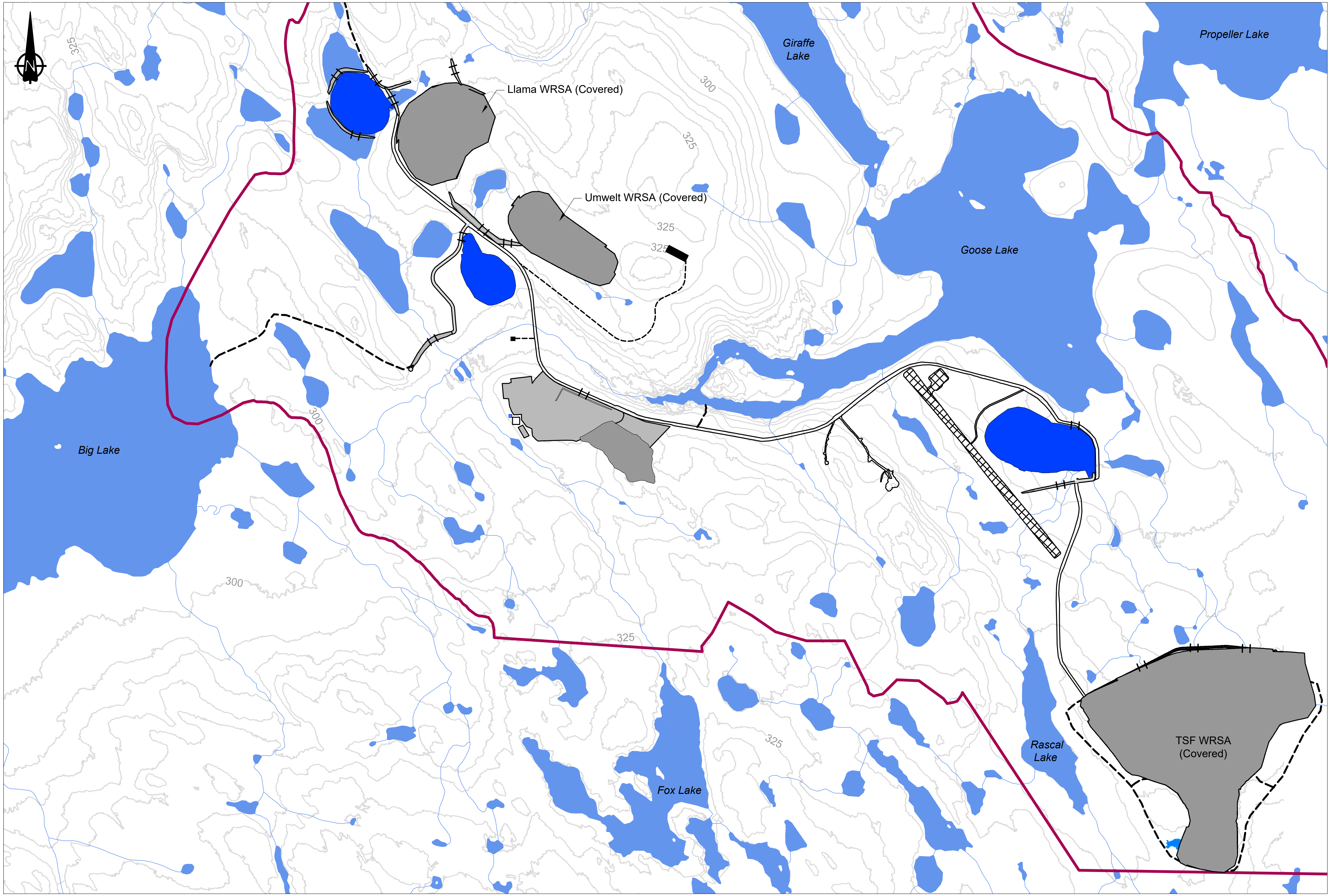
Back River Project

SRK JOB NO.: 1CS020.018

Water Licence Phase

DRAWING TITLE: Phase 3: Closure Year 13 to Year 20

DRAWING NO.: A-07 | SHEET 1 OF 26 | REVISION NO.: A



LEGEND

- Breach Berm Location
- Service Road
- Watercourse
- Breached Berm
- Potential Development Area

GOOSE LAYOUT

- Proposed Airstrip
- Decommissioned Pads
- Other Infrastructure
- TSF Containment Dam Embankment
- Decommissioned Berms
- Haul Road
- Inactive Waste Rock Storage
- Pit Lake (Closed)
- Waterbody

NOTES

1. Contours are shown at 5.0m intervals.
2. All units are in meters unless otherwise specified.
3. TSF WRSA pond breached to Goose Main TF.

REFERENCES

1. NAD83 UTM Zone 13.
2. Footprint obtained from client.
3. Hydrography data obtained from Geogratis, © Department of Natural Resources Canada. All rights reserved.

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FILE NAME: 1CS020.018 - Site Overview - PostClosure.dwg

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Back River Project

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Water Licence Phase

DRAWING TITLE: Phase 4: Post-Closure Year 21+

DRAWING NO.: A-08 | SHEET 1 OF 26 | REVISION NO. A

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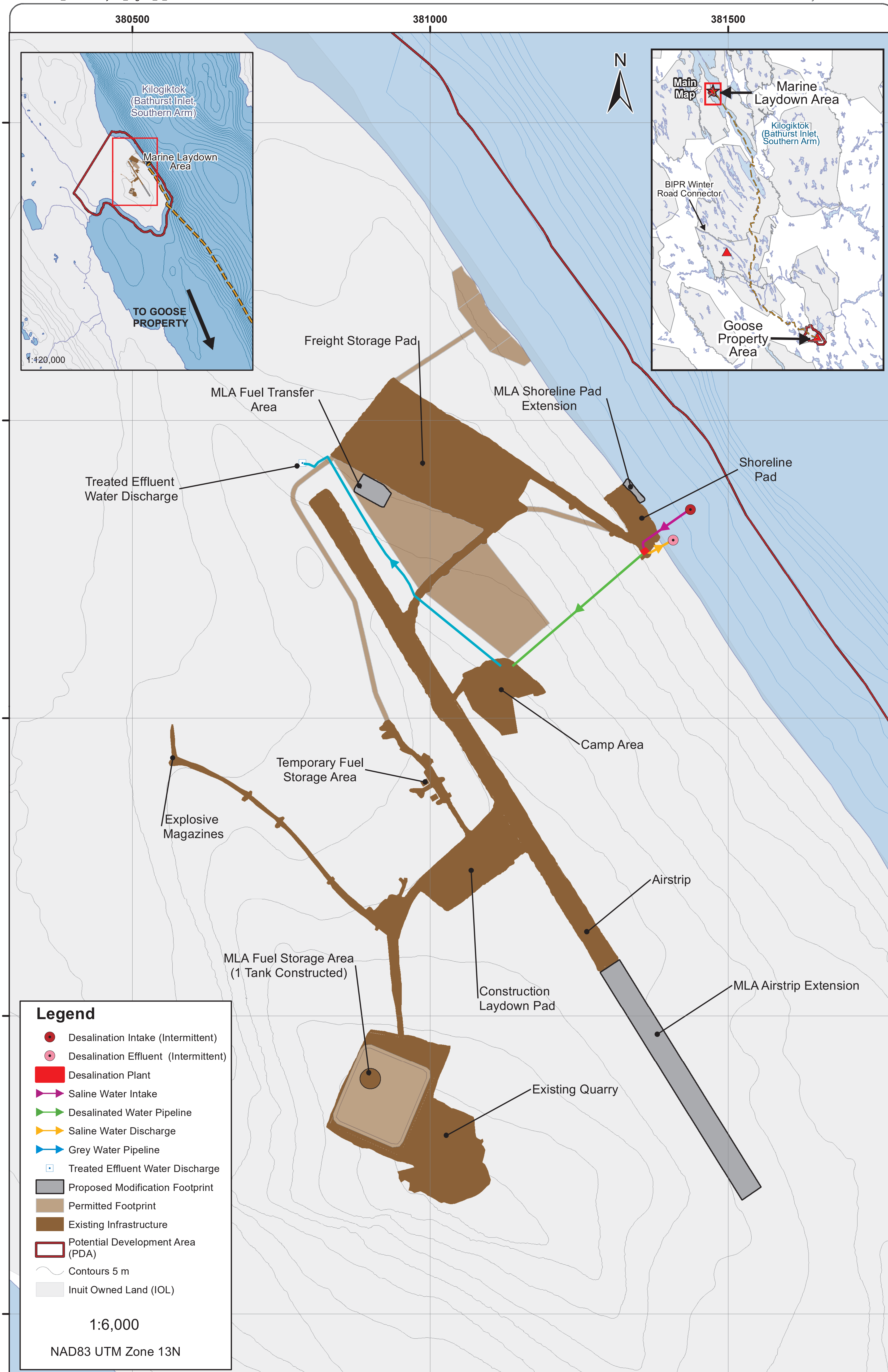


Figure A-09

Sabina GOLD & SILVER CORP.

Back River Project - Marine Laydown Area
Potential Development Area and Layout
2020 Modification Package

GIS # Modification Package_Fig_A-10 ...\BackRiver\04_Exploration\BackRiverRegion\GIS_Products\ESRI_MXD\Water_Permitting\Modification Package\Modification Package_Fig_A-10.mxd

May 7, 2020

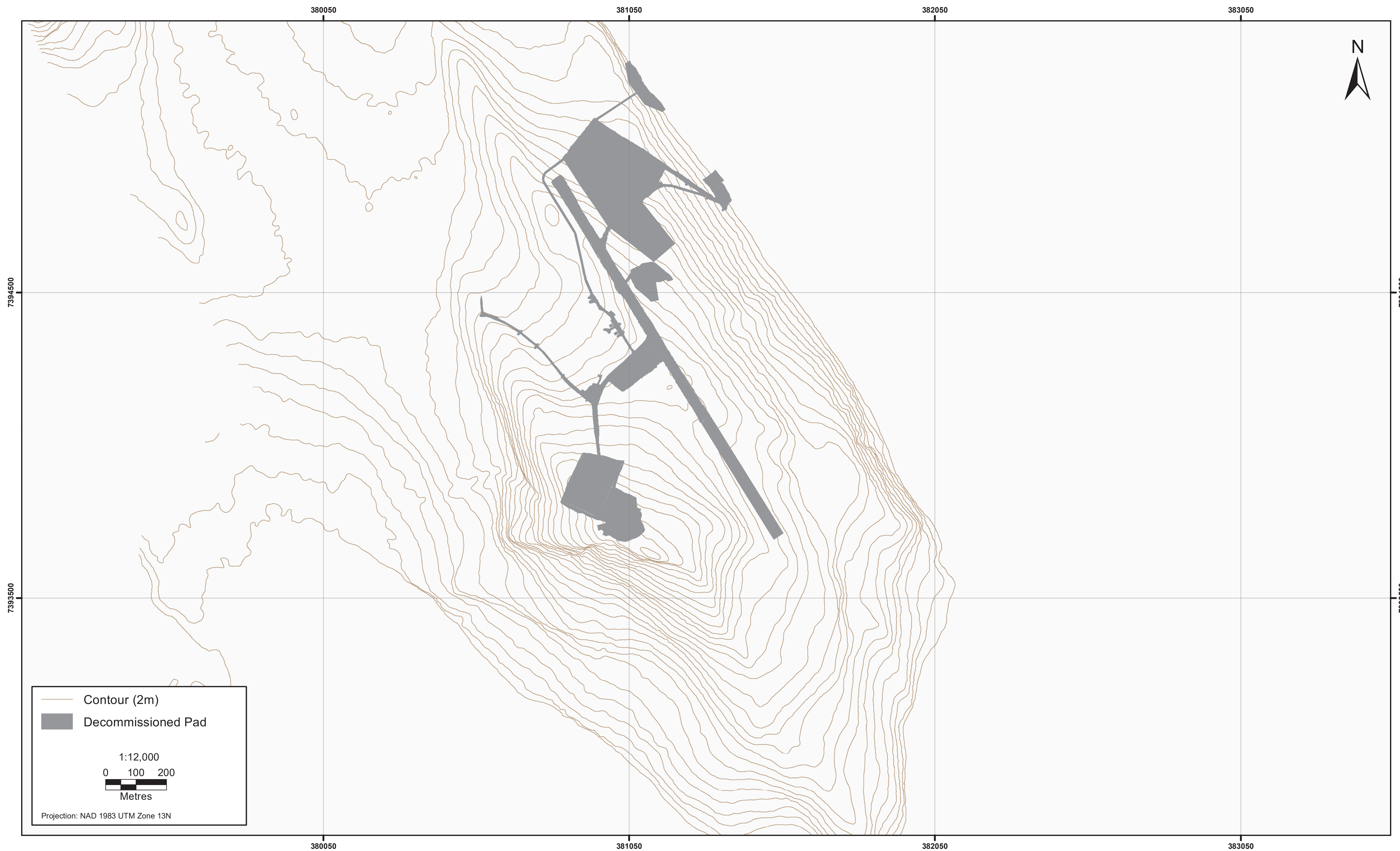
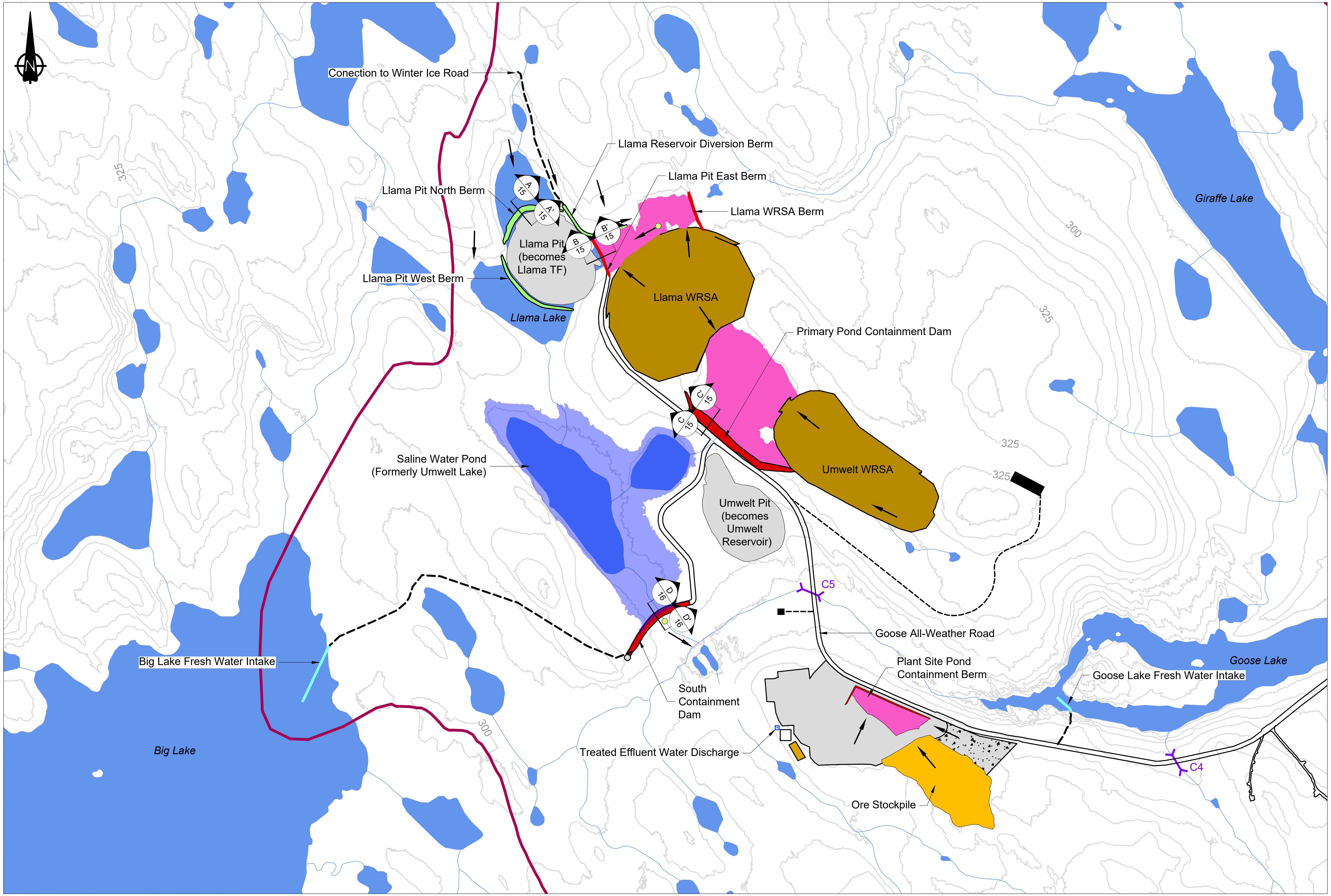


Figure A-10

Sabina
GOLD & SILVER CORP.

Phase 3 & 4 Closure & Post Closure
Marine Laydown Area (Year 13+)



LEGEND

- Discharge Location
- Culvert
- Flow Direction
- Service Road
- Water Intake Pipeline
- Watercourse
- Contact Water Pond
- Contact Water Containment Dam (lined)
- Non-contact Water Diversion Berm (unlined)

GOOSE LAYOUT LEGEND

- U/G Laydown Area
- Other Infrastructure
- Resource Pit
- Camp / Plant Site
- Waste Rock Storage Area
- Ore Stockpile
- Haul Road
- Landfarm
- Potential Development Area
- Waterbody

NOTES

1. Contours are shown at 5.0m intervals.
2. All units are in meters unless otherwise specified.

REFERENCES

NAD83 UTM Zone 13.

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FILE NAME: 1CS020.018 - General Arrangements.dwg

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Back River Project

SRK JOB NO.: 1CS020.018

Water Licence Phase

DRAWING TITLE:
Goose Property General Arrangement Sheet 1 of 2

DRAWING NO. A-11 | SHEET 11 OF 26 | REVISION NO. A

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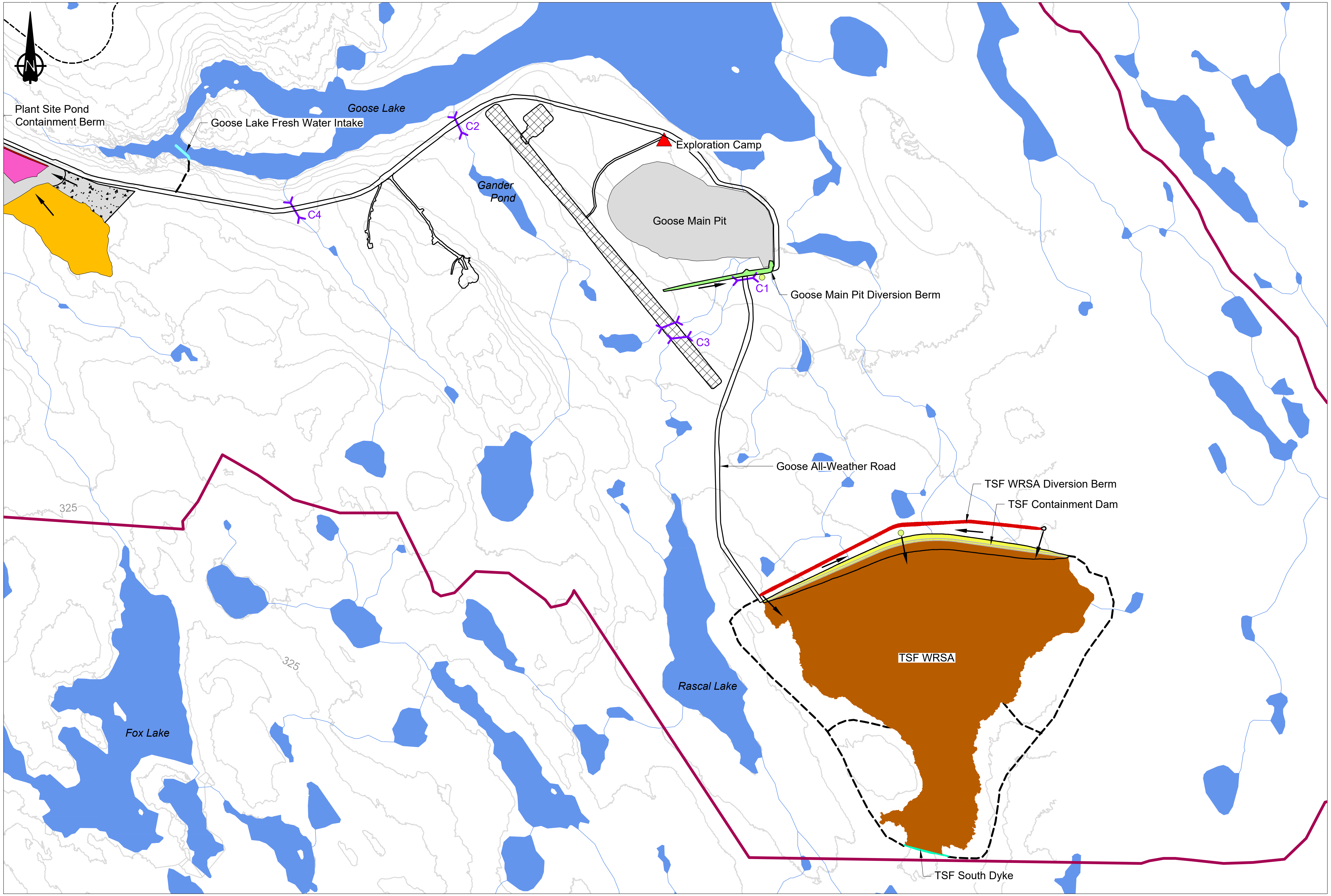

LEGEND

- Discharge Location
- Culvert
- Flow Direction
- Service Road
- Water Intake Pipeline
- Watercourse
- Contact Water Pond
- Contact Water Containment Dam (lined)
- Non-contact Water Diversion Berm (unlined)

GOOSE LAYOUT LEGEND

- Other Infrastructure
- Resource Pit
- Camp / Plant Site
- Waste Rock Storage Area
- Ore Stockpile
- Haul Road
- Potential Development Area
- Waterbody

NOTES

1. Contours are shown at 5.0m intervals.
2. All units are in meters unless otherwise specified.

REFERENCES

NAD83 UTM Zone 13.

0m 200 400 600 800

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Water Licence Phase

DRAWING TITLE:
Goose Property General Arrangement
Sheet 2 of 2

DRAWING NO. A-12
SHEET 12 OF 26
REVISION NO. A

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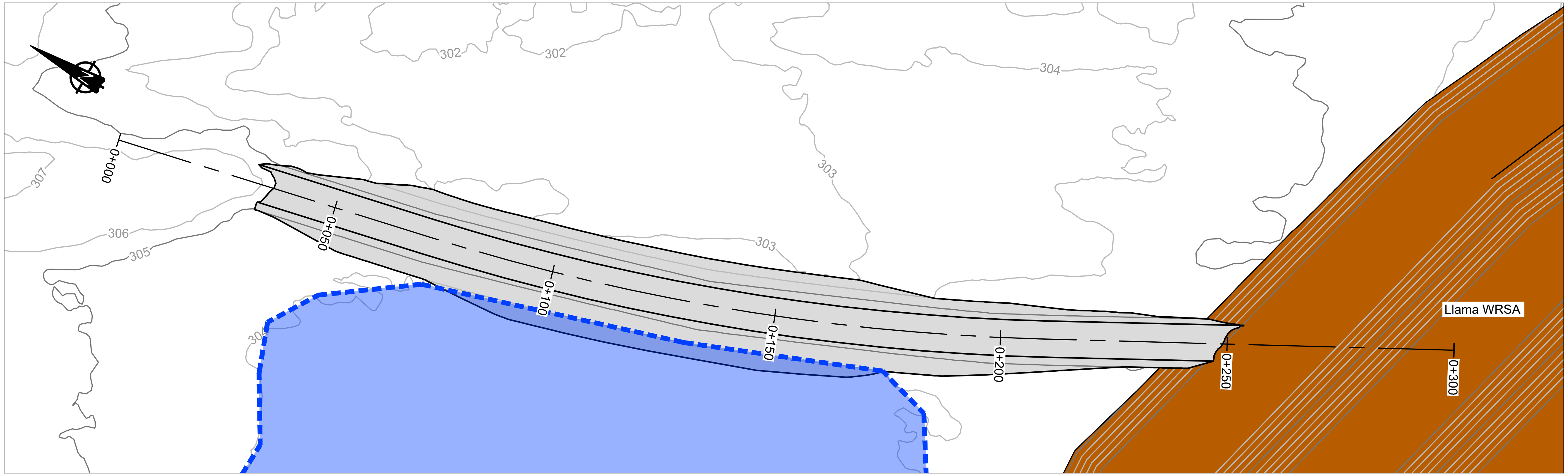


LEGEND

- Full Supply Level (Elev. 304.0m)
- Design Infrastructure
- Waste Rock Storage Area
- Rockfill
- Maximum Water Level (304.0m)

NOTES

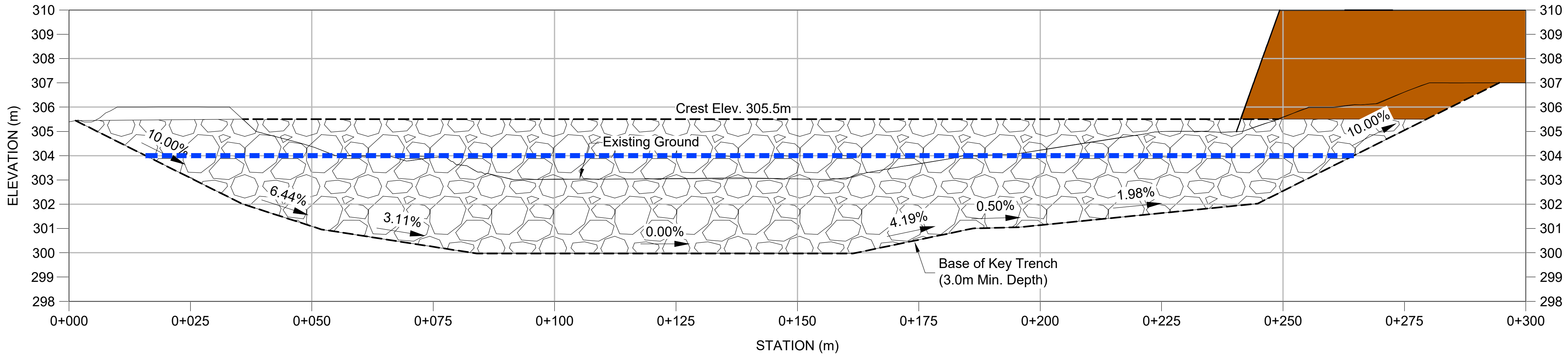
1. Contours shown at 1.0m intervals.
2. All units are in meters unless otherwise specified.
3. Required key trench depth and dam and berm cross sections designs to be confirmed at detailed design stage.

REFERENCES

NAD83 UTM Zone 13.

Llama Reservoir East Dam

0m 10 20 30 40



Llama Reservoir East Dam Profile

0m 2 4 6 8

0m 10 20 30 40

DRAWING NO.	DRAWING TITLE
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DRAWING TITLE:
Llama Reservoir WRSA Containment Dam Plan and Profile

DRAWING NO. A-13 | SHEET 13 OF 26 | REVISION NO. A

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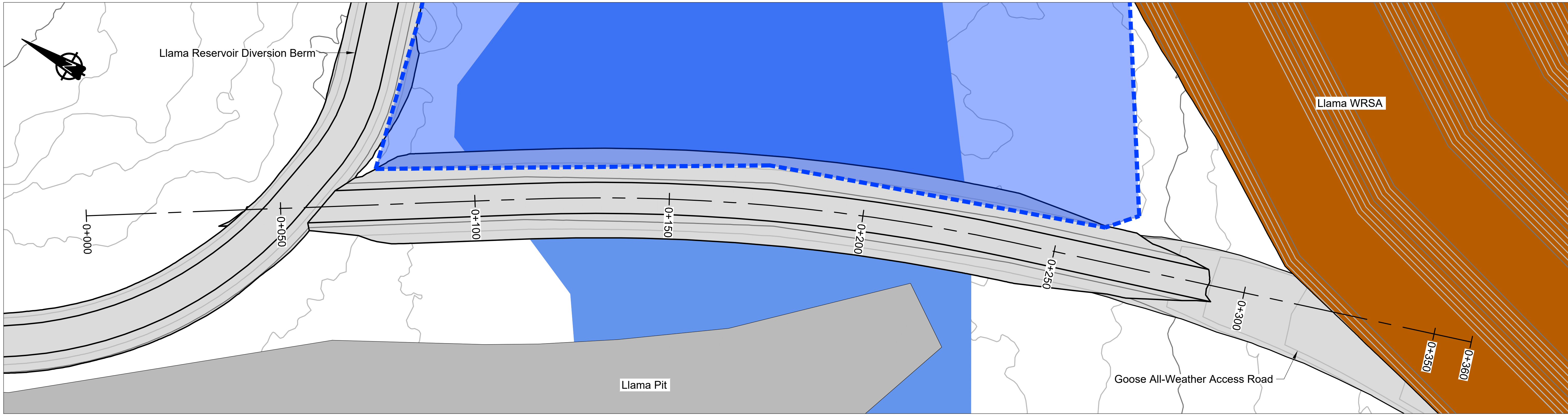

Llama Pit East Dam

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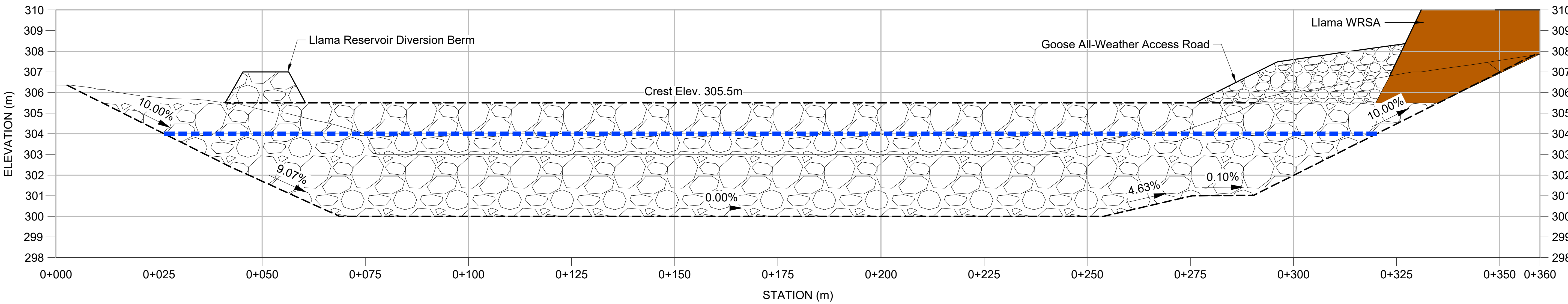

Llama Pit East Dam Profile

0m 2 4 6 8

0m 10 20 30 40

LEGEND

- Full Supply Level (Elev. 304.0m)
- Design Infrastructure
- Waste Rock Storage Area
- Rockfill
- Maximum Water Level (304.0m)

NOTES

1. Contours shown at 1.0m intervals.
2. All units are in meters unless otherwise specified.
3. Required key trench depth and dm and berm cross sections designs to be confirmed at detailed design stage.

REFERENCES

NAD83 UTM Zone 13.

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DRAWING TITLE: Llama Pit East Dam Plan and Profile

DRAWING NO.: A-14 — SHEET 14 OF 26 — REVISION NO.: A

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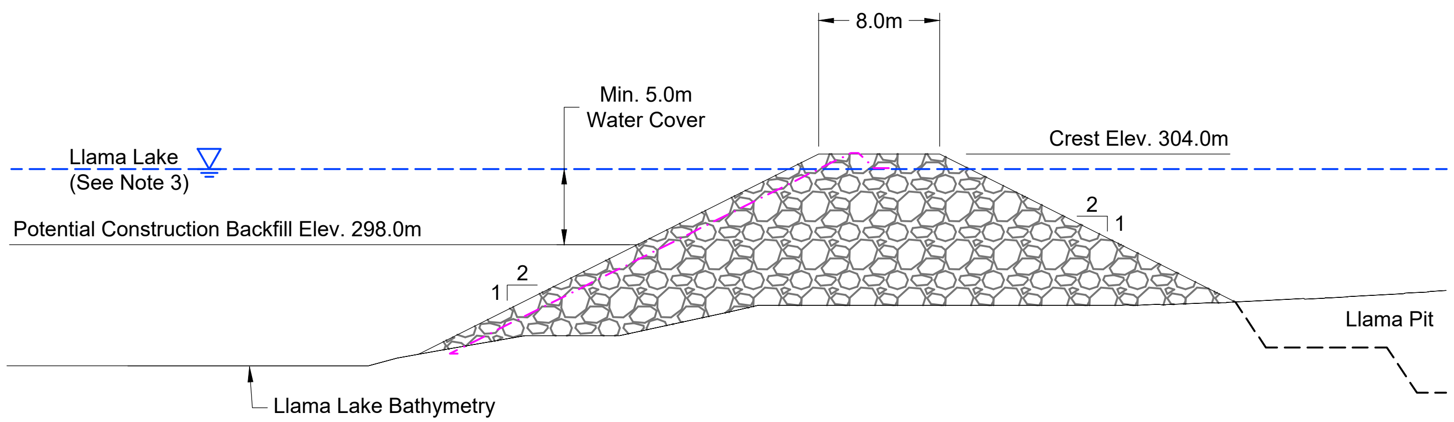
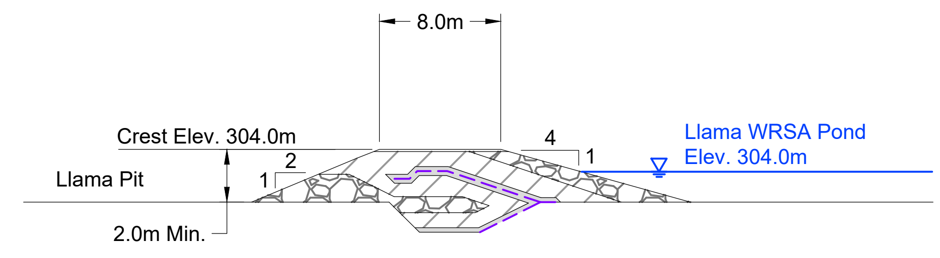


A / 11 **Cross Section A-A' - Llama Pit North Berm**



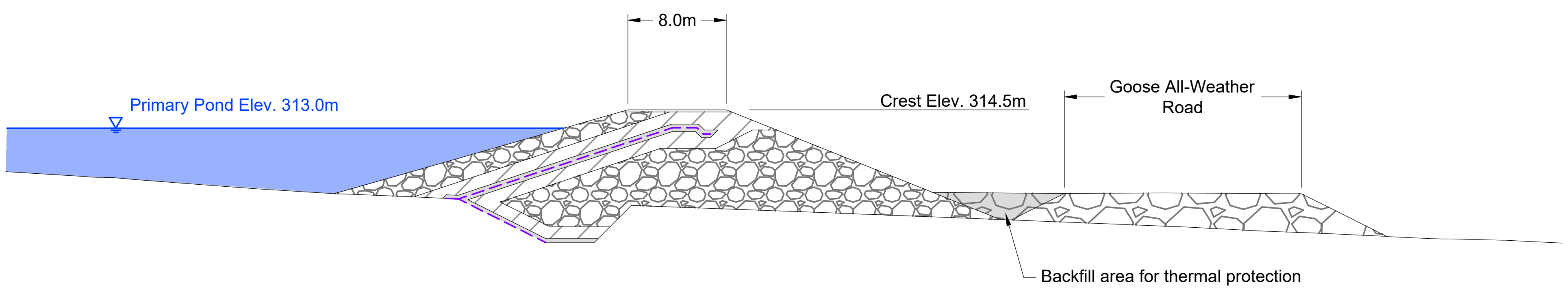
B / 11 **Cross Section B-B' - Llama Pit East Dam**

LEGEND

- Non-woven Geotextile
- Liner System
- Full Supply Water Level
- Run of Mine Material
- Rockfill Material
- Transition Material
- Bedding Material
- Surfacing Material

NOTES

1. Remove 1.0m organics at ground surface along berm / dam contact area.
2. All dimensions are in meters unless otherwise noted.
3. Lake dewatered for mining activities then berm breached and pit flooded at closure.
4. Required key trench depth and dam and berm cross sections designs to be confirmed at detailed design stage.



C / 11 **Cross Section C-C' - Primary Pond Dam**

0m 5 10 15 20

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DRAWING TITLE: Typical Dam Sections (Sheet 1 of 2)

DRAWING NO.: A-15 | SHEET: 15 OF 26 | REVISION NO.: A

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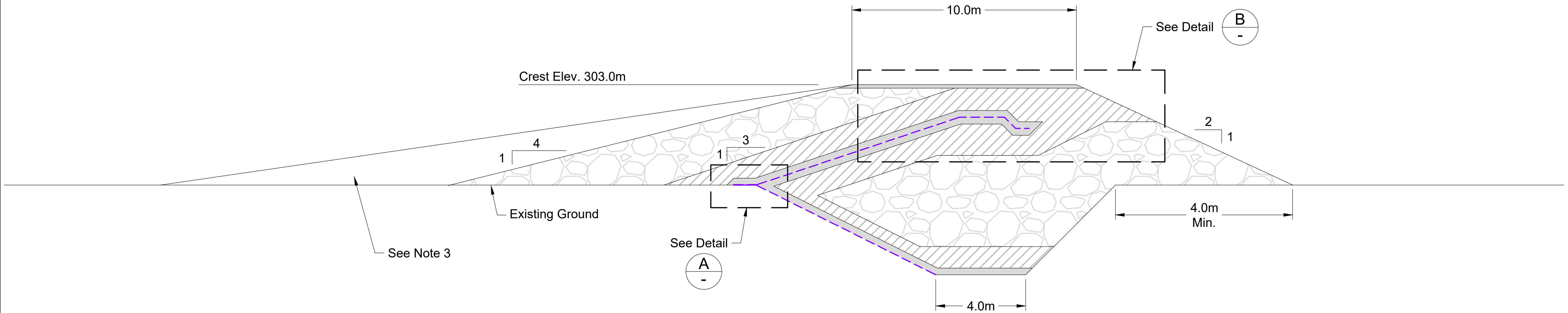
LEGEND

- Liner System
- Full Supply Water Level
- ROM
- Engineered Fill
- Bentonite Plug

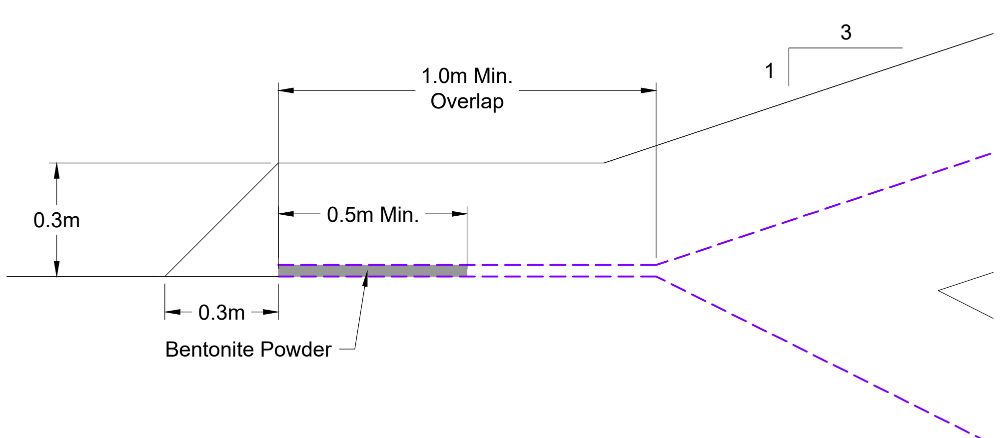
NOTES

1. Existing ground is based on a 2012 LiDAR survey reduced to 1m horizontal resolution provided by Sabina.
2. All dimensions are in meters unless otherwise noted.
3. Overburden may be placed off the upstream face for the Saline Water Pond to help spread out the seepage pathway and limit long-term thermal impacts on the foundation.
4. Required key trench depth and dam and berm cross sections designs to be confirmed at detailed design stage.



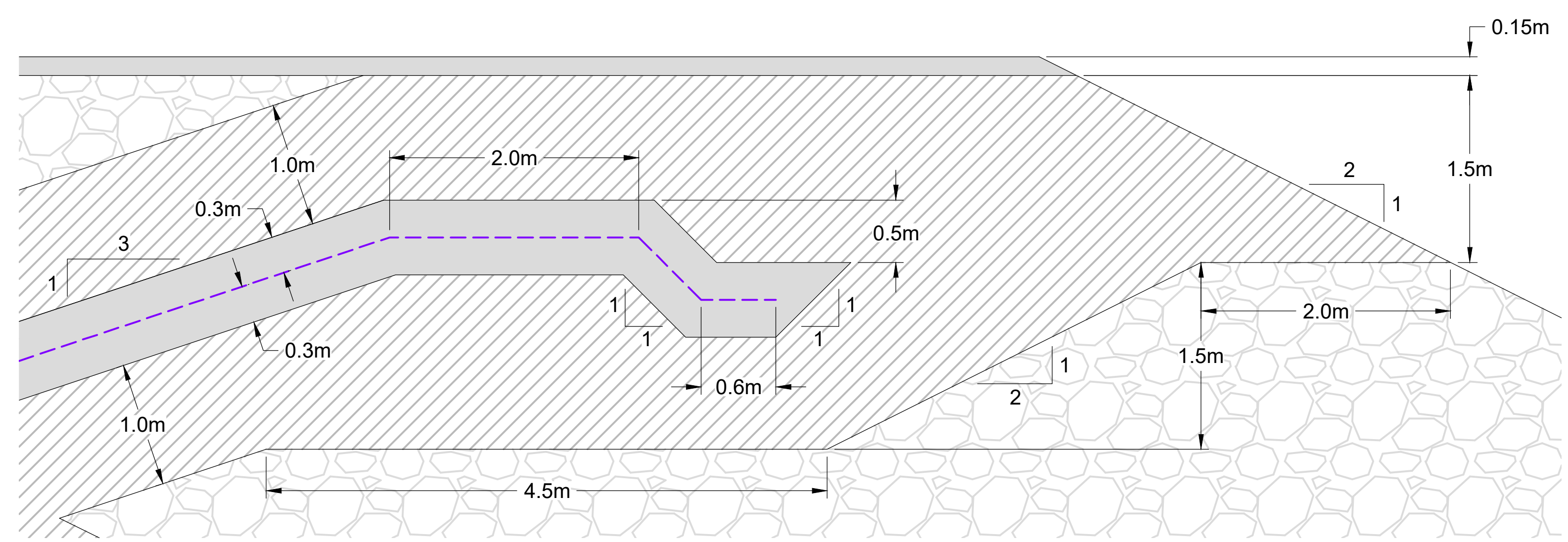
D 11 **Cross Section D-D' - Saline Water Pond South Dam**

0m 2 4 6 8



1 - **Typical Upper and Lower GCL Joint Detail**

0 200 400 600 800mm



2 - **Typical Liner Anchor Trench Bedding Detail**

0m 0.5 1.0 1.5 2.0m

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FILE NAME: 1CS020.018 - Typical Sections.dwg

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Water Licence Phase

DRAWING TITLE: Typical Dam Sections and Details (Sheet 2 of 2)

DRAWING NO. A-16 SHEET 16 OF 26 REVISION NO. A

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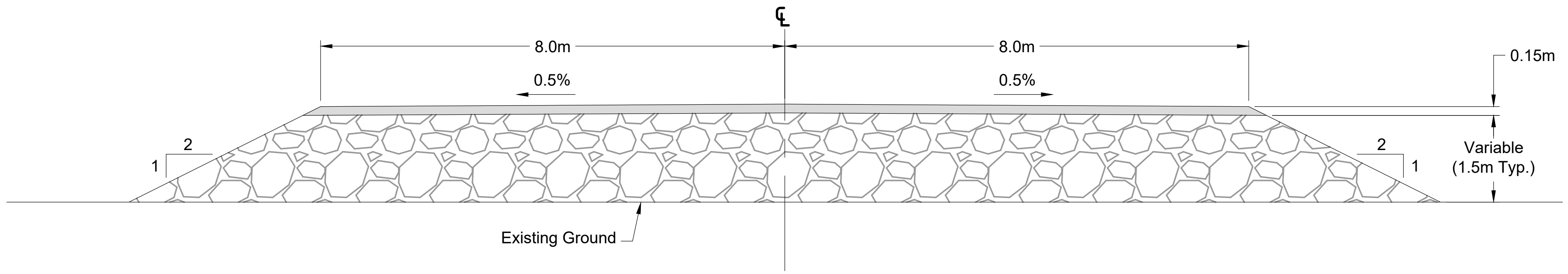
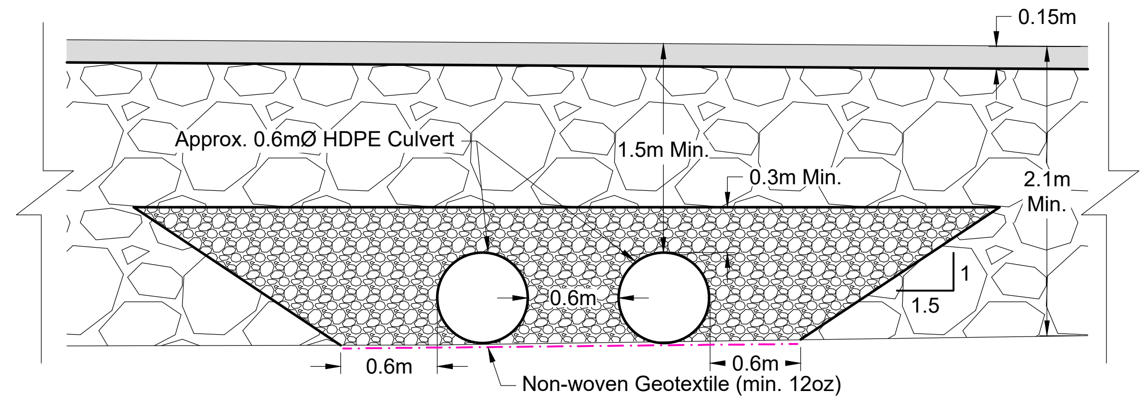


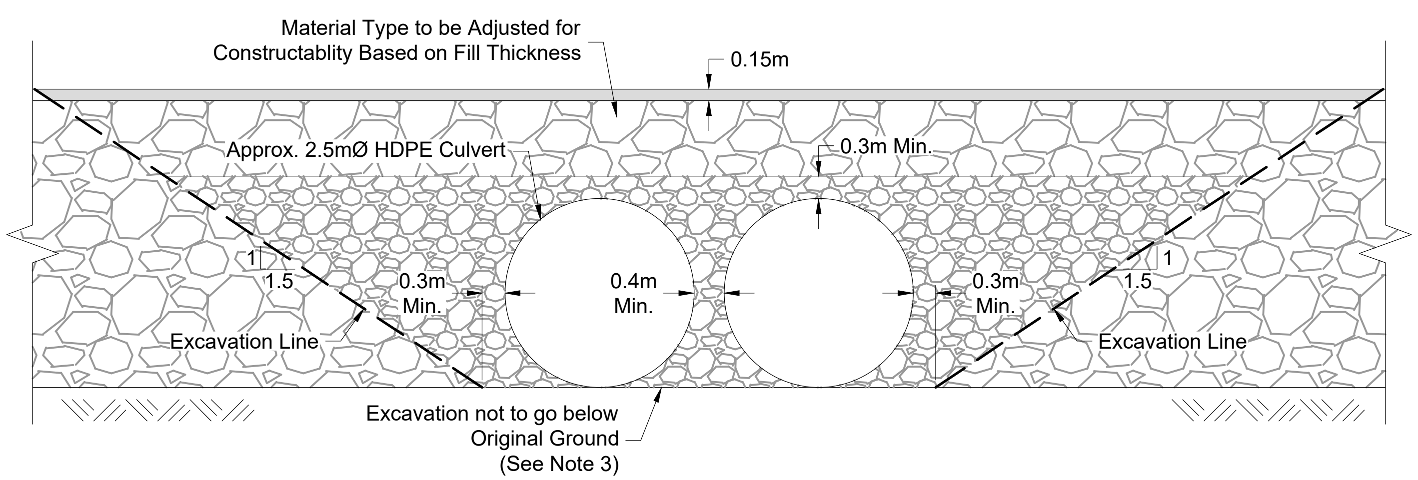
Typical Road Section

0m 1 2 3 4



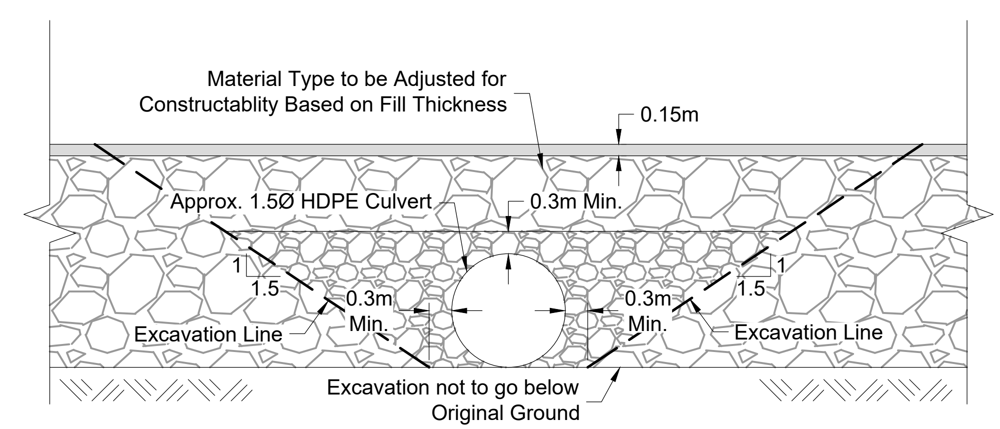
3 - Detail 3 - Typical Cross Section of Small Diameter Double HDPE Culvert Crossing

0m 0.5 1.0 1.5 2.0



4 - Detail 4 - Typical Cross Section of Large Diameter Double Culvert Crossing

0m 1 2 3 4



5 - Detail 5 - Typical Cross Section of Single Culvert Crossing

0m 1 2 3 4

LEGEND

- Non-Woven Geotextile
- ROM Material
- Engineered Fill / Crush material
- Surfacing Material

NOTES

1. All dimensions in meters unless otherwise stated.
2. Installation of culverts to follow the manufacturers assembly and installation guide.
3. Total depth of cover above culvert, including bedding material, surfacing material, and ROQ material, will be 1.5m minimum.
4. For safety barrier sizing, height to be a minimum ¾ the diameter of the largest vehicle tire.
5. If natural ground is less that 1% grade, fill material (surfacing material) to be placed below culvert to establish minimum 1% grade.
6. Non-woven geotextile is suggested to be placed below all culvert pipes to help low rates of permafrost degradation from surface water flow, and to help reduce differential settlement.
7. Ultimate crest width of roads will be set based on the design vehicles. The minimum road crest width of single land traffic shall be twice the width of the largest design vehicle as per WSCC (2015). Dual lane traffic requires road width three times the largest design vehicle.
8. Culverts on site may be HDPE (High-density polyethylene) or CSP (corrugated steel pipe). Final materials to be determined during detailed design.

DRAWING NO.	DRAWING TITLE	NO.	DESCRIPTION	CHK'D	APP'D	DATE	NO.	DESCRIPTION	CHK'D	APP'D	DATE
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CHECKED: JBK | APPROVED: CP | DATE: 2020/06/05
FILE NAME: 1CS020.018 - Typical Sections.dwg

Sabina Gold & Silver Corp.

Back River Project

SRK JOB NO.: 1CS020.018

Water Licence Phase

DRAWING TITLE: Typical Road and Crossing Sections

DRAWING NO.: A-17 | SHEET 17 OF 26 | REVISION NO.: A

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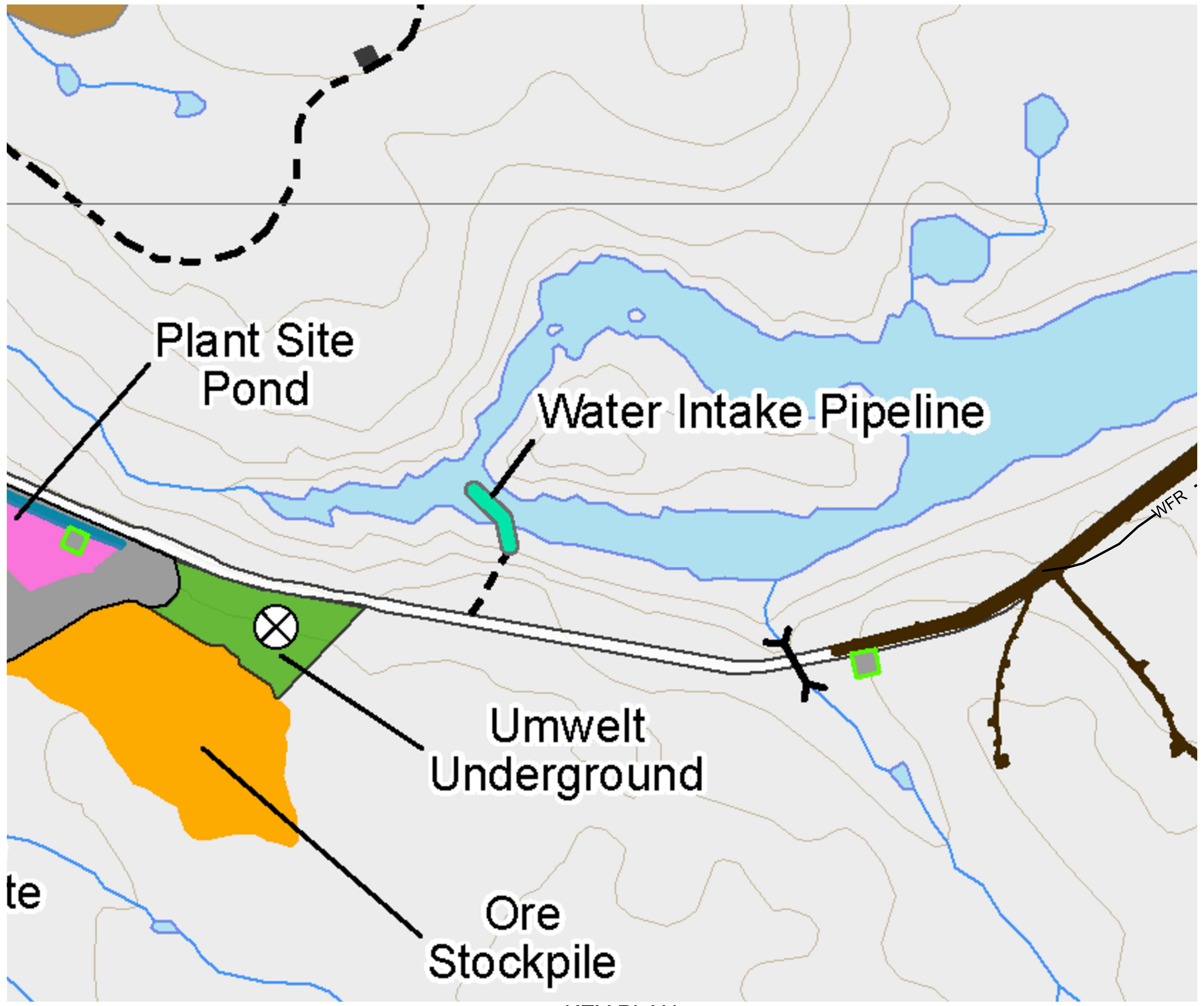
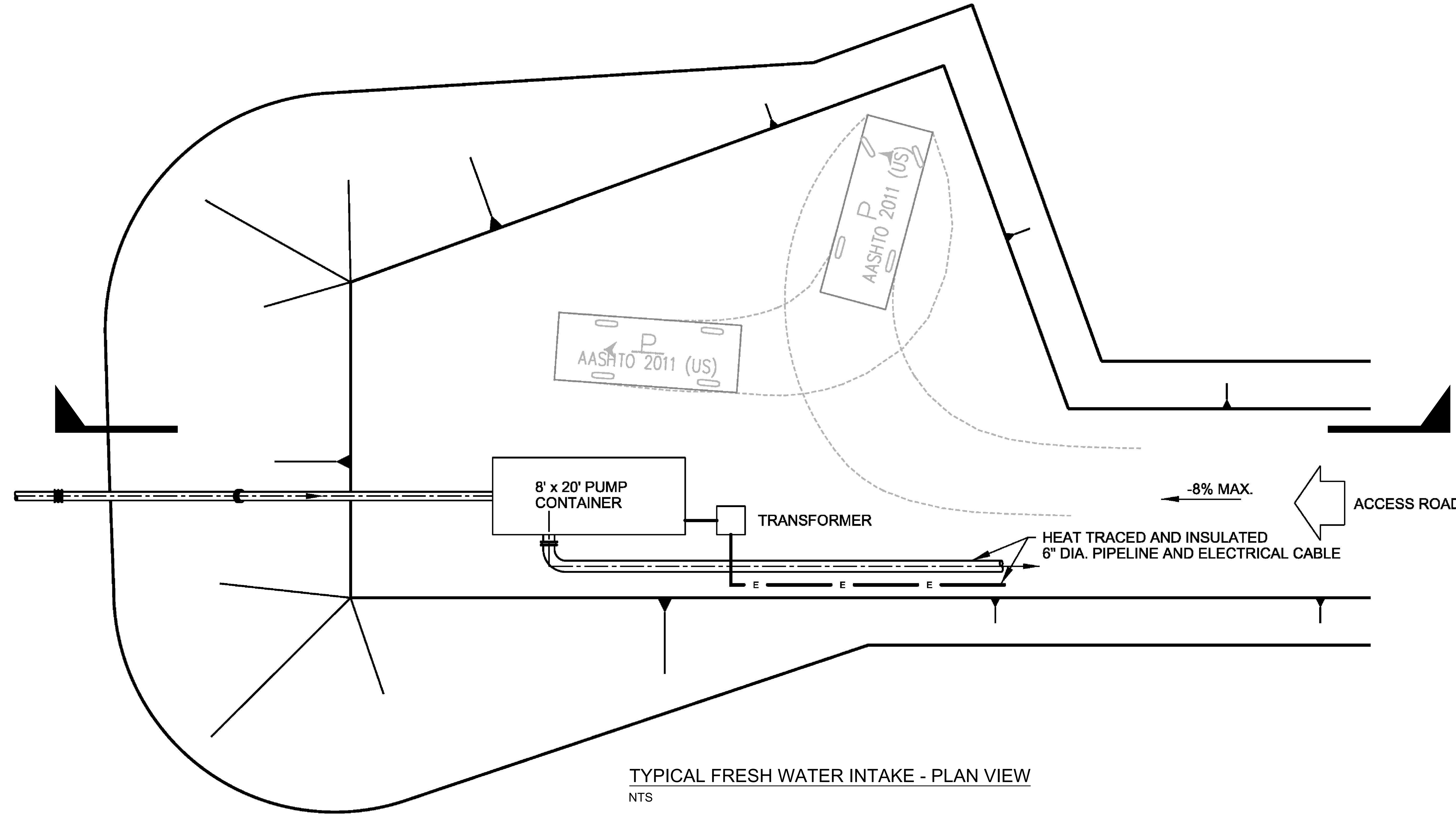
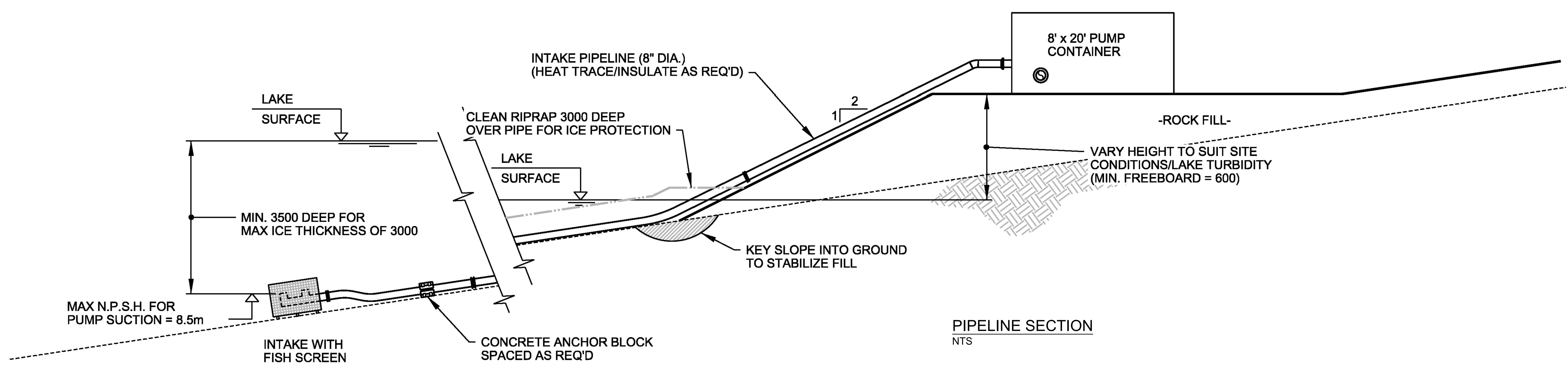


KEY PLAN
NTS



TYPICAL FRESH WATER INTAKE - PLAN VIEW
NTS



PIPELINE SECTION
NTS

LEGEND

⊗	UNDERGROUND PORTAL
	WATER INTAKE PIPELINE
	WATER MANAGEMENT STRUCTURE
	TAILINGS EMERGENCY POND
	WATER BODIES

NOTES

1. ALL DIMENSIONS ARE IN MILLIMETRES UNLESS OTHERWISE NOTED.
2. ENGINEERING DESIGN IS CONSISTENT FOR ALL FRESHWATER INTAKES (GOOSE LAKE AND BIG LAKE).

REFERENCES

1. BASE DRAWING OBTAINED FROM SRK CONSULTING. FILE NAME: 1CS020.011_WMP_FIGURE_A-20.DWG. RECEIVED DATE: 2017-06-02.
2. KEY PLAN OBTAINED FROM SABINA GOLD & SILVER. FILE NAME: GSE_FEIS_NA_TAB_GOOSE_WL_2020_COPY.PDF

YYYY-MM-DD	2020-05-13
DESIGNED	SRK
PREPARED	AF
REVIEWED	DRW
APPROVED	

CLIENT
Sabina GOLD & SILVER CORP.

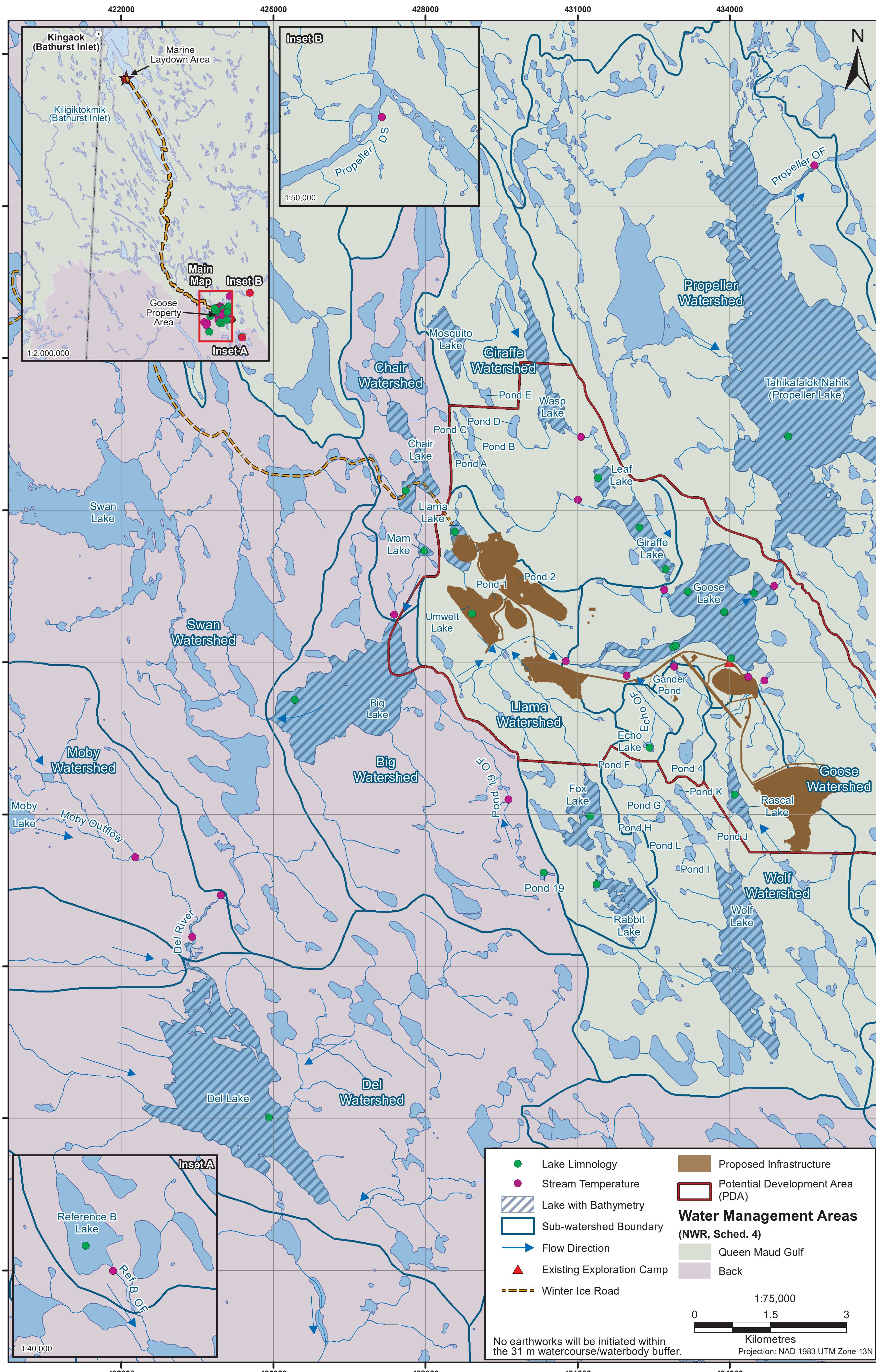
CONSULTANT
GOLDER

PROJECT
BACK RIVER PROJECT
2020 MODIFICATION PACKAGE

TITLE
FRESH WATER INTAKE TYPICAL PLAN AND SECTION

PROJECT NO. | FIGURE A-18 | REV. A

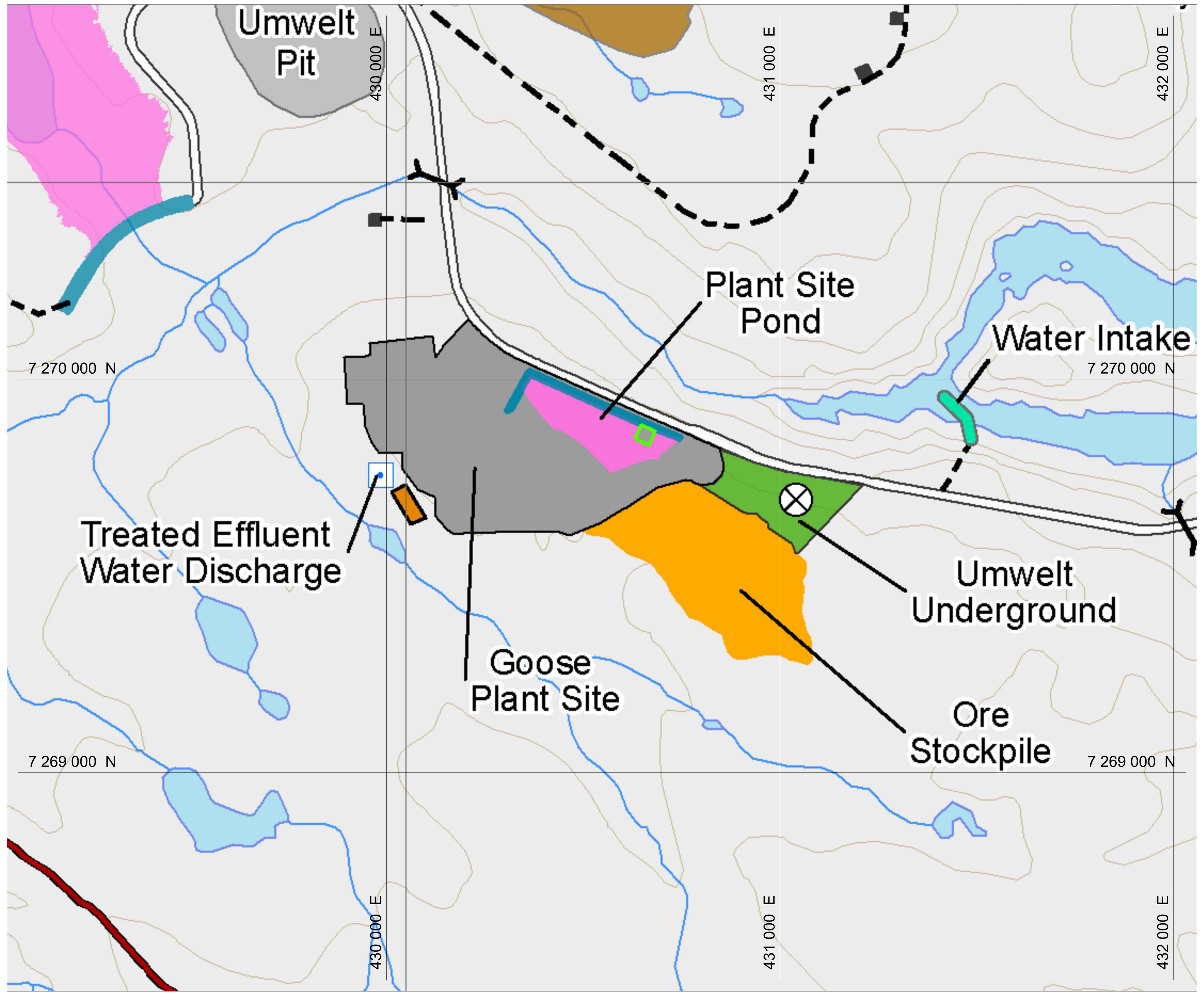
GIS # BAC-01-057b_WL_A W:\BackRiver\04_Exploration\BackRiverRegion\GIS_Products\ESRI_MXD\Water_Permitting\FINAL FIGURES\BAC-01-057b_WL_A.mxd April 30 2020



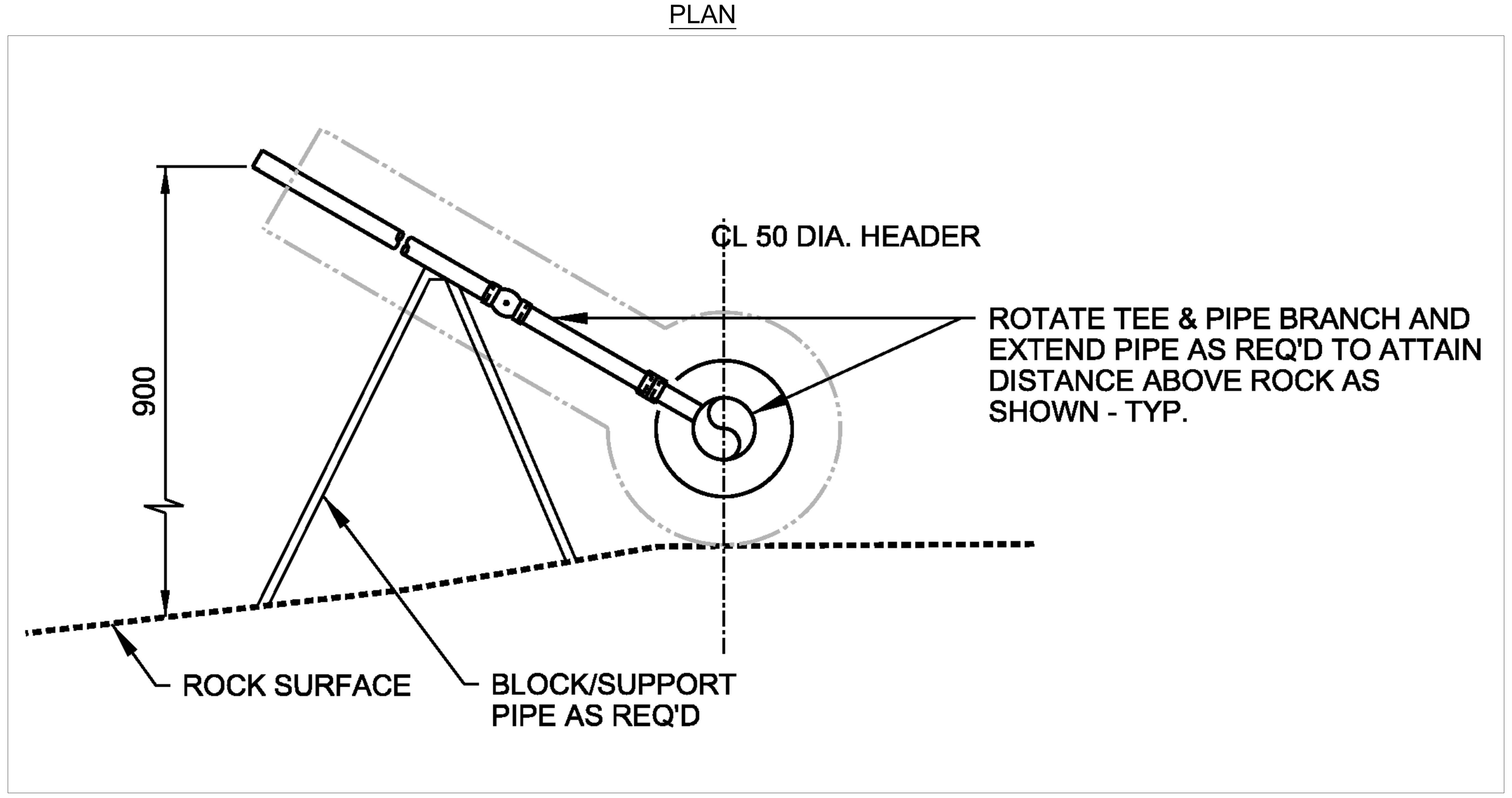
Sabina

Figure A-19

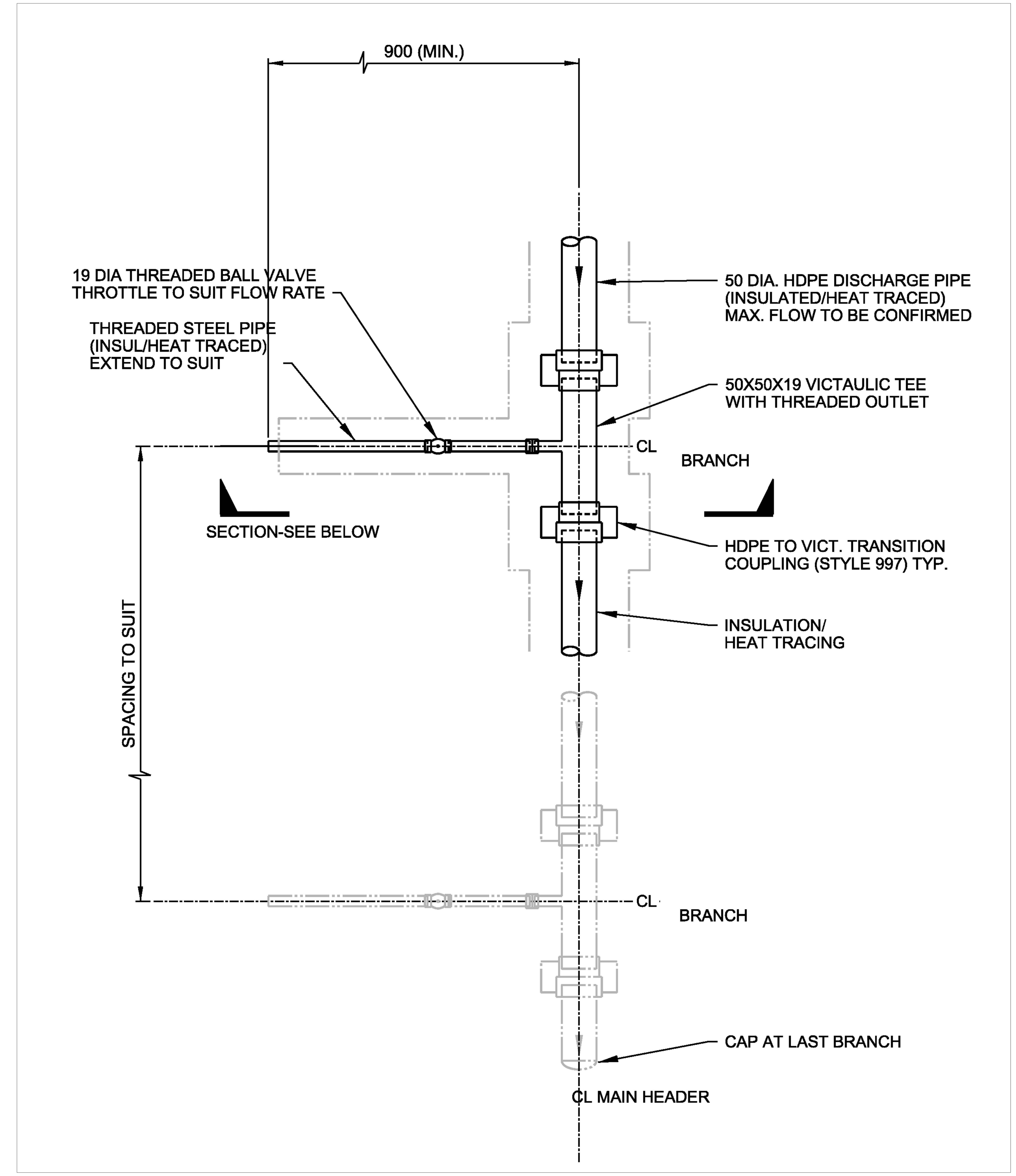
Limnology and Bathymetry Sampling Conducted in the Goose Property Area for the Back River Project, 1994 to 2013



PLAN



SECTION



S.T.P. TREATED WATER OUTLETS - PLAN VIEW
(# OF OUTLETS AND PIPE DIA. TO SUIT FINAL S.T.P. DISCHARGE)

LEGEND

- UNDERGROUND PORTAL
- WATER INTAKE PIPELINE
- WATER MANAGEMENT STRUCTURE
- TAILINGS EMERGENCY POND
- WATER BODIES

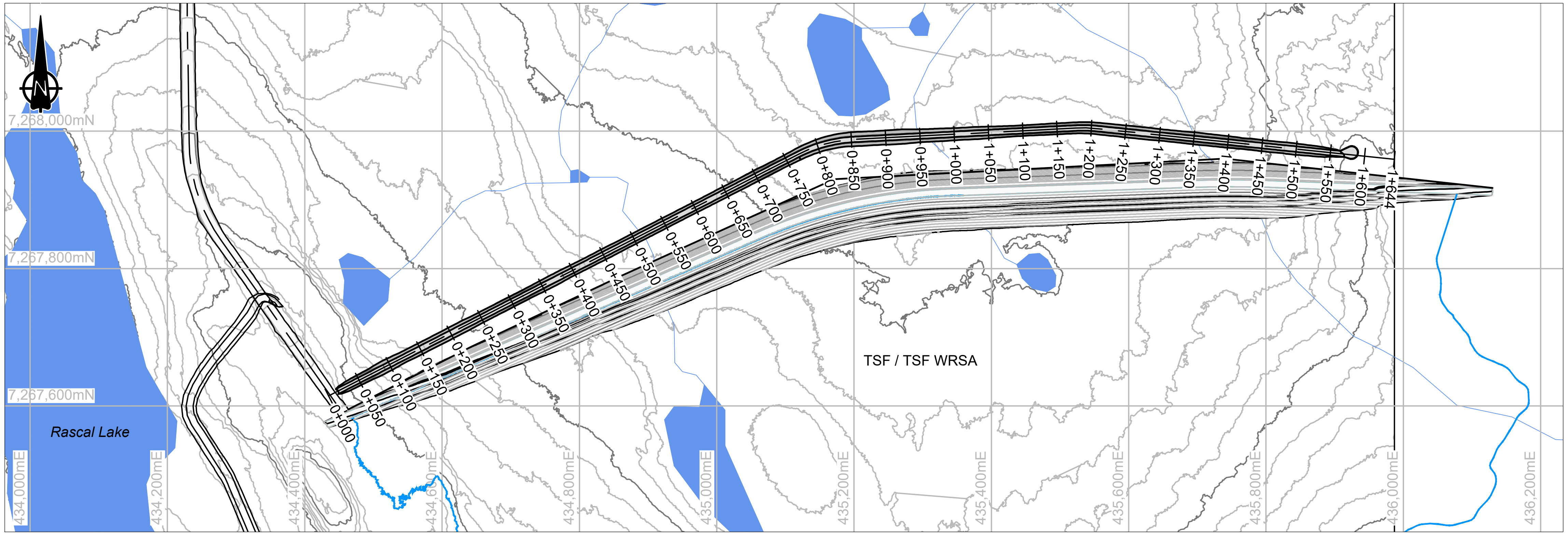
NOTES

1. ALL DIMENSIONS ARE IN MILLIMETRES UNLESS OTHERWISE NOTED.

REFERENCES

1. BASE DRAWING OBTAINED FROM SRK CONSULTING. FILE NAME: 1CS020.011_WMP_FIGURE_A-20.DWG. RECEIVED DATE: 2017-06-02.
2. KEY PLAN OBTAINED FROM SABINA GOLD & SILVER. FILE NAME: GSE_FEIS_NA_tab_Goose_WL_2020_Copy.pdf

YYYY-MM-DD	2020-05-13	CLIENT: Sabina Gold & Silver Corp.	PROJECT: BACK RIVER PROJECT 2020 MODIFICATION PACKAGE
DESIGNED	SRK		
PREPARED	AF	CONSULTANT: GOLDER	TITLE: S.T.P TREATED WATER DISCHARGE PLAN AND SECTION
REVIEWED	DRW		
APPROVED			PROJECT NO. / FIGURE A-20 / REV. A



TSF WRSA Diversion Berm Plan

0m 50 100 150 200 250 300

LEGEND

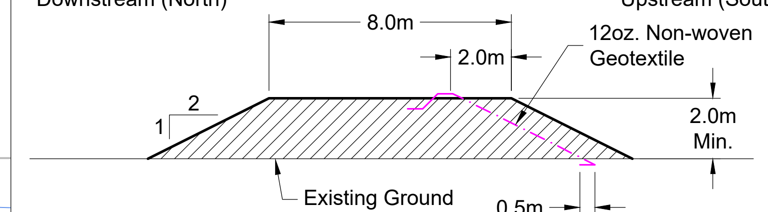
Design Infrastructure

NOTES

1. Contours shown at 1.0m intervals.
2. All units are in meters unless otherwise specified.
3. A minimum fill thickness of 2.0m or greater must be maintained for the entire TSF Containment Dam Berm.
4. Required key trench depth and dam and berm cross sections designs to be confirmed at detailed design stage.

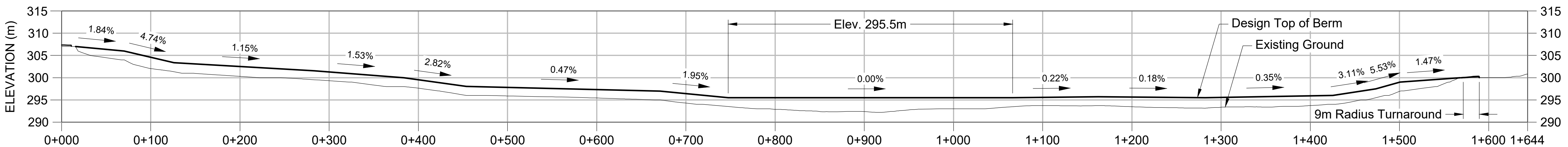
REFERENCES

NAD83 UTM Zone 13.



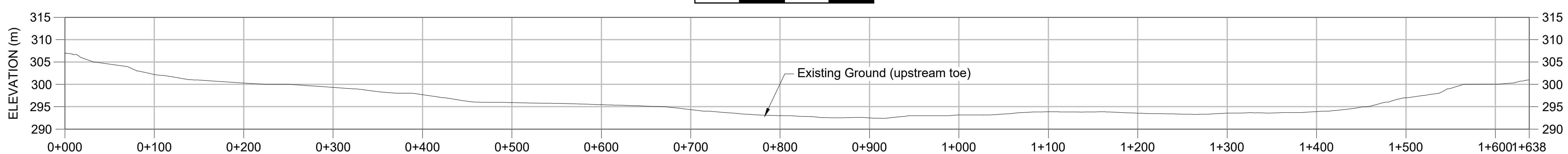
TSF WRSA Diversion Berm Typical Section

0m 2 4 6 8 10



TSF WRSA Diversion Berm Centerline Profile

0m 50 100 150 200



TSF WRSA Diversion Berm Upstream Toe Profile

0m 50 100 150 200

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- -	- -	- -	- -	- -	- -	- -	A	Permit Amendment Dwg	JBK	CP	20/06/05

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FILE NAME: 1CS020.018 - TSF Berm.dwg

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Back River Project

SRK JOB NO.: 1CS020.018

Water Licence Phase

DRAWING TITLE: TSF WRSA Diversion Berm Plan and Profile

DRAWING NO.: A-21 | SHEET 21 OF 26 | REVISION NO. A

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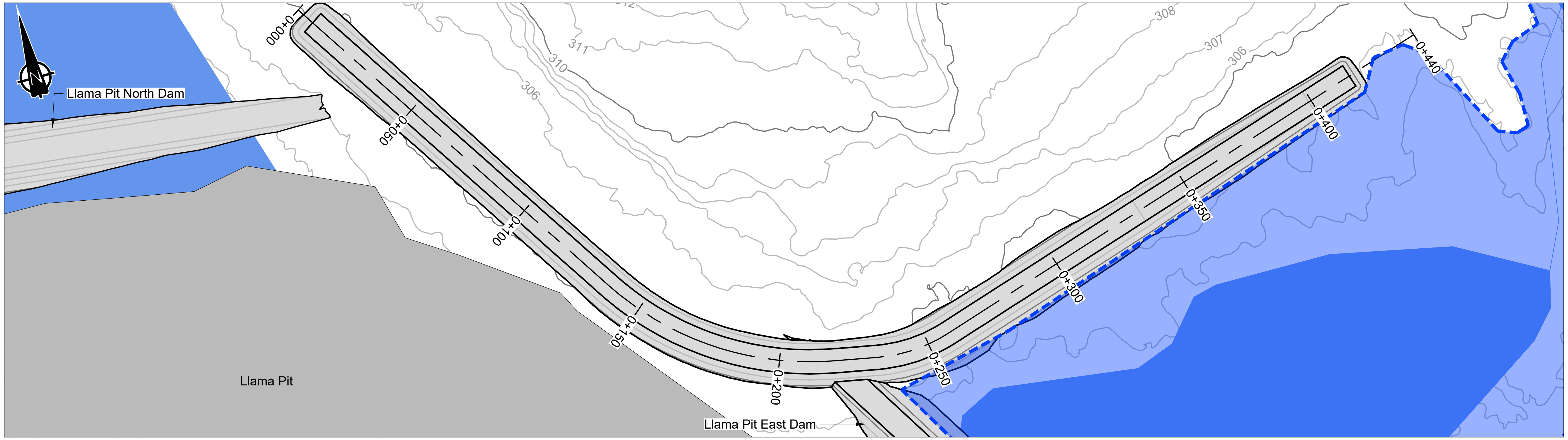


LEGEND

- Full Supply Level (Elev. 304.0m)
- Design Infrastructure
- Rockfill
- Maximum Water Level (304.0m)

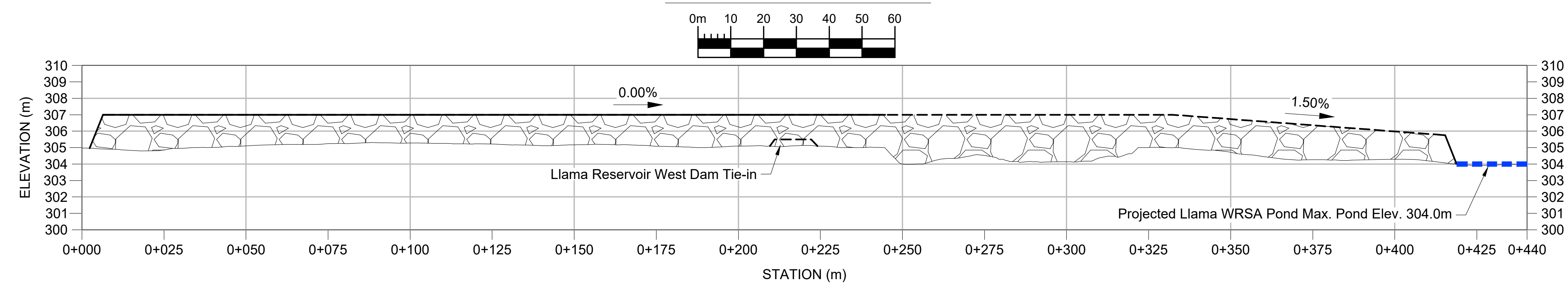
NOTES

1. Contours shown at 1.0m intervals.
2. All units are in meters unless otherwise specified.
3. Water diversion / conveyance will be at the upstream / upslope toe. Contours will be required to be confirmed to ensure that minimum 0.5% grade established / maintained.
4. Additional fill material or alignment adjustment expected to be required to ensure that water will not pond against berm. Final alignment optimizations to be based on field ground survey.
5. Required key trench depth and dam and berm cross sections designs to be confirmed at detailed design stage.

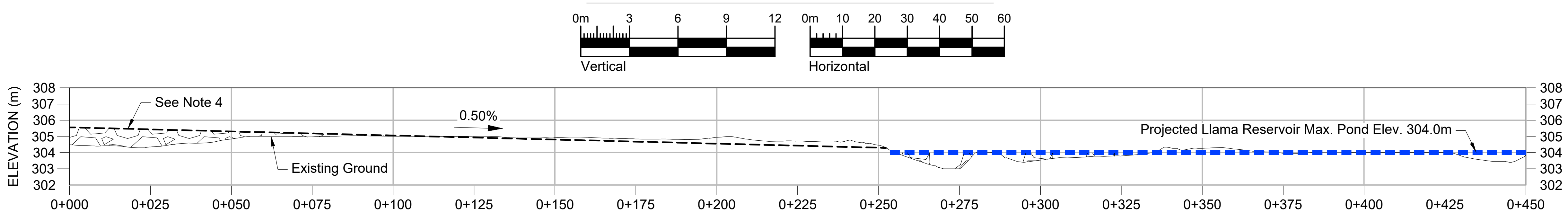
REFERENCES

NAD83 UTM Zone 13.

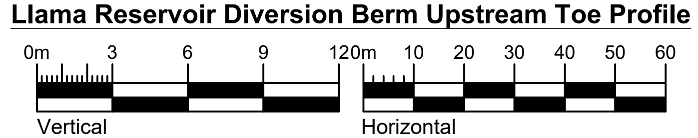
Llama Reservoir Diversion Berm



Llama Reservoir Diversion Berm Centerline Profile



Llama Reservoir Diversion Berm Upstream Toe Profile



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FILE NAME: 1CS020.18 - Llama Reservoir.dwg

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Back River Project

SRK JOB NO.: 1CS020.018

Water Licence Phase

DRAWING TITLE: Llama Reservoir Diversion Berm Plan and Profile

DRAWING NO. A-22 | SHEET 22 OF 26 | REVISION NO. A

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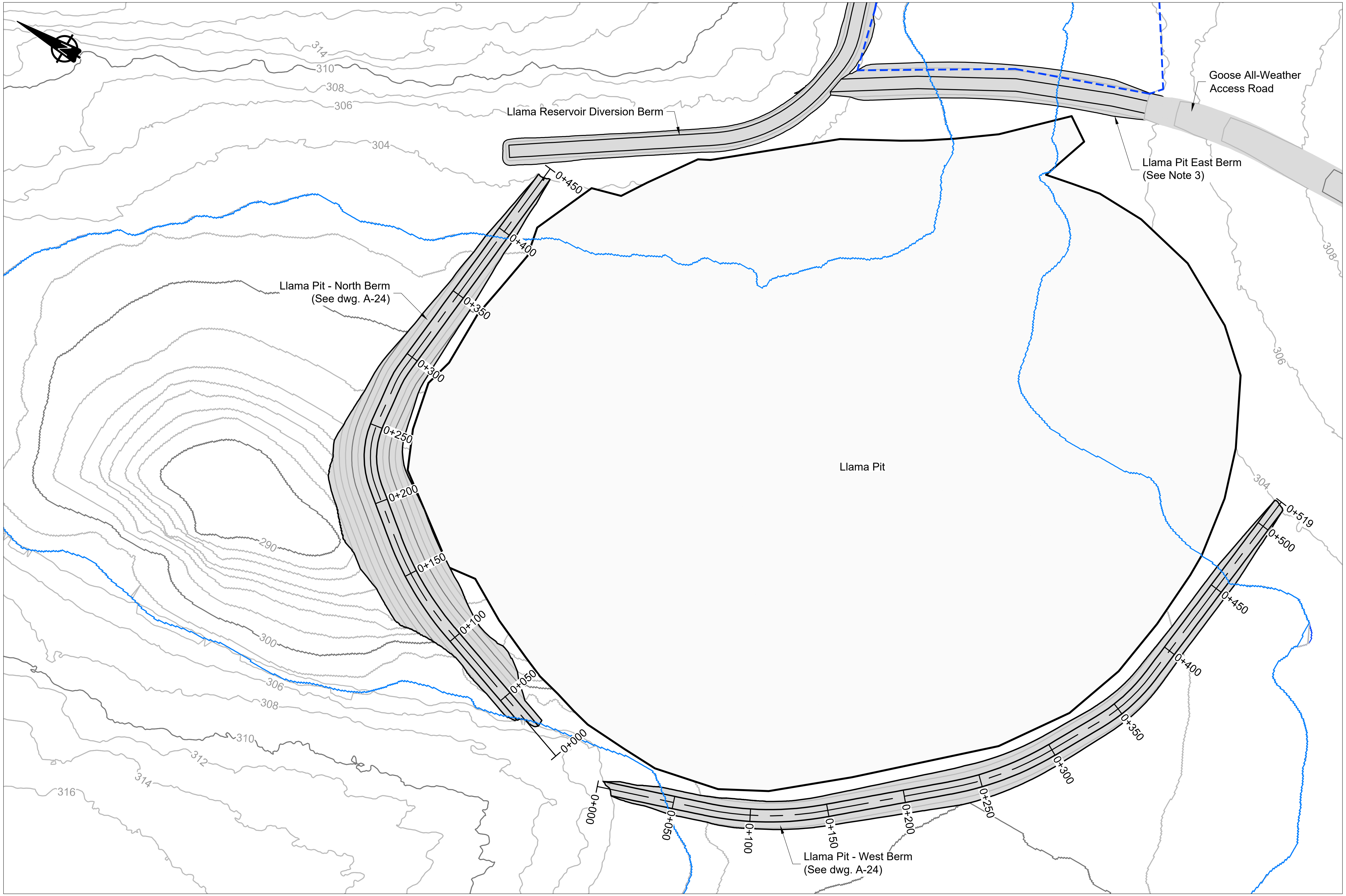

LEGEND

- Full Supply Level (Elev. 304.0m)
- Design Infrastructure
- Pit Outline
- Previous Llama Lake Water Level

NOTES

1. Contours are shown at 2.0m intervals.
2. All units are in meters unless otherwise specified.
3. Required key trench depth and dam and berm cross sections designs to be confirmed at detailed design stage.
4. Any backfill at or around the mined out Llama Pit to have a minimum 5.0m water cover.

REFERENCES

NAD83 UTM Zone 13.

0m 20 40 60 80 100

DRAWING NO.	DRAWING TITLE	NO.	DESCRIPTION	CHK'D	APP'D	DATE	NO.	DESCRIPTION	CHK'D	APP'D	DATE
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FILE NAME: 1CS020.18 - Llama Pit.dwg

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Back River Project

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Water Licence Phase

DRAWING TITLE:

Llama Pit North and West Diversion Berms

DRAWING NO.: A-23 | SHEET 26 OF 26 | REVISION NO. A

LEGEND

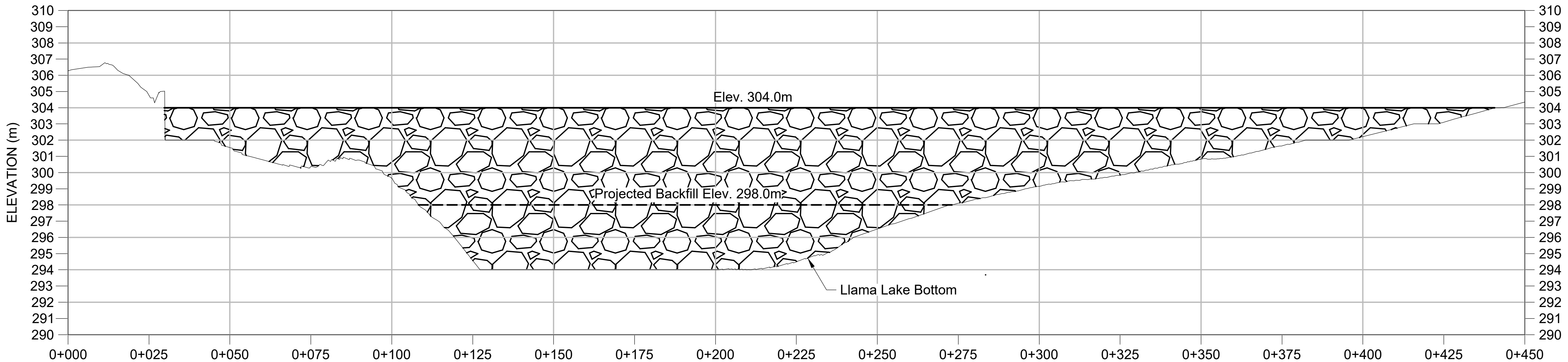
Rockfill

NOTES

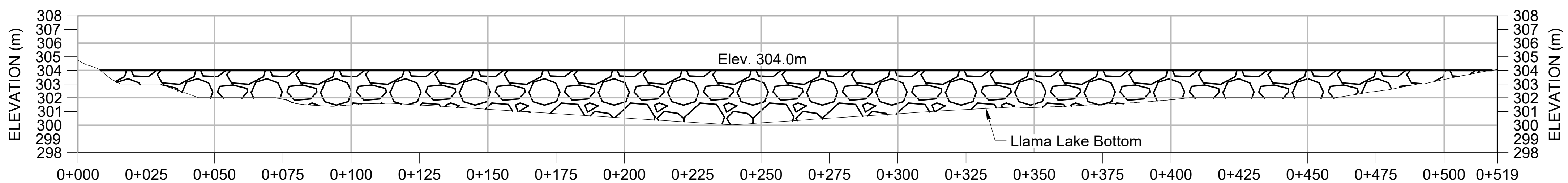
1. All units are in meters unless otherwise specified.
2. Required key trench depth and dam and berm cross sections designs to be confirmed at detailed design stage.
3. Any backfill at or around the mined out Llama Pit to have a minimum 5.0m water cover.

REFERENCES

NAD83 UTM Zone 13.



North Berm Plan View



West Berm Plan View

DRAWING NO.	DRAWING TITLE	NO.	DESCRIPTION	CHK'D	APP'D	DATE	NO.	DESCRIPTION	CHK'D	APP'D	DATE
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FILE NAME: 1CS020.18 - Llama Pit.dwg

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Water Licence Phase

DRAWING TITLE: Llama Pit North Berm and West Berm Profiles

DRAWING NO. A-24 | SHEET 24 OF 26 | REVISION NO. A

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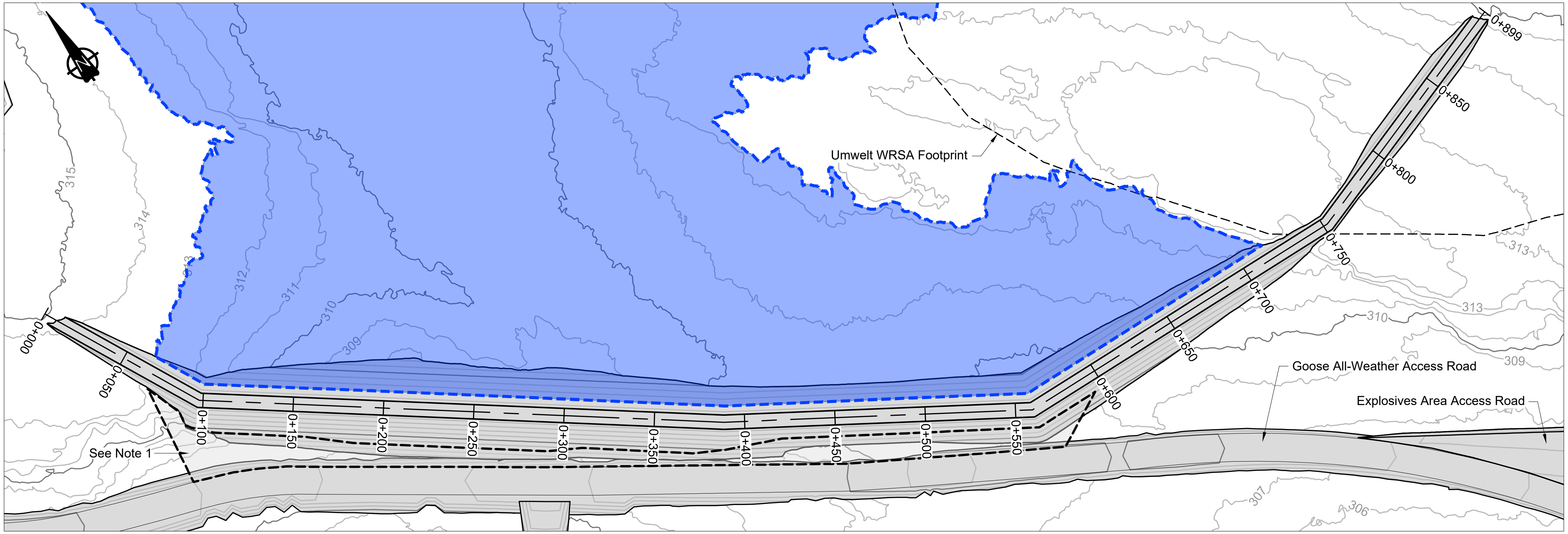


LEGEND

- Design Infrastructure
- Rockfill
- Maximum Water Level (313.0m)

NOTES

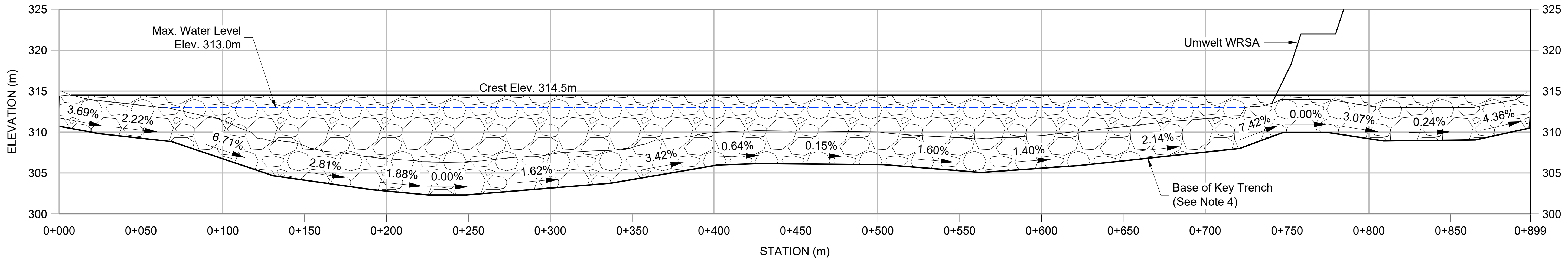
1. Contours shown at 1.0m intervals.
2. All units in meters unless otherwise stated.
3. The downstream area between the Goose All-Weather Road (AWR) and downstream side of the Primary Pond Dam to be filled with a minimum 2.0m thick layer of bulk rockfill to assist with thermal protection of the downstream toe of the Primary Pond. Extreme care must be taken when building the AWR in the area and the road should be built to a minimum 2.0m thickness in this area to ensure that the downstream areas from the Primary Pond does not become thermally degraded / impacted.
4. Required key trench and dam and berm cross sections designs to be confirmed at detailed design stage.

REFERENCES

NAD83 UTM Zone 13.

Primary Pond Diversion Berm

0m 20 40 60 80 100



Primary Pond Diversion Berm Profile

0m 5 10 15 20 Vertical

0m 20 40 60 80 100 Horizontal

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FILE NAME: 1CS020.018 - Primary Pond.dwg

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Water Licence Phase

DRAWING TITLE: Primary Pond Dam Plan and Profile

DRAWING NO.: A-25 | SHEET 25 OF 26 | REVISION NO. A

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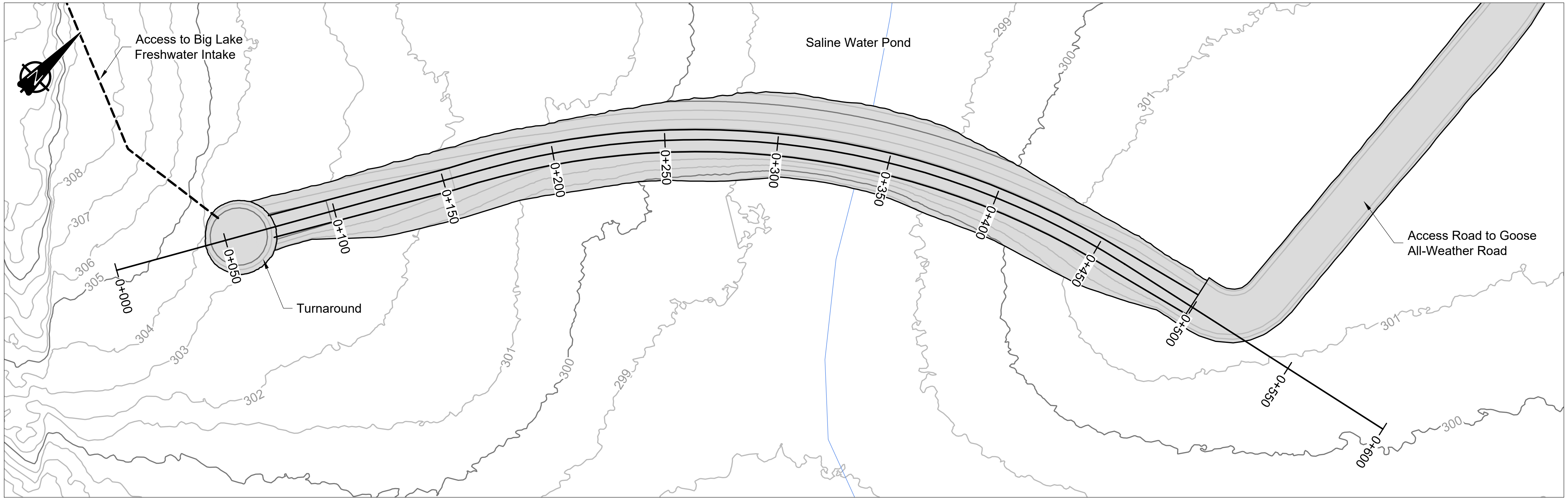


Saline Water Pond Dam

0m 20 40 60 80

LEGEND

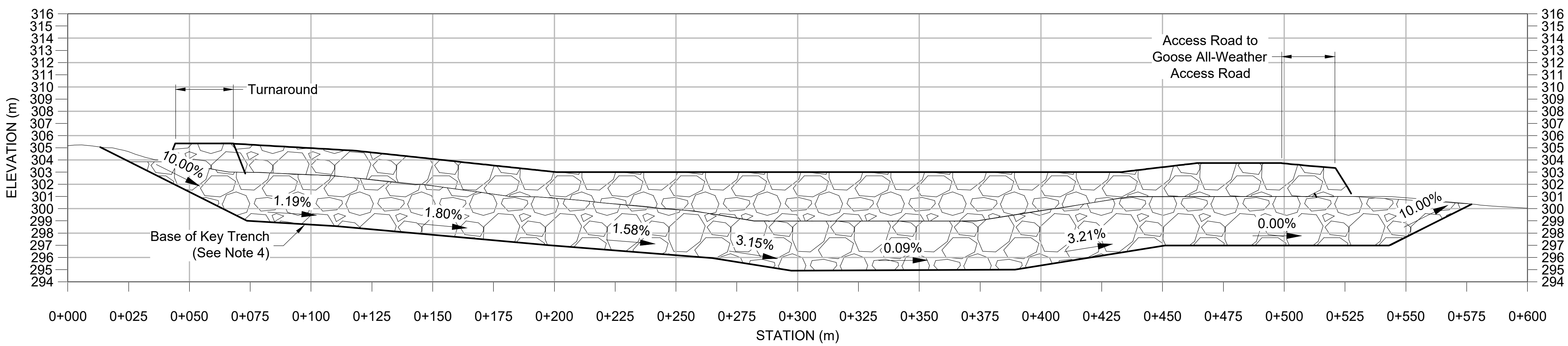
- Design Infrastructure
- Rockfill

NOTES

1. Contours shown at 1.0m contours.
2. All dimensions shown in meters unless otherwise stated.
3. Overburden may be placed off the upstream face for the Saline Water Pond to help spread out the seepage pathway and limit long-term thermal impacts on the foundation.
4. Required key trench and dam and berm cross sections designs to be confirmed at detailed design stage.

REFERENCES

NAD83 UTM Zone 13.



Saline Water Pond Dam Profile

Vertical: 0m 4 8 12 16

Horizontal: 0m 20 40 60 80

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REFERENCE DRAWINGS

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FILE NAME: 1CS020.018 - SWP.dwg

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Back River Project

SRK JOB NO.: 1CS020.018

Water Licence Phase

DRAWING TITLE: Saline Water Pond Dam Plan and Profile

DRAWING NO.: A-26 | SHEET 26 OF 26 | REVISION NO. C

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Appendix B. Water Quality Monitoring

All water on the Project is categorized into three types: contact water (i.e., impacted by mine workings), non-contact water (i.e., undisturbed areas runoff), and saline water (i.e., groundwater). Only non-contact water will be diverted off-site without treatment.

Each type of water will be managed separately throughout each Project Phase.

Construction Phase

The following monitoring activities are proposed during the Construction Phase:

- Visual inspections to confirm that mitigation measures identified in this document and other relevant management plans (i.e., the Environmental Management and Protection Plan [2AM-BRP1831 Part I, Item 1], Borrow Pits and Quarry Management Plan [2AM-BRP1831 Part D, Item 1]) are implemented satisfactorily.
- Visual inspections to monitor the effectiveness of sediment and erosion control and runoff collection measures on a regular basis (daily or weekly as appropriate).
- Monitor treated sewage effluent discharges on a weekly basis for key indicators (i.e., TSS and ammonia), and monthly sampling using laboratory analysis for the parameters listed in Table B-01.
- Periodically sample runoff at active construction fronts for the parameters listed in Table B-03.
- Monitoring of runoff from quarries and borrow pits in relation to the quarry runoff criteria identified in Table 7.5-1.
- Monitoring of runoff at the Umwelt WRSA Pond and the Plant Site Pond for compliance with MDMER limits.
- Recording daily and monthly water consumption.
- Monitoring of waste and water management aspects including remediated soil, oily water, and landfill seepage.
- Monitoring of water quantity and quality will occur during all dewatering activities. The volume of water transferred will be measured on a continuous basis using appropriate flow meters.
- Field turbidity and TSS will be monitored daily. As data becomes available, a TSS and turbidity curve will be generated to manage dewatering activities. Water transferred during dewatering activities will meet a TSS or turbidity threshold discharge criteria. The trigger level to suspend dewatering activities will be 90% of the limit to avoid releasing water above the threshold. Clean lake water will be transferred and monitored until the trigger level is reached. When the TSS trigger level is reached, lake water will be treated for TSS through the WTP before discharge into Goose Lake.
- If released volumes of water change stream base flows or water levels by greater than 10% of baseline, then water transfer rates will be adjusted as required.
- During Construction, the emphasis of monitoring will be on the implementation and success of mitigation at construction areas. Toward the end of Construction, Operations Phase monitoring activities will be implemented, and monitoring will shift to include the relevant aspects of Operations Phase monitoring. Operations Phase activities beginning before the end of the Construction Phase will include the installation of Operations Phase water management facilities, milling, pre-stripping and mining of open pits and underground facilities, and the development of WRSAs.

Operations Phase

In addition to the above efforts during Construction, the following is proposed for monitoring during the Operations Phase:

- Recording daily and monthly water consumption;
- Regular visual monitoring of Operations Phase water management facilities;
- Visual inspections and monitoring of construction areas as described in Section 8.4 of the Environmental Management and Protection Plan (2AM-BRP1831 Part I, Item 1);
- Daily monitoring of the tailings discharge and the supernatant water level within the TSF;
- Monitoring of effluents prior to discharge in relation to the criteria identified for various effluents within the tables of Section 7.5;
- Underground mine inflows will be sampled to verify water quantity predictions and verify storage requirements;
- Monitoring of desalination discharge water to Bathurst Inlet to ensure that the salinity of the water remains within natural variability or CCME guidelines in sensitive marine areas;
- Monitoring of mine contact water effluent discharges as prescribed by a study design developed under the MDMER; and
- Implementation of the future AEMP to monitor effects to downstream aquatic environments.

During Operations, the emphasis will be on inspecting and monitoring construction fronts as aspects of construction will be ongoing throughout the mine life. The Operations Phase monitoring program will also incorporate the monitoring of mining activities and water management systems associated with the active tailings management facilities, pits, WRSA ponds, and the Saline Water Pond.

Closure Phase

The following is proposed for monitoring during Closure:

- Regular inspections to confirm that closure activities are being undertaken as identified in the final approved Mine Closure and Reclamation Plan;
- Construction-type monitoring is undertaken during decommissioning activities as described above;
- TSF/TF water quality monitoring until water quality objectives are met;
- Water quality monitoring of water being discharged from pits and the WRSAs to confirm all meet water quality objectives; and
- Water quality monitoring in Llama TF to confirm treatment is progressing as planned such that the discharge schedule may go ahead.

Due to the relatively long Closure Phase, there will be sufficient opportunities to conduct post-closure monitoring of the closed-out Project features. The WRSAs will be substantively closed during Operations, and the open pits will overtop and be closed early in the Closure Phase; this will allow for a number of years of post-closure monitoring during the Passive Closure Stage. Closure monitoring at receiving waters will be measured against water quality objectives.

Post-Closure Phase

Post-Closure monitoring is expected to be required for five years after completion of closure activities and the completion of water treatment in Llama TF. This is consistent with mine reclamation at other northern sites and is believed to be a reasonable monitoring period given the amount of verification monitoring that can performed during the Operations and Closure phases. Post-Closure monitoring is expected to include:

- Water quality sampling at mine contact water discharge locations in accordance with water quality objectives; and
- Final Environmental Effects Monitoring studies in accordance with the water quality objectives needed to obtain status as a recognized closed mine from ECCC.

Sampling Plan

The sampling plan has been designed to consider the various phases of the Project, but updates will be made as based on advancement of the Project and outcome of monitoring results.

Environmental monitoring station locations are shown on Figure B-01 and Figure B-02 for the Goose Property and MLA, respectively. In addition, Table B-01 and Table B-02 summarizes proposed water quality and flow monitoring of the Project during the Construction, Operations, Closure phases, and includes monitoring station location, monitoring type, description, purpose, mine phase, parameters grouping, and sample frequency for each location. The list of constituents in each parameter group is provided in Table B-03. It is anticipated that some locations will be initiated in Construction and maintained through Post-Closure, while other locations will come on-line in Operations once water is present. Proposed locations will be confirmed in the field.

To the extent practical, water samples will be analyzed for the same suite of constituents as analyzed for the AEMP. This will aid interpretation of AEMP results and linkages to mine related effects.

Figures and details regarding physical, chemical, and biological parameters in the AEMP sampling program are provided in the AEMP (2AM-BRP1831 Part I, Item 1); full details regarding marine monitoring are provided in the Marine Monitoring Plan (Sabina 2018).

Sabina committed to developing a stand-alone marine monitoring plan (Term and Condition, FA-ECCC-T-1). While marine monitoring is outside the jurisdiction of the NWB, details on marine monitoring can be found in the Marine Monitoring Plan (Sabina 2018).

Sample Collection

Field measurements of specific conductivity, pH, and temperature will be recorded whenever samples are collected using a multi-meter (e.g., YSI 6-Series Multimeter), along with measurements of total water depth, and sample collection depth.

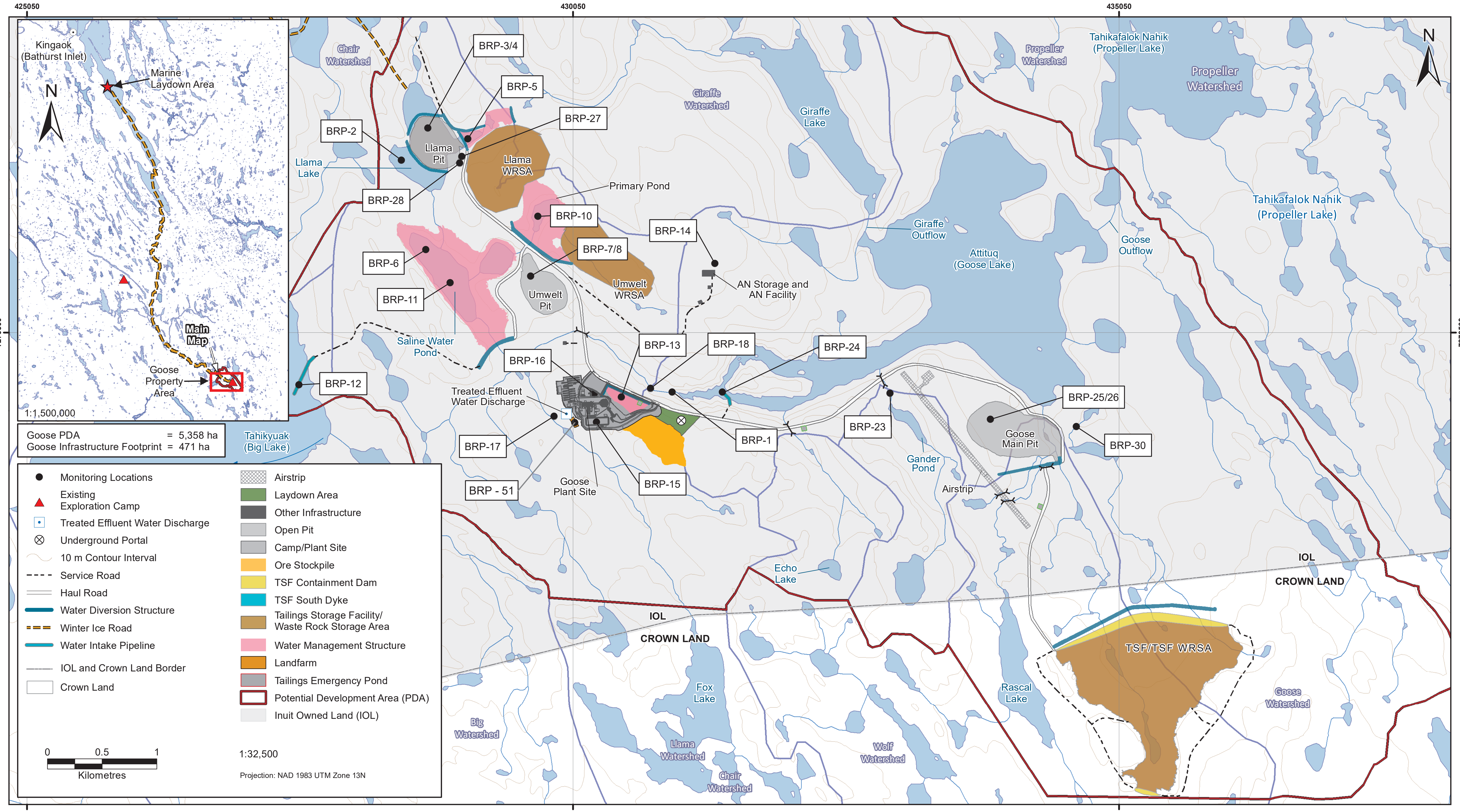
Water quality samples will be collected from specific sampling stations (coordinates still to be confirmed) using a grab sampler or directly into bottles provided by an accredited analytical laboratory. Water quality samples will be analyzed by an accredited laboratory at detection limits less than aquatic life guidelines or as appropriate for site contact water type samples. The specific limits will be provided once the analytical laboratory has been selected.

Quality Assurance and Quality Control

Samples will be collected following standard sampling protocol (e.g., see the Quality Assurance/Quality Control Plan [2AM-BRP1831 Part I, Item 1]) by qualified personnel using suitable sampling equipment. Water samples for laboratory analysis will be filtered and preserved (as required) and stored in a cool environment before shipping to the laboratory. Quality control samples (i.e., blanks and duplicates) will be collected at a quantity of 10% of all samples collected.

Reporting

Results collected in any given year will be included in the annual report. Descriptive summary statistics will be calculated, and results will be analyzed by comparison to Water Licence criteria and aquatic life guidelines (CCME 1999) or baseline conditions, as appropriate.



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Proposed Surface Water Monitoring Locations
Goose Property Area, Back River Project

Figure B-02

GIS # BR_FEIS_NA_tab_MLASiteLayout_WL2020_B-02

May 25 2020

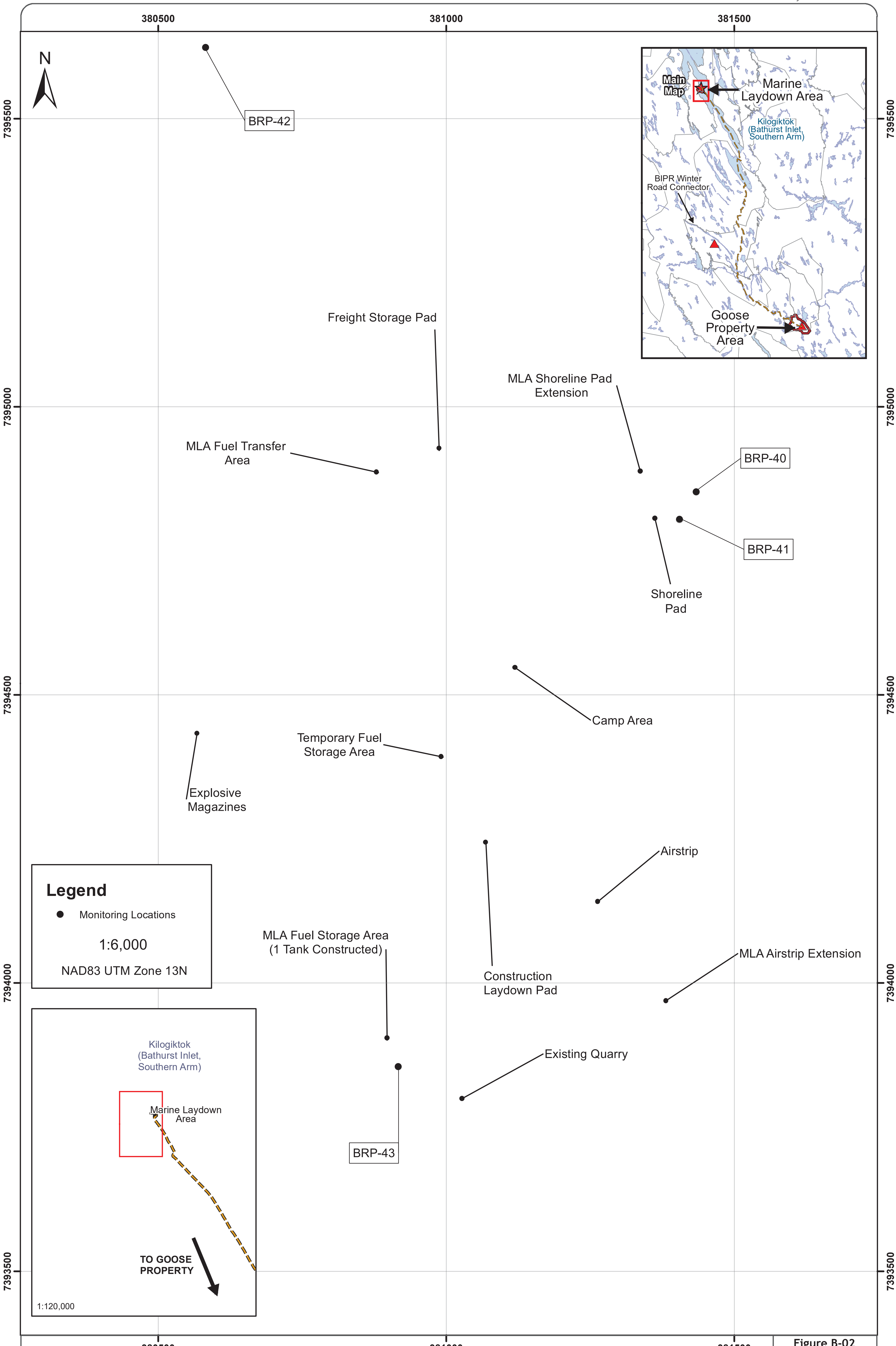

Figure B-02

Proposed Surface Water Monitoring Locations
Marine Laydown Area, Back River Project

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Table B-01. Proposed Water Quality Monitoring for the Project during Construction, Operations, and Closure in Goose Property Area

Status	2020 Modification Package Revision	Monitoring Location Number	Monitoring Type	Description	Purpose	Mine Phase	Parameter Group Code[5]	Frequency
Active	No Change	BRP-G-01 to BRP-G-TBD	Regulated Monitoring[1]	General Site Runoff including Quarries - both Goose and MLA	Applies anywhere on the site; monitoring for erosion and sedimentation	Construction	C	Weekly if flow enters a waterbody
Active	No Change	BRP-S-01 to BRP-S-TBD	General Monitoring	General Seeps Seepage or runoff from excavated and/or stockpiled material	Applies anywhere at both Goose Property and MLA, including quarries, that does not gather into a collection system or the site is reclaimed.	Construction and Operations	A, D	Monthly during flow, or as found
Active	Updated Location	BRP-01	Regulated Monitoring[2]	Discharge to Goose Lake (after treatment)	Test of dewatering discharge (i.e., effluent), at final point of control. If water does not meet TSS discharge criteria, water will be treated prior to release[2].	Construction	A, B, G	Weekly during dewatering
							D	Four times during dewatering, at the same time as the weekly samples
							H	Once per month during dewatering, at the same time as groups D and F
							I	One time during dewatering, at the same time as groups D and F
Active	No Change	BRP-02	General Monitoring	Llama Lake Dewatering (prior to treatment) if required	If treatment is required, this station will test pretreated water.	Construction	C (TSS only)	Weekly if treatment is required; no sample if treatment is not required
Active	No Change	BRP-03	Verification Monitoring	Llama Pit	Pit water quality prior to transfer to a tailings facility	Operations (Stage 1) to Operations (Stage 2)	A, G	See note [6]
Active	No Change	BRP-04	General Monitoring	Llama Pit Lake	During pit flooding and before overflow to the downstream environment	Closure to Post-closure	A, D	Twice per year
Active	No Change	BRP-05	Verification Monitoring	Llama WRSA Pond	Test quality of drainage water from Llama WRSA	Operations (Stage 1) to Closure	A, G	See note [6]
Active	No Change	BRP-06	General Monitoring	Umwelt Lake Dewatering (prior to treatment) if required	If treatment is required, this station will test pretreated water.	Construction	C (TSS only)	Weekly if treatment is required; no sample if treatment is not required
Active	No Change	BRP-07	Verification Monitoring	Umwelt Pit	Pit water quality prior to transfer to a tailings facility	Construction to Operations (Stage 2)	A, G	See note [6]

Status	2020 Modification Package Revision	Monitoring Location Number	Monitoring Type	Description	Purpose	Mine Phase	Parameter Group Code[5]	Frequency
Active	No Change	BRP-08	General Monitoring	Umwelt Pit Lake	During pit flooding and before overflow to the downstream environment	Closure to Post-closure	A, D	Twice per year
Inactive	Not Shown	BRP-09	Verification Monitoring	Umwelt WRSA Pond	Test quality of drainage water from Umwelt WRSA. A landfill is located in this WRSA. Appropriate landfill parameters will be tested for; see the LWMP (2AM-BRP1831 Part F, Item 1) for details.	Construction to Closure (early)	A, G	See note [6]
Active	Updated Purpose	BRP-10	Verification Monitoring	Primary Water Pond	Test quality of water in pond for industrial water use. Test quality of drainage water from Umwelt WRSA. A landfill is located in the Umwelt WRSA. Appropriate landfill parameters will be tested for; see the LWMP (2AM-BRP1831 Part F, Item 1) for details.	Construction to Closure (early)	A, D, G	See note [6]
Active	No Change	BRP-11	Verification Monitoring	Saline Water Pond	Test quality of water in pond; Formerly Umwelt Lake	Construction (late) to Closure (early)	A, D	See note [6]
Active	No Change	BRP-12	General Monitoring	Big Lake Intake;	Source intake water quality for potable and industrial use	Construction to Closure	A, D	Four times per year
							B	Weekly
Active	Updated Location & Description	BRP-13	Verification Monitoring	Plant Site Pond (formerly Ore Stockpile Pond)	Test quality of drainage water from Ore stockpile	Construction to Closure (early)	A, D	See note [6]
Active	No Change	BRP-14	Verification Monitoring	ANFO Plant	Test quality of runoff water in the ANFO plant containment area	Construction to closure	A, E	See note [6]
Active	Updated Location	BRP-15	Regulated Monitoring[3]	Goose Fuel Tank Farm	Test quality of runoff water in the Fuel Tank Farm containment area	Construction to closure	A, E	Prior to discharge or transfer of water
Active	Updated Location	BRP-16	Regulated Monitoring[3]	Goose Hazardous Waste Mgmt. Area	Test quality of runoff water in the Hazardous Waste Management containment area	Construction to closure	A, E	Prior to discharge or transfer of water
Active	Updated Location	BRP-17	Regulated Monitoring[4]	Treated sewage discharge to land	Test quality of sewage effluent discharge water quality	Construction to closure	A, E	Prior to discharge or transfer of water

Status	2020 Modification Package Revision	Monitoring Location Number	Monitoring Type	Description	Purpose	Mine Phase	Parameter Group Code[5]	Frequency
Active	Updated Frequency	BRP-18	General Monitoring	Llama Watershed Outflow (PN04 from water and load balance)	Test quality of non-contact water runoff from the "Llama" watershed	Construction to closure	A, D	Once during freshet, and monthly during upstream construction while visible flow is present at the stations
Inactive	Not Shown	BRP-19	General Monitoring	Echo Outflow (PN09 from water and load balance)	Test quality of non-contact water runoff from the "Echo" watershed	Operations (Stage 1) to Closure	A, D	Once during freshet, and monthly during upstream construction while visible flow is present at the stations
Inactive	Not Shown	BRP-20	Verification Monitoring	Echo Pit	Pit water quality prior to transfer to a tailings facility; Echo underground water is always directed to the TSF	Operations (Stage 2)	A, G	See note [6]
Inactive	Not Shown	BRP-21	General Monitoring	Echo Pit Lake	During pit flooding and before overflow to the downstream environment	Closure to Post-closure	A, D	Twice per year
Inactive	Not Shown	BRP-22	Verification Monitoring	Echo WRSA Pond	Test quality of drainage water from Echo WRSA	Operations (Stage 2) to Closure (early)	A, G	See note [6]
Active	Updated Frequency	BRP-23	General Monitoring	Gander Pond Outflow (PN07 from water and load balance)	Test quality of non-contact water runoff from the "Gander" watershed	Operations (Stage 1) to Closure	A, D	Once during freshet, and monthly during upstream construction while visible flow is present at the stations
Active	Updated Location	BRP-24	General Monitoring	Goose Lake Intake	Source intake water quality; for operational use (mill water make-up)	Operations (Stage 2) to Closure (early)	B	Weekly
Active	Updated Purpose	BRP-25	Verification Monitoring	Goose Main Pit	Pit water quality prior to transfer to a tailings facility	Operations (Stage 1) to Operations (Stage 2)	A, G	See note [6]
Active	No Change	BRP-26	General Monitoring	Goose Main Pit Lake	During pit flooding and before overflow to the downstream environment	Closure to Post-closure	A, D	Twice per year
Active	Updated Location, Description, & Mine Phase	BRP-27	Verification Monitoring	Llama TF Intake; collected at "inlet" to treatment facility	Pre-treatment quality	Operations (Stage 2) to Closure	A, G	See note [6]

Status	2020 Modification Package Revision	Monitoring Location Number	Monitoring Type	Description	Purpose	Mine Phase	Parameter Group Code[5]	Frequency
Active	Updated Location, Description, & Mine Phase	BRP-28	Verification Monitoring	Llama TF Discharge into Llama TF (after treatment); collected at "outlet" of treatment facility; no discharge to the receiving environment	Post-treatment quality to confirm treatment efficiency	Operations (Stage 2) to Closure	A, G	See note [6]
Inactive	Not Shown	BRP-29	Verification Monitoring	TSF WRSA Pond	Test quality of drainage water from TSF; A landfill is located in this WRSA. Appropriate landfill parameters will be tested for; see the LWMP (2AM-BRP1831 Part F, Item 1) for details.	Operations (Stage 1) to Closure	A, G	See note [6]
Active	No Change	BRP-30	General Monitoring	Goose Southeast Inflow (PN06 from water and load balance)	Test quality of non-contact water runoff from the "TSF" watershed	Operations (Stage 1) to Closure	A, D	Once during freshet
Active	Updated Location	BRP-51	Regulated Monitoring[3]	Goose Landfarm	Test quality of runoff water in the Landfarm containment area	Construction to Closure	E	Prior to discharge or transfer of water

Notes BRP = Back River Project; MLA = Marine Laydown Area
1) See Table 7.5-2 (Dewatering Discharge Criteria) in the Water Management Plan
2) See Table 7.5-1 (Site Runoff Discharge Criteria) in the Water Management Plan
3) See Table 7.5-3 (Discharge to Land Criteria) in the Water Management Plan
4) See Table 7.5-4 (Treated Sewage Effluent Criteria) in the Water Management Plan
5) See Table B-03 for parameters in each monitoring group
6) Monitoring parameters and frequency at the discretion of Sabina as results from the verification stations are used for operational and management purposes

Table B-02. Proposed Water Quality Monitoring for the Project during Construction, Operations, and Closure in Marine Laydown Area

Status	2020 Modification Package Revision	Monitoring Location Number	Monitoring Type	Description	Purpose	Mine Phase	Parameter Group Code[4]	Frequency
Active	No Change	BRP-G-01 to BRP-G-TBD	Regulated Monitoring[1]	General Site Runoff including Quarries - both Goose and MLA	Applies anywhere on the site; monitoring for erosion and sedimentation	Construction	C	Weekly if flow enters a waterbody
Active	Updated Location	BRP-40	General Monitoring	Bathurst Inlet Intake (pre-treatment)	Source intake water quality for potable and industrial use	Construction to Closure	A, D	See note [5]
							B	See note [5]
Active	Updated Location	BRP-41	General Monitoring[1]	Bathurst Inlet Discharge (post treatment)	Test quality at final point of control	Construction to Closure	A, J	See note [5]
Active	Updated Location	BRP-42	Regulated Monitoring[2]	MLA Treated Effluent Discharge Location to land (greywater)	Confirm quality of greywater before release	Construction to Closure	A, F	Prior to discharge or transfer of water
Active	No Change	BRP-43	Regulated Monitoring[3]	MLA Fuel Tank Farm	Test quality of runoff water in the Fuel Tank Farm containment area	Construction to closure	A, E	Prior to discharge or transfer of water
Inactive	Not Shown	BRP-44	Regulated Monitoring[3]	MLA Landfarm	Test quality of runoff water in the Landfarm containment area	Construction to closure	A, E	Prior to discharge or transfer of water
Inactive	Not Shown	BRP-45	Regulated Monitoring[3]	MLA Hazardous Waste Mgmt. Area	Test quality of runoff water in the Hazardous Waste Management containment area	Construction to closure	A, E	Prior to discharge or transfer of water

Notes BRP = Back River Project; MLA = Marine Laydown Area
1)Marine Discharge Criteria not required for the Water Licence
2) See Table 7.5-4 (Treated Sewage Effluent Criteria) in the Water Management Plan
3) See Table 7.5-3 (Discharge to Land Criteria) in the Water Management Plan
4) See Table B-03 for parameters in each monitoring group
5) Monitoring parameters and frequency at the discretion of Sabina as results from the verification stations are used for operational and management purposes

Table B-03. List of Constituents in Each Parameter Group

Parameter Group	Parameter Group Code	Specific parameters
Field Chemistry	A	pH, specific conductivity, and temperature.
Flow	B	Flow datalogger, calculated volume
General Surface runoff	C	Total Suspended Solids (TSS), Oil and Grease, pH
General Chemistry	D	Conventional: turbidity, hardness, alkalinity, calcium, chloride, fluoride, magnesium, potassium, sodium, sulphate, total dissolved solids, TSS, total cyanide, free cyanide, and weak acid dissociable (WAD) cyanide. Nutrients: ammonia, nitrate, nitrite, total phosphorus (TP), and dissolved organic carbon. Total and dissolved metals: aluminum, arsenic, barium, cadmium, chromium, copper, iron, lead, manganese, mercury, molybdenum, nickel, selenium, silver, strontium, thallium, uranium, and zinc Other: radium-226, *Escherichia coli,* and Total coliforms, when required
Secondary Containment	E	TSS, pH, ammonia, total arsenic, total copper, total lead, total nickel, total zinc, benzene, toluene, ethylbenzene, xylene, Oil and Grease
Sewage	F	Biochemical Oxygen Demand (5-day), TSS, Fecal coliform, ammonia, phosphorus, Oil and Grease, pH, Acute toxicity (Rainbow Trout and Daphnia magna)
MDMER deleterious substances	G	TSS, total cyanide, total arsenic, total copper, total lead, total nickel, total zinc, and radium-226
MDMER toxicity	H	Acute toxicity (Rainbow Trout and Daphnia magna)
MDMER sublethal toxicity	I	Sublethal toxicity (Fathead Minnow or Rainbow Trout, Ceriodaphnia dubia, Lemna minor, Pseudokirchneriella subcapitata)
Discharge to Marine	J	Salinity, total metals (aluminum, arsenic, barium, cadmium, chromium, copper, iron, lead, manganese, mercury, molybdenum, nickel, selenium, silver, strontium, thallium, uranium, and zinc), oil and grease

Note: Detection limits may vary for site monitoring and for downstream receiving environment monitoring

REFERENCES

1985. *Fisheries Act*. R.S.C. 1985, c. F-14.

1988. *Environmental Protection Act*. RSNWT (Nu) 1988, c E-7.

1993. *Nunavut Agreement Act*. S.C. 1993, c. 29.

CCME (Canadian Council of Ministers of the Environment). 1999 (with updates to 2017). Canadian Environmental Quality Guidelines for the Protection of Aquatic Life – Summary Table. Available at: http://st-ts.ccme.ca/.

Sabina. 2018. Back River Project Marine Monitoring Plan. Version 1.1. May 2018.

Appendix C. Saline Water Management Plan

Water Management Plan

Appendix C: Saline Water Management Plan

October 2020

BACK RIVER PROJECT

MINE WASTE ROCK MANAGEMENT PLAN

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Revision Log

Version	Date	Section	Page	Revision
1	June 2018	All	All	Addition of Appendix C: Saline Water Management
2	May 2020	All	All	Updated to reflect the 2020 Modification Package changes, and as a Supporting Document; submitted to the Nunavut Planning Commission (NPC) and Nunavut Impact Review Board (NIRB).
3	October 2020	All	All	Submitted as a Supporting Document for the Type A Water Licence Amendment Application to the Nunavut Water Board (NWB).

Acronyms

CCME	Canadian Council of Ministers of the Environment
MDMER	Metal and Diamond Mining Effluent Regulations
MAD	Main Application Document, submitted October 2017 (2AM-BRP1831)
NWB	Nunavut Water Board
Project	Back River Project
Sabina	Sabina Gold & Silver Corp.
SD	Supporting Document
SWMP	Saline Water Management Plan
SWP	Saline Water Pond
TF	Tailing Facility
WMP	Water Management Plan

1. Introduction

The Saline Water Management Plan (SWMP or the Plan) is developed as an appendix to the Water Management Plan (WMP) to provide additional details related to the management of saline groundwater in compliance with the Type A Water Licence, 2AM-BRP1831. The WMP outlines the procedures required to manage the quantity and quality of water interacting with Project components throughout the Construction, Operations, Closure, and Post-Closure phases of the Project.

The SWMP outlines the procedures required to manage the quantity and quality of saline groundwater interacting with Project components throughout the mine life, and characterization of saline water inflows into the underground mine workings. The Plan also includes monitoring of thermal conditions, monitoring of saline water at the Goose Property, mitigation measures designed to address the potential for higher-than-predicted volumes of saline water inflows into the open pits and the underground mine, and potential water treatment and disposal methods.

2. Scope and Objectives

The SWMP is provided as an addendum to the WMP with the objective of further detailing the saline water management strategies and designs for the Project, including considerations about contingencies, monitoring, and potential adaptive management strategies. The SWMP applies to all phases of the Project during which saline water will be managed. The SWMP has been written to meet requirements of the Type A Water Licence (2AM-BRP1831) and NIRB Project Certificate (No. 007).

The purpose of the SWMP is to:

- outline procedures and processes specific to management of saline water through all phases of the Project, as proposed in the WMP;
- summarize designs of infrastructure dedicated to management of saline water;
- meet relevant laws and regulations;
- detail mitigation (adaptive management) strategies to manage potential adverse environmental effects; and
- define steps that will be taken to monitor potential mitigation measures for success.

The WMP incorporates strategies for saline water management that allow full containment of saline water within the Project site throughout the various phases of the Project. Additional details related to the closure and reclamation of saline water management structures can also be found in the Interim Closure and Reclamation Plan (2AM-BRP1831 Part J, Item 1).

The SWMP, as part of the WMP, will be updated as needed to reflect changes in operations and technology. Any updates will be submitted as an addendum to the Annual Report in accordance with the NIRB Project Certificate (PC No. 007), or as directed by the NIRB (NIRB 2020). Any further revisions will be subject to the direction of the NWB following regulatory review of the amendment application.

The SWMP is divided into the following sections:

- Applicable Legislation and Guidelines (Section 3);
- Saline Water Management Strategy (Section 4);
- Monitoring and Reporting Program (Section 5);
- Quality Assurance/Quality Control Procedures (Section 6);
- Adaptive Management (Section 7); and
- Reclamation (Section 8).

2.1 RELATED DOCUMENTS

The SWMP should be read in conjunction with the following key plans, which have been approved for implementation by the NWB in accordance with the Type A Water Licence, 2AM-BRP1831 Part B, Item 14 and 15. Additional documents and studies that support the SWMP has also been listed.

- Water Management Plan (Part B, Item 14p);
- Environmental Management and Protection Plan (Part B, Item 14c);
- Aquatic Effects Management Plan (Part B, Item 14a);
- Quality Assurance/Quality Control Plan (Part B, Item 15a *accepted by the NWB);
- Interim Closure and Reclamation Plan (Part B, Item 14g);
- Hydrogeological Characterization and Modelling Report (Sabina 2017, Appendix F-5);
- Hydrology Report (Sabina 2015, Appendix V2-7B); and
- Water and Load Balance Report (Appendix E of the WMP).

3. Applicable Legislation and Guidelines

Specific legislation, regulations, and guidelines related to water management in Canada, and specifically within Nunavut, are summarized in the Table 3-1 of the WMP.

Sabina is bound by the terms and conditions of its land use permits issued by the Kitikmeot Inuit Association for Inuit Owned Land, Crown-Indigenous Relations and Northern Affairs Canada for Crown Land, and the Type A Water Licence (2AM-BRP1831).

4. Saline Water Management Strategy

As defined in the WMP, saline water for the Project is the groundwater that flows into Llama Open Pit (only pit not in permafrost) and the underground workings, refer to Figure A-11 and A-12 of the WMP for the location of Goose Property infrastructure and the Saline Water Pond. A small volume of brine water may be used for drilling in the underground mine workings. This brine water would be recirculated during drilling as much as feasible, with any excess managed synonymously with other saline water from the Project as described below.

This section provides a description of the saline water management strategy throughout the Construction, Operations, and Closure phases of the Project. In summary, the saline water management strategy consists of collecting saline water from Llama Open Pit and the underground mine workings, and temporarily storing this groundwater in a dedicated storage facility until it can be returned back into the mined-out underground workings and the exhausted Umwelt Open Pit.

4.1 PERMAFROST CHARACTERISTICS AND GROUNDWATER INFLOWS

The Back River Property is located in the continuous permafrost region of the Canadian Arctic. While permafrost may extend in excess of 400 metres below the ground surface (mbgs), it is expected that some of the underground development will extend below this depth into unfrozen rock and soil. In addition, Llama Open Pit will be located within a through talik underneath Llama Lake.

As part of the Project, a groundwater prediction model was completed to estimate potential groundwater inflows during mining at the Goose Property (Sabina 2017, Appendix F-5); this model was employed in both the FEIS (Sabina 2015) and the Type A Water Licence Application (Sabina 2017). Sabina subsequently scaled the quantity and quality of groundwater inflows predicted to match the new mine schedule. A summary of the estimated quarterly groundwater inflows at the Goose Property and corresponding Total Dissolved Solids (TDS) concentrations is provided in Table 4.1-1 and Table 4.1-2, for Llama Pit and Umwelt Underground, respectively.

The refined mine plan outlined in this SWMP and associated WMP is a subset of the previously approved permitted mine and currently does not include Llama Underground, Goose Main Underground, Echo Open Pit, and Echo Underground (PC No. 007 and Type A Water Licence 2AM-BRP1831). Sabina highlights that, with the continued advancement in detailed engineering and market considerations, the previously approved deposits may be reintegrated into the mine plan at a later date. Sabina will update the WMP as outlined in Part B Item 17 of the Type A Water Licence, 2AM-BRP1831. Refer to Section 5.2.6 of the WMP for additional details.

Table 4.1-1. Llama Open Pit Quarterly Groundwater Inflows and TDS Concentrations

Mine Year	Inflow		Total Dissolved Solids	
	Volume (m^3)	Rate (m^3/day)	Mass (tonne)	Concentration (mg/L)
Y1Q3	82,200	900	700	8,500
Y1Q4	48,300	500	400	9,300
Y2Q1	21,500	200	200	9,800
Y2Q2	20,100	200	200	10,100
Y2Q3	49,100	500	500	9,900
Y2Q4	28,800	300	300	9,600
Y3Q1	38,400	400	400	9,300
Y3Q2	35,700	400	300	9,300
Y3Q3	46,800	500	400	7,800
Y3Q4	44,600	500	300	7,600
Y4Q1	32,900	400	200	7,300
Y4Q2	37,700	400	200	6,500
Y4Q3	35,300	400	200	5,900
Y4Q4	44,400	500	200	5,600
Y5Q1	48,800	500	300	5,800

Table 4.1-2. Umwelt Underground Quarterly Groundwater Inflows and TDS Concentrations

Mine Year	Inflow		Total Dissolved Solids	
	Volume (m3)	Rate (m3/day)	Mass (tonne)	Concentration (mg/L)
Y1Q1	11,000	100	300	29,000
Y1Q2	27,000	300	900	33,300
Y1Q3	38,200	400	1,400	37,500
Y1Q4	60,500	700	2,500	41,000
Y2Q1	71,200	800	3,100	43,400
Y2Q2	74,400	800	4,400	59,000
Y2Q3	74,400	800	4,400	59,000
Y2Q4	74,400	800	4,400	59,000
Y3Q1	74,400	800	4,400	59,000
Y3Q2	74,400	800	4,400	59,000
Y3Q3	62,000	700	3,000	48,900
Y3Q4	51,900	600	2,600	49,400
Y4Q1	45,700	500	2,300	49,500
Y4Q2	45,700	500	2,400	53,500
Y4Q3	63,500	700	3,800	60,500
Y4Q4	74,400	800	4,400	59,000

(continued)

Table 4.1-2. Umwelt Underground Quarterly Groundwater Inflows and TDS Concentrations (completed)

Mine Year	Inflow		Total Dissolved Solids	
	Volume (m3)	Rate (m3/day)	Mass (tonne)	Concentration (mg/L)
Y5Q1	72,900	800	4,100	56,900
Y5Q2	60,500	700	3,500	57,000
Y5Q3	54,500	600	3,100	57,200
Y5Q4	51,100	600	2,900	57,300
Y6Q1	48,100	500	2,800	57,500
Y6Q2	44,700	500	2,600	57,700
Y6Q3	43,300	500	2,500	57,900
Y6Q4	42,200	500	2,500	58,200
Y7Q1	40,700	400	2,400	58,400
Y7Q2	38,700	400	2,300	58,700
Y7Q3	38,000	400	2,200	58,900
Y7Q4	37,400	400	2,200	59,200
Y8Q1	36,500	400	2,200	59,500
Y8Q2	35,000	400	2,100	59,700
Y8Q3	34,600	400	2,100	60,000
Y8Q4	34,300	400	2,100	60,200
Y9Q1	33,700	400	2,000	60,500

At the Goose Property, groundwater modelling and analysis determined that inflows are expected from Llama Open Pit, and Umwelt Underground. Llama open pit mining will be developed below Llama Lake within a through talik that is connected to the groundwater system. It is also expected that Umwelt underground workings will intercept the groundwater system below the basal permafrost layer. The remaining developments (Umwelt Open Pit, and Goose Main Open Pit) are not expected to have notable groundwater inflows.

The inflows and concentrations in Table 4.1-1 and Table 4.1-2 were derived from hydrogeological parameters obtained from the field investigation program results, including installation of the Westbay Well to conduct groundwater quality sampling at the Goose Property. Multiple hypothetical scenarios were modelled to assess the sensitivity of groundwater model predictions to hydraulic conductivity (K) values, the potential presence of fault conduits, lake sediment K values, and permafrost distribution. The hypothetical scenarios were used to contextualize the overall groundwater model in terms of both quantity and quality of water estimated to report to the mine workings.

Groundwater inflows in Table 4.1-1 and Table 4.1-2 represent quarterly average flows, meaning they are estimated as the total annual inflow volumes equally distributed over three months. As such, these inflow volumes do not fully account for the actual schedule of mining completion in the last year of facility. If the facilities are completed in the first few weeks of the production quarter, the inflow rates for those months would be higher than the quarterly average inflow rates, as the total annual estimated inflow volume would be concentrated in a period of time shorter than three months. Linear interpolation was assumed for groundwater flow into Llama Open Pit during pit flooding; this is further described in Water and Load Balance Report, Appendix E of the WMP.

A detailed description of the groundwater prediction model and results through all mine phases can be found in the Hydrogeological Characterization and Modelling Report for the Project (Sabina 2017, Appendix F-5).

4.2 SALINE WATER MANAGEMENT STRATEGY AND ASSOCIATED CONTROL STRUCTURES

Sabina recognizes that there is a chance that groundwater flow in the mine workings may be dominated by specific fractures or features that are intercepted. This uncertainty exists for all mining projects and is never completely alleviated, which is the reason why structural geology and hydrogeology data are regularly collected from mining operations. The influx of groundwater into a mine is a normal and well understood phenomenon and is regularly managed by standard operating procedures in operating mines. Sabina is aware of the uncertainty related to fault zones and will take advanced actions where feasible to help safely and appropriately manage groundwater inflows reporting to the mine workings. These actions may include use of surface and underground exploration information to identify enhanced permeability that may be intercepted by the mine workings, advancing cover and probe drilling (i.e., exploration drainage holes), and interpretation of groundwater pressure and inflow data when high permeability formations are encountered.

A series of options to manage saline water as it reports to the mine workings was identified and assessed during the development of the WMP. These options included, but were not limited to, physical barriers to cut off inflow, temporary and/or permanent storage in dedicated storage facilities, and an array of pumps and sumps to collect and transfer saline water. Potential saline water management options are listed in order of preference (from most preferred or applicable to least preferred or applicable) in Table 4.2-1, along with a discussion of the applicability of each option given the current mine plan.

Table 4.2-1. Saline Water Management Options Considered

Management Option/Location	Discussion of Applicability
Exhausted open pits (Umwelt, Llama, Goose Main, or other open pits)	A possible option if the future pit lake could be managed to support meromictic conditions, resisting turnover due to pit lake geometry, and therefore unlikely to result in a discharge of saline water to local freshwater streams. Currently, Umwelt Pit is expected to be developed as meromictic, but depending on the developing mine plan, all pits could be considered for the possibility of temporary or permanent saline water storage. In-pit tailings disposal in all pits would be prioritized over disposal of saline water. The use of exhausted open pits, along with mined-out underground workings, provide the most suitable permanent saline water disposal locations; however, the timing of saline water discharges, relative to the availability of either as permanent storage, may not match.
Closed U/G workings (Umwelt or other underground workings)	A possible temporary or final disposal option. It is noted that underground workings are the main source of saline water and could not be used for disposal until mining is completed. The use of mined-out underground workings, along with exhausted open pits, provide the most suitable permanent disposal locations; however, the timing of saline water discharges, relative to the availability of either as permanent storage, may not match.

(continued)

Table 4.2-1. Saline Water Management Options Considered (completed)

Management Option/Location	Discussion of Applicability
Modified natural containment area (Llama Lake or Umwelt Lake)	A modified natural containment area (for example, Llama or Umwelt lakes) could be suitable as a temporary saline water storage area and could be used for permanent saline water storage as long as any overflow meets appropriate discharge criteria. A modified natural containment area is technically feasible and economically viable. Impacts to fish and fish habitat for use of Umwelt Lake and dewatering of Llama Lake have already been assessed (refer to Fish Out Plan [Sabina 2015, Volume 10, Chapter 21] for details). No additional impacts to fish or fish habitat would be realized as a result of using Llama or Umwelt lakes as modified natural containment areas. Llama Lake is the only natural containment area currently identified that provides the estimated required storage volume (approximately 1.1 M-m^3). Current water management planning identifies Umwelt Lake as the Saline Water Pond; it is the preferred temporary saline water storage area and could be used if inflow volumes are greater than anticipated.
Tailings Storage Facility / Tailings Facility (any mined-out open pit)	Supernatant pond water from the active Tailings Storage Facility (TSF) or Tailings Facility (TF) will be reclaimed for the Process Plant. The Process Plant cannot easily tolerate the expected high salinity levels in the saline water, and as such, storing saline water in the active TSF/TF is not the preferred option. However, saline water may be sufficiently diluted in the supernatant pond to temporarily provide storage for limited periods (i.e., months), if required, and not upset the process. In addition, if the groundwater is of better quality than currently predicted, or salinity tolerances in the Process Plant are higher, saline water could be permanently stored with the supernatant pond. Once a TF is no longer used for Process Plant reclaim (i.e., tailings deposition moved to the next TF), the facility could be used to store saline water as long as an appropriate freshwater cover was maintained over existing tailings, and discharge criteria are met for overflows.
Man-made surface containment ponds	Similar to the modified natural containment area, man-made surface containment ponds could be constructed (or a current water management pond could be utilized) to temporarily or permanently store saline groundwater; this would be at a higher (than other options) cost and could increase the footprint of the surface disturbance within the Property. The man-made surface containment ponds would be designed and constructed to avoid additional impacts to fish or fish habitat.
Local watercourses following treatment	Saline groundwater could be processed in a reverse osmosis (or similar) water treatment process for discharge to the environment. Saline water treated to meet effluent discharge criteria acceptable to the NWB could be released to a local watercourse. However, such treatment produces a small volume of high salt brine that would require management and disposal.
Transport and disposal to Bathurst Inlet	Should on-site storage volumes be insufficient, saline water, or high salt brine from reverse osmosis treatment, could be transported to Bathurst Inlet and discharged via a diffuser. Should this option be required it is noted that significant additional regulatory requirements (including MDMER) may be required.
Physical barriers to cut off groundwater inflow	Current data suggest that permafrost and tight ground conditions will limit the volume of inflows. Use of physical barriers to cut off groundwater inflows prior to it reporting to the mine workings is a high cost measure, especially if used on a large scale, and is therefore not the preferred option for the Project. However, this option will be considered as an adaptive management measure to mitigate local, higher than expected inflows, if encountered.

The availability and applicability of the above options depend upon a number of factors, including timing (when the saline water will be generated relative to when the appropriate storage location is available), actual Project development schedule, the need for prioritizing the disposal of tailings over saline water, and the fact that, unlike solid mine wastes such as tailings or waste rock, saline groundwater can be temporarily stored more easily as it can be moved (i.e., pumped) to its final disposal location with relative ease.

Selection of the available permanent storage location for saline water is a function of current Project timing. As the Umwelt Pit will become available for storage in Year 3, this is the basis for selecting this location as permanent storage for saline water. In addition, this location is close to the temporary saline water storage in the former Umwelt Lake (called the Saline Water Pond [SWP]). The underground workings at Umwelt become available in the later years of the mine life and can be used to store any remaining saline water at that time, if necessary.

Should contingency measures for saline water storage in open pits or other above-listed storage locations be identified (other than what is currently captured in the mine plan), Sabina intends to provide the NWB at least 60 days' notice prior to implementation with the following: water disposal volumes, disposal timing, maximum pit/storage capacity, effects to pit closure, and appropriate mitigation and monitoring plans.

4.3 SALINE WATER POND DESIGN CRITERIA

The Saline Water Pond (SWP), in the former Umwelt Lake, was selected as the preferred alternative for the temporary storage of Project saline water before permanent storage capacity becomes available in Umwelt Pit. Details on the SWP design are provided in Section 6 of the WMP.

The SWP will have one containment dam located south end of the Umwelt Lake basin (WMP Figure A-11). The design event for the containment structures was defined based on a qualitative assessment of the risk level associated with overtopping or breaching of the structure. The SWP Containment Dam was assigned a "high risk" classification based on the consideration that discharge from these structures in the unlikely event of an overtop/breach would be directly into the environment; this consideration is consistent with overall Project design criteria.

In 2018, Sabina completed a geotechnical drill program at the Goose Property that included field characterization at the SWP location at that time (which has now been updated). In part based on this drilling, the decision was made to move the SWP Containment Dam slightly south of the previously proposed location, that appears more geomorphologically favourable (Figure A-26 of the WMP). Sabina will be conducting more field characterization studies in support of final design of the SWP, and further characterization, in the form of drilling and field percolation testing, will be carried out immediately prior to construction of the facility. The information from the field characterization will verify that the design meets the required intent of full containment of the saline water and will inform Sabina on the need for implementation of additional measures to provide containment of saline water. Information, including geological cross sections, collected in support of final designs of the infrastructure, will be provided to the NWB, and any additional information relevant to the design gathered during construction will be documented in the as-built drawings for the facility.

4.4 EXISTING GROUNDWATER MANAGEMENT CONTROL STRUCTURES

There are currently no existing groundwater management control structures in place at the Project.

4.5 SALINE WATER MANAGEMENT SCHEDULE

Table 4.5-1 outlines the timeline for key saline water management activities, including tasks and facilities. A detailed Mine schedule for overall Mine Water Management (e.g., building of culverts, berms, and containment dams) is presented in the WMP.

During Phase 1 (Construction), Umwelt Lake will be dewatered to construct the SWP. The SWP Containment Dam will be constructed before the pumped saline water level requires containment.

For Phase 2 (Operations), saline water from the Umwelt underground mine and the Llama Open Pit will be collected and pumped to the SWP. In Year 3, saline water from the SWP will be pumped at a rate of around 13,000 m^3/day to the bottom of Umwelt Reservoir (formerly Umwelt Open Pit). A freshwater cap will be generated from contact and non-contact runoff water, creating a meromictic (stratified) lake. In total, approximately 1.3 Mm^3 of saline water will be pumped into the Umwelt Reservoir. Saline water will also be pumped into the mined-out Umwelt Underground, after mining of Umwelt Underground is complete in Year 10.

Following the dewatering of the SWP, sediment in the basin will be tested, and removed, if required, to meet defined discharge water quality criteria; see Section 5.2 for additional details. The containment dam will be breached once water from the SWP area is deemed suitable for discharge.

Table 4.5-1. Overview of Saline Water Management Activities

Activity	Mine Year	Notes
Umwelt Lake is fished out in preparation for lake dewatering	-2	
Umwelt Lake is dewatered to Goose Lake to allow for construction of the Saline Water Pond.	-1	Portion of water is treated for TSS.
The Saline Water Pond is constructed.	-1	
Saline water from Umwelt Underground mine is pumped to the Saline Water Pond.	1	Approximately until end of Year 2, Q2
Saline water inflow from Llama Open Pit is pumped to the Saline Water Pond.	1	Approximately until end of Year 2, Q2
Saline water from the Saline Water Pond will be pumped to the bottom of Umwelt Reservoir to create a meromictic lake.	3	In total, approximately 1.3 Mm^3 of saline water will be pumped into the Umwelt Reservoir.
Saline water is pumped from the Umwelt Reservoir into the Umwelt Underground mine.	10+	Umwelt Reservoir volumes currently conservatively assume no saline water is pumped into the underground, which creates additional conservatively assessed storage capacity of this facility.
Surficial soils in the footprint of former Umwelt Lake lakebed are excavated and placed in the Llama TF	4	Top 1-2m will be removed.
Decommissioning of Saline Water Pond Containment Dam	4	After dewatering of Saline Water Pond and removal of soils.

Source: Water Management Plan

5. Monitoring and Reporting Program

This section presents a summary of the saline water monitoring and reporting programs that will be carried out during Construction and Operations related to mine development water quantity and quality.

As part of effective mine water management, monitoring is important to verify the predicted water quality and quantity trends and conduct adaptive management should differing trends be observed. Monitoring will occur at three levels:

- Regulated discharge monitoring occurring at monitoring points specified in the approved Licence or regulations.
- Verification monitoring carried out for operational and water management purposes by Sabina. This monitoring data will not be reported to the Regulators in the Annual Water Licence Report but can be provided upon request by the Regulators.
- General monitoring included in the Licence requirements and subject to compliance assessment to confirm sampling was carried out using established protocols, including quality assurance/quality control provisions, and addressing identified issues. General monitoring is subject to change as directed by an Inspector, or by the Licensee, subject to approval by the NWB.

All three types of monitoring will be used at the Mine. Appendix B of the WMP presents the monitoring plan relating to water management during Construction, Operations, and Closure. More detailed information on the planned monitoring programs for the Project are provided in the Environment Management and Protection Plan (2AM-BRP1831 Part I, Item 1).

5.1 WATER QUANTITY

The volume of saline water being collected and transferred to and from the SWP will be measured using flow meters. This data will be supplemented by periodic seepage surveys which will record visually observed groundwater inflows in the open pits and underground mines. Measured groundwater inflow rates will be compared to model predictions on an annual basis. If significant variations from model predictions are observed, the assumptions behind the analysis will be reviewed and the analysis updated, if required. In addition, updates to the groundwater model may be required based on operational changes as the Project advances.

The prediction node PN04 will illustrate flows downstream of Umwelt Open Pit and the SWP.

5.2 WATER QUALITY

Saline water quality will be monitored in the SWP to assess the quality of groundwater flowing into Llama Open Pit and the underground workings. The Water Quality Monitoring for the Project (WMP Appendix B) provides information on proposed water quality sampling stations to be monitored. Saline water inflows from Llama Open Pit and underground mines will be monitored. The proposed BRP-11 monitoring station at the SWP will be used monitor the quality of water in this pond. Refer to WMP Appendix B, Table B-01, Figures B-01 and B-02 for exact location of monitoring stations.

To understand and plan for treatment requirements at surface, if deemed necessary, water accumulating in sumps underground will also be sampled on a monthly basis prior to recirculation for underground use or pumping to the SWP.

Water quality results will be compared to regulated water licence requirements, Metal and Diamond Mining Effluent Regulations (MDMER; Canada Gazette 2017), Canadian Council of Ministers of the Environment (CCME), and Site-Specific Water Quality Objectives guidelines.

Sabina notes the potential for chloride concentrations within sediments encountered at the bottom of the Saline Water Pond, once the saline water has been removed. Sabina has identified a number of mitigation measures to reduce chloride concentrations within the sediment, including removal of sediments for disposal within Llama TF. Sabina will track sediment and pore water chloride concentrations for the SWP to ensure appropriate water quality for the reconnection of Umwelt Lake to surface waters. A target chloride concentration of 120 mg/L (following the CCME guideline for the Protection of Aquatic Life) would be achieved at the receiving environment (defined as per the *Fisheries Act*).

Sabina also notes the potential exists for migration of saline water from the SWP to the surrounding environment. Sabina will therefore monitor the permafrost in the locations where seepage may occur as well as monitor the condition of vegetation in the vicinity of the SWP for effects due to the presence of saline groundwater.

5.3 THERMAL CONDITIONS MONITORING

The potential effect of the underground operations to the permafrost thermodynamics and hydrogeological system will consist of minor local modification of the thermal regime at the vicinity of the underground workings and a mobilization of frozen groundwater into the regional system.

During Operations, the underground workings will be backfilled progressively with waste rock and the groundwater encountered at depth will be pumped to the SWP (or Umwelt Reservoir) at surface. Once mining and backfilling are complete, the saline water stored in the SWP will be pumped into the remaining underground void space. As water saturates the mined-out areas, the heat will transfer to the surrounding permafrost and generate local thawing of the frozen ground surrounding the workings. The underground areas will be expected to freeze back where the minimum ground temperature is less than -2°C (above ~350 mbgs depth). However, it is possible that parts of the underground areas will not completely freeze back due to the large latent heat requirements combined with relatively warm permafrost temperatures at depth.

The underground mines are in competent rock and the structural stability of this bedrock does not rely on permafrost. The Project mine design parameters for the permafrost and talik zones are identical demonstrating that the structural integrity of the mines does not rely on presence of permafrost. There are therefore no concerns that permafrost thawing would lead to subsidence at surface. Pending final engineering designs and additional field characterization, Sabina will review and assess the requirements associated with thermal conditions monitoring. Sabina will undertake verification monitoring if needed.

6. Quality Assurance/Quality Control Procedures

Quality Assurance refers to plans or programs that encompass a wide range of internal and external management and technical practices designed to ensure the collection of data of known quality that matches the intended use of the data. Quality Control is a specific aspect of Quality Assurance that refers to the internal techniques used to measure and assess data quality.

Quality Assurance and Quality Control specific guidelines for the Project are provided in the Quality Assurance/Quality Control Plan (2AM-BRP1831 Part I, Item 1). These guidelines will equally apply to the saline water management structures and the saline water monitoring program.

7. Adaptive Management

The mine design, including the management of saline water, has been carefully prepared taking into consideration the vast database of site characterization data gathered for the Project, coupled with rigorous engineering analysis. Where data were limited, conservative assumptions were consistently applied. While there is a high level of confidence that the plans are viable and realistic, it is understood that mining activities are by nature inherently uncertain. Therefore, additional mitigation or adaptive management may be required as an outcome of monitoring activities described in Section 5. This may include changes to saline water management as a result of operational, engineering, and/or environmental monitoring. Any additional mitigation or adaptive management that is found to be required will be implemented in a timely manner.

Possible upset scenarios, and contingency strategies to address, are outlined Table 7-1.

Table 7-1: Saline Water Contingency Strategies

Possible Scenario	Contingency Strategy
Saline inflow volumes into the mine workings are greater than expected.	Modification and/or adjustment of the mine plan to avoid areas of concern, or to use mined-out underground stopes to provide surge capacity. Additional sump capacity to handle higher than predicted inflows. Pre-grouting of highly conductive structures prior to intersection with the mine workings. Isolation of mining sections with bulkheads to control or minimize mine inflows. If the average long-term groundwater inflows are higher despite these measures, the meromictic lake in the Umwelt Reservoir has extra capacity for saline water storage. Additional storage locations could be identified, blending of saline water with other contact water may be investigated, or treatment to desalinate the water may be required.
Water quality in the Saline Water Pond does not meet wildlife guidelines and wildlife (such as migratory waterfowl or caribou) are found to be using the pond or drinking from the pond.	Wildlife will be excluded from the ponds following an adaptive management approach.
Underground mining operations cease prior to the underground deposition of the required volume of saline water from the Saline Water Pond.	Additional storage locations will need to be identified, or treatment to desalinate the water may be required. If necessary, the meromictic lake in the Umwelt Reservoir has extra capacity for saline water storage.
Chloride sediments are encountered at the bottom of the Saline Water Pond once the saline water has been removed.	Sediments will be excavated and deposited in Llama Tailings Facility (TF). Alternatively, the base of the dewatered SWP could be washed down with freshwater and the rinse water will be pumped out. If necessary, this rinsing method would be repeated until the salinity of the rinse water is acceptably low (i.e., chloride concentration of 120 mg/L or less).
Water quality within the re-watered Umwelt Lake does not meet the requirements (Section 5.2) at the time of release.	Additional water treatment may be necessary.

The SWMP is part of a continually evolving process that relies not only on the efficacy of data collection and analytical results, but is also dependent on feedback from the communities, government, Indigenous groups, and the public. Having an adaptive and flexible program allows for appropriate and necessary changes to the design of monitoring studies, and the mitigation and monitoring plans. Some changes may come about through the observation of unanticipated effects or inadequacies in the sampling methods to detect measurable effects. Other changes may result from ecological knowledge acquired through working with Indigenous community members and discussions with Elders, both in the field and through workshops.

The SWMP will be reviewed on a regular basis to incorporate lessons learned, major changes to facility operation or maintenance, and environmental monitoring results relating to the management of saline water at the Project. Any updates will be filed with the Annual Report submitted under the Type A Water Licence (2AM-BRP1831), unless otherwise directed by the NWB.

8. Reclamation

The majority of the SWP closure activities will occur as progressive reclamation with the remainder occurring in the Closure Phase. The SWP will be dewatered to the Umwelt Reservoir using separate pumping and pipeline infrastructure during Operations.

Once the SWP has been dewatered, sediments will be tested and if the chloride content would be considered to be too high to achieve Site-specific Water Quality Objectives and/or CCME guidelines for the Protection of Freshwater Aquatic Life when the facility was re-watered, these sediment would be removed and placed in the Llama TF. Based on average hydraulic conditions, the Llama TF will take approximately six years to fill with water (i.e., the facility is expected to overflow in Year 11). Therefore, SWP sediments placed in the Llama TF will have six years to settle prior to overflows from the facility are anticipated. This is considered a sufficient length of time for the sediments to settle; however, the water will be tested prior to overflow, and treatment for suspended sediment will be implemented if necessary.

Once the water in the re-watered SWP meets Site-specific Water Quality Objective and/or CCME guidelines for the Protection of Freshwater Aquatic Life, the SWP Containment Dam will then be breached allowing Umwelt Lake to re-establish.

Additional details pertaining to reclamation and closure are provided in the Interim Closure and Reclamation Plan (2AM-BRP1831 Part J, Item 1).

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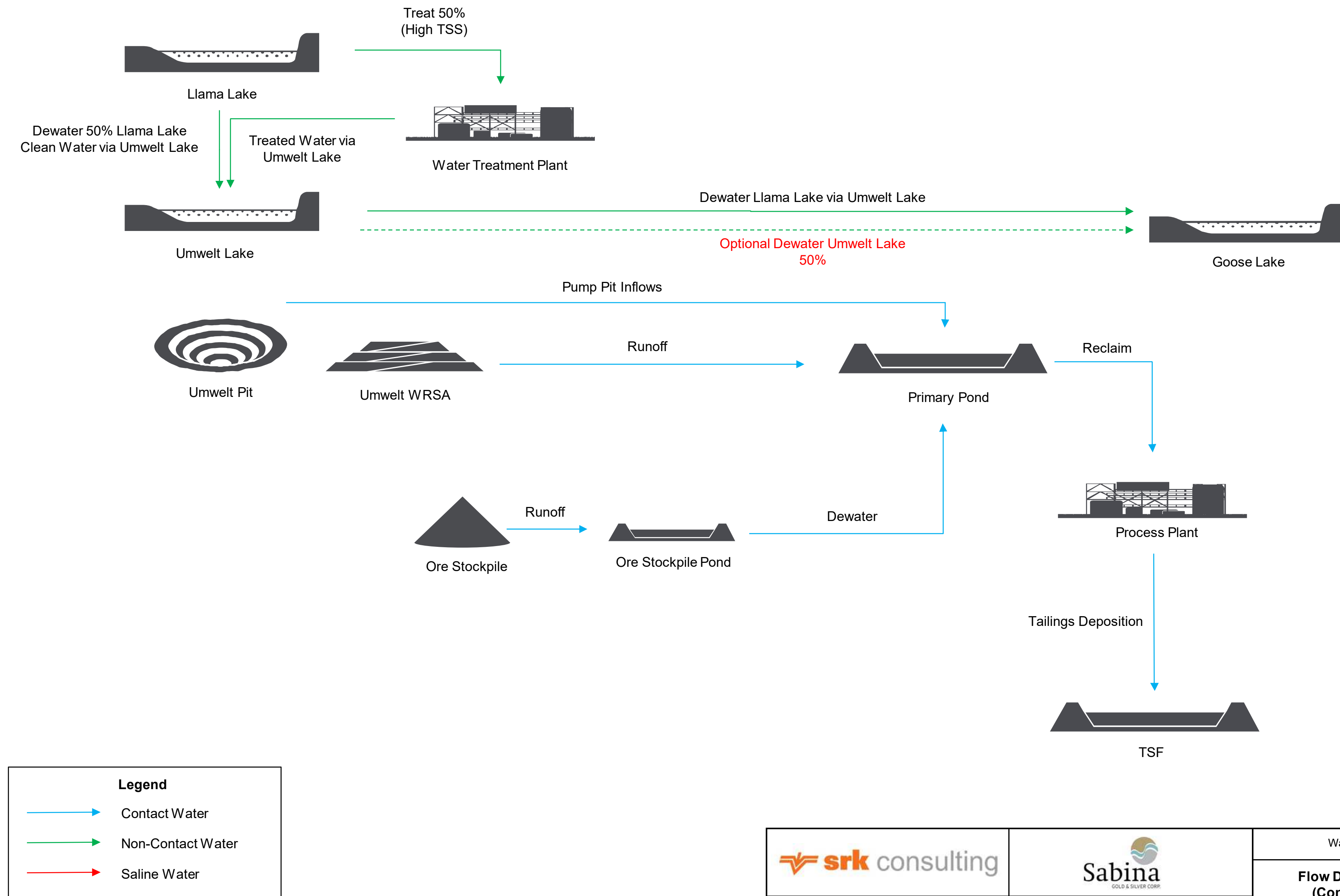
Appendix D. Water Management Flowsheets



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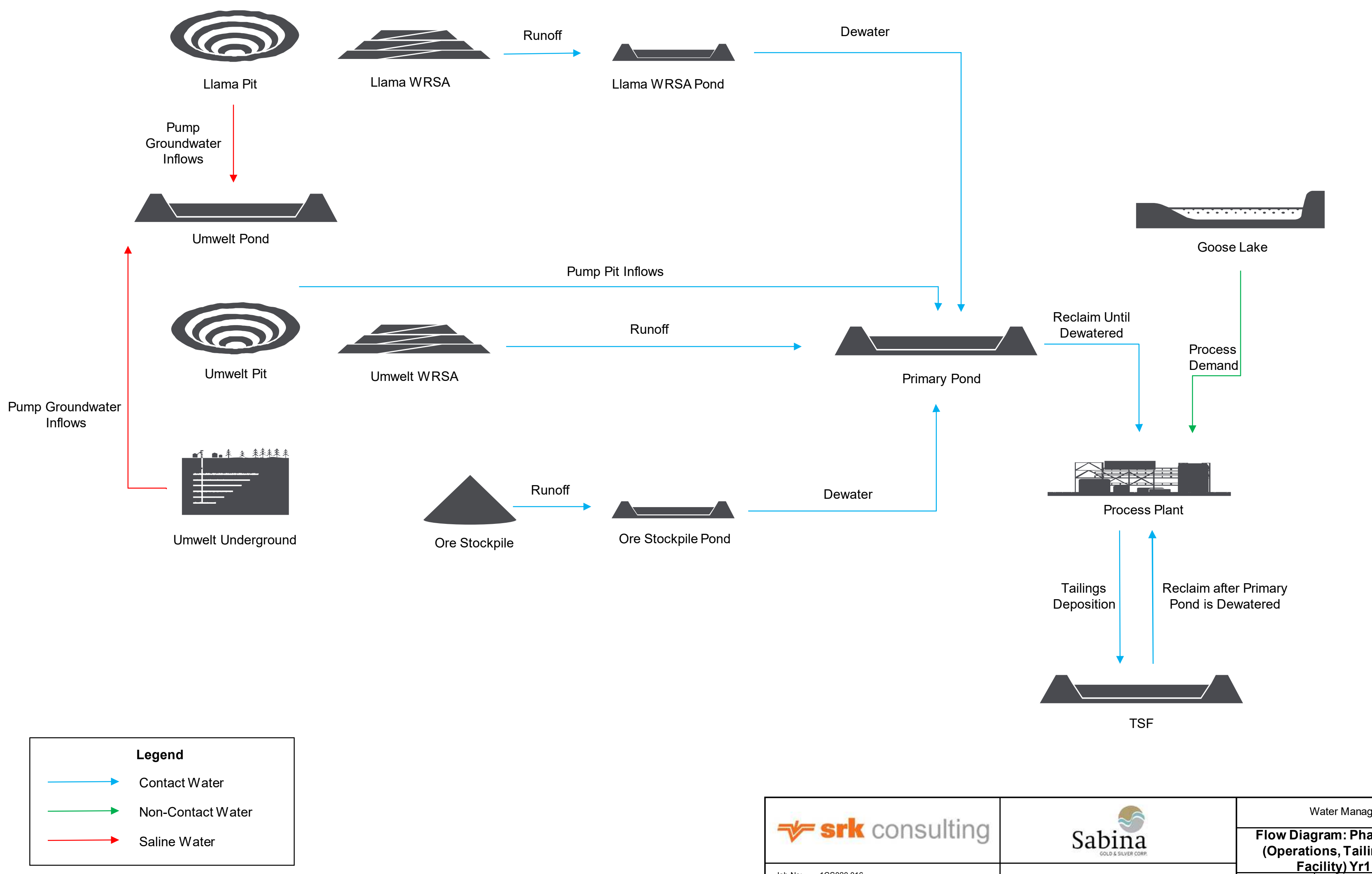

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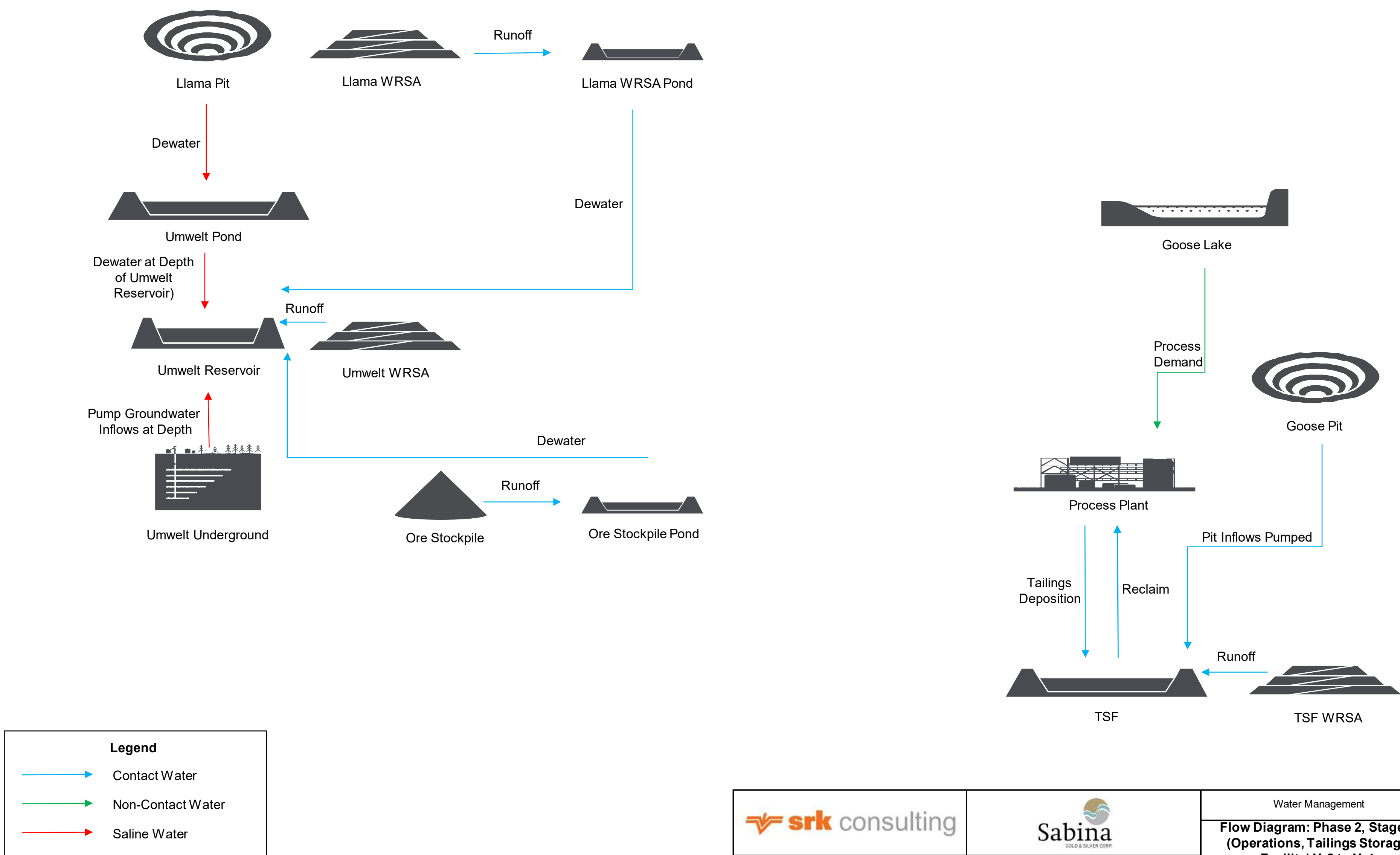

srk consulting	Sabina	Water Management
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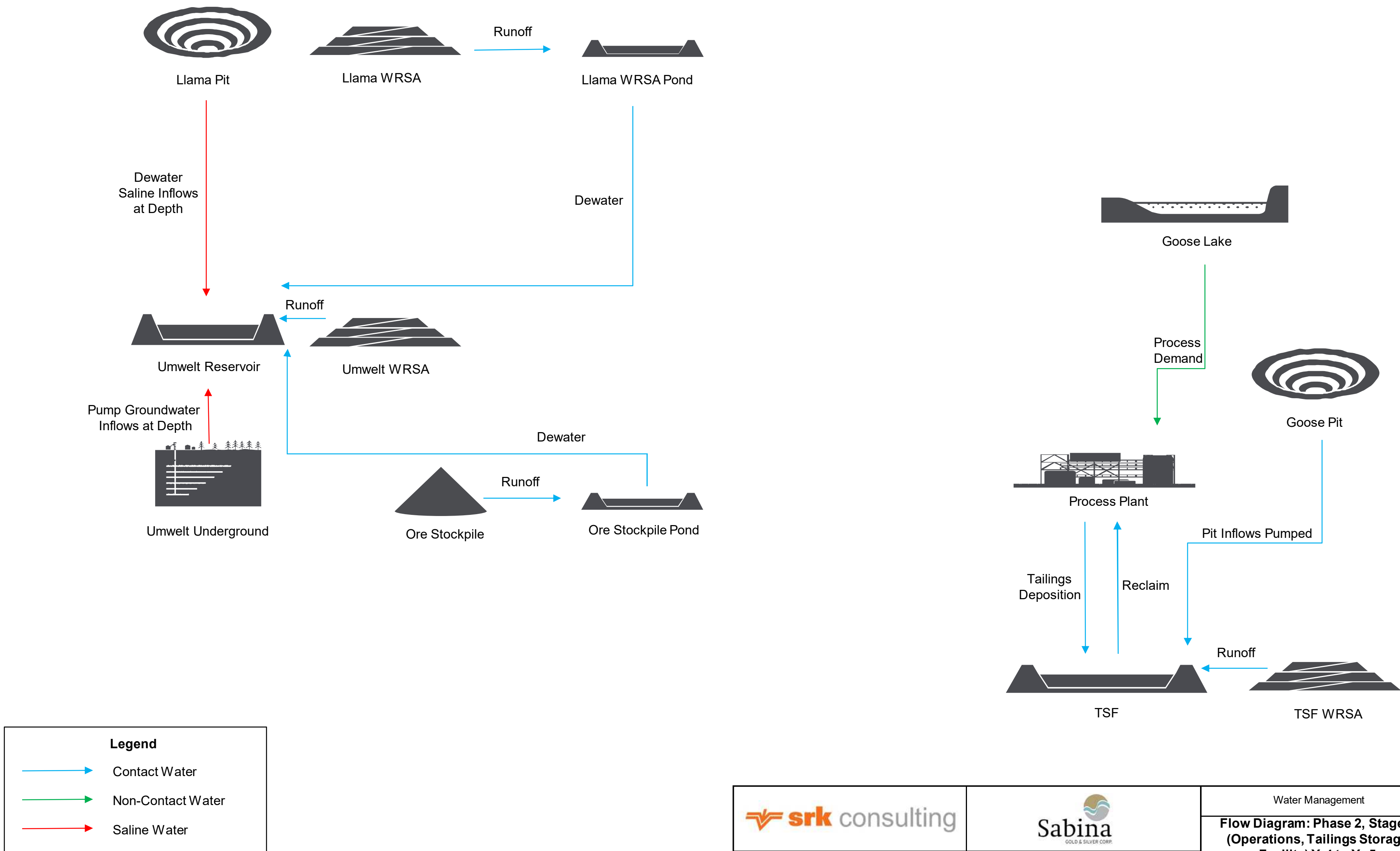

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Sabina GOLD & SILVER CORP.

Water Management

Flow Diagram: Phase 2, Stage 1 (Operations, Tailings Storage Facility) Yr4 to Yr 5

Job No: 1CS020.016

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Back River

Date: 2019-05-03

Approved: MGS

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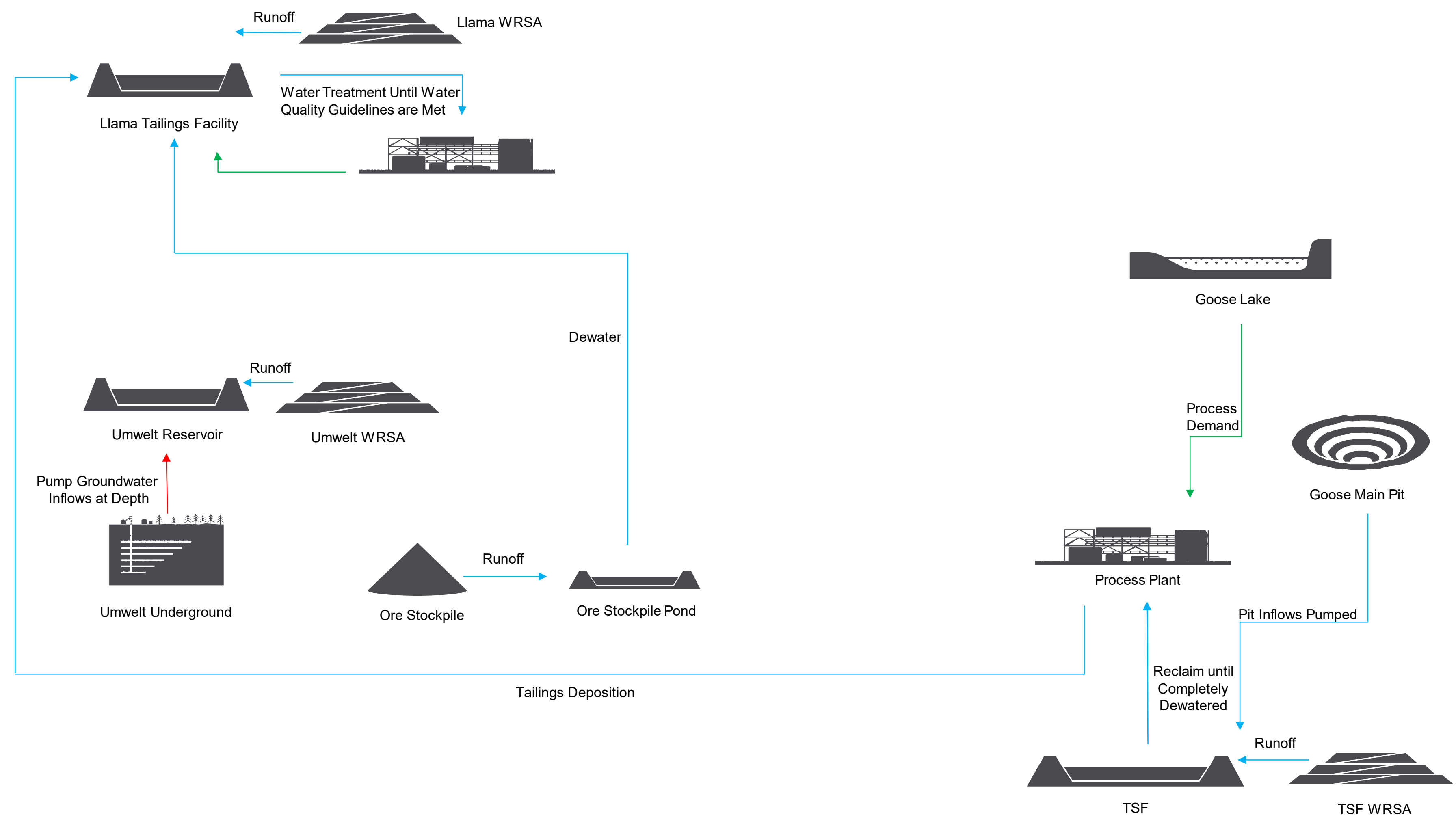

Legend

- Contact Water
- Non-Contact Water
- Saline Water

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Water Management

Flow Diagram: Phase 2, Stage 2 (Operations, Llama Tailings Facility) Yr 5 to Yr 8

Job No: 1CS020.016

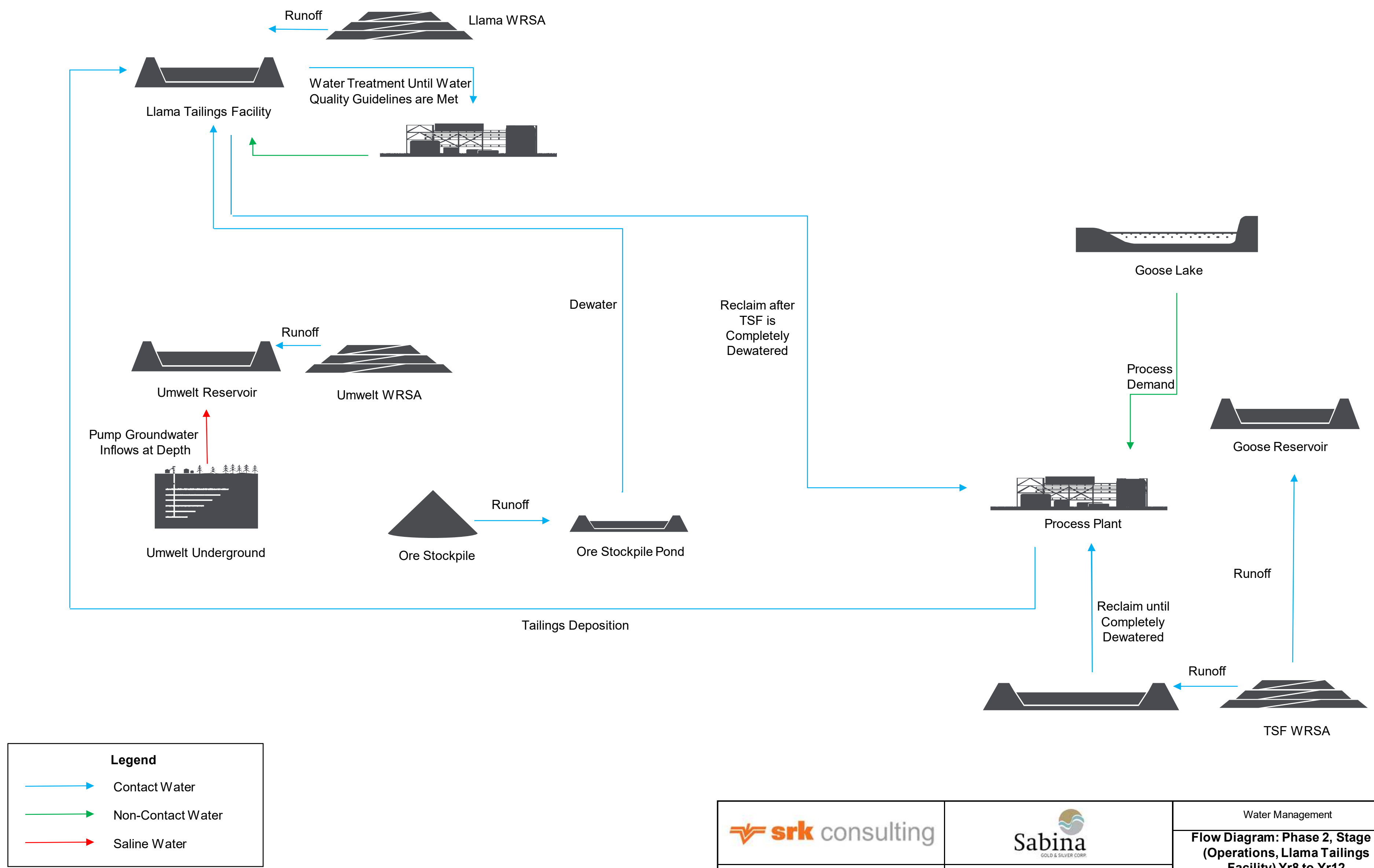
Filename: BackRiver_WaterMgmt_FlowDiagram.pptx

Back River

Date: 2019-05-03

Approved: MGS

Figure: 5



srk consulting	Sabina GOLD & SILVER CORP.	Water Management

Flow Diagram: Phase 2, Stage 2 (Operations, Llama Tailings Facility) Yr8 to Yr12

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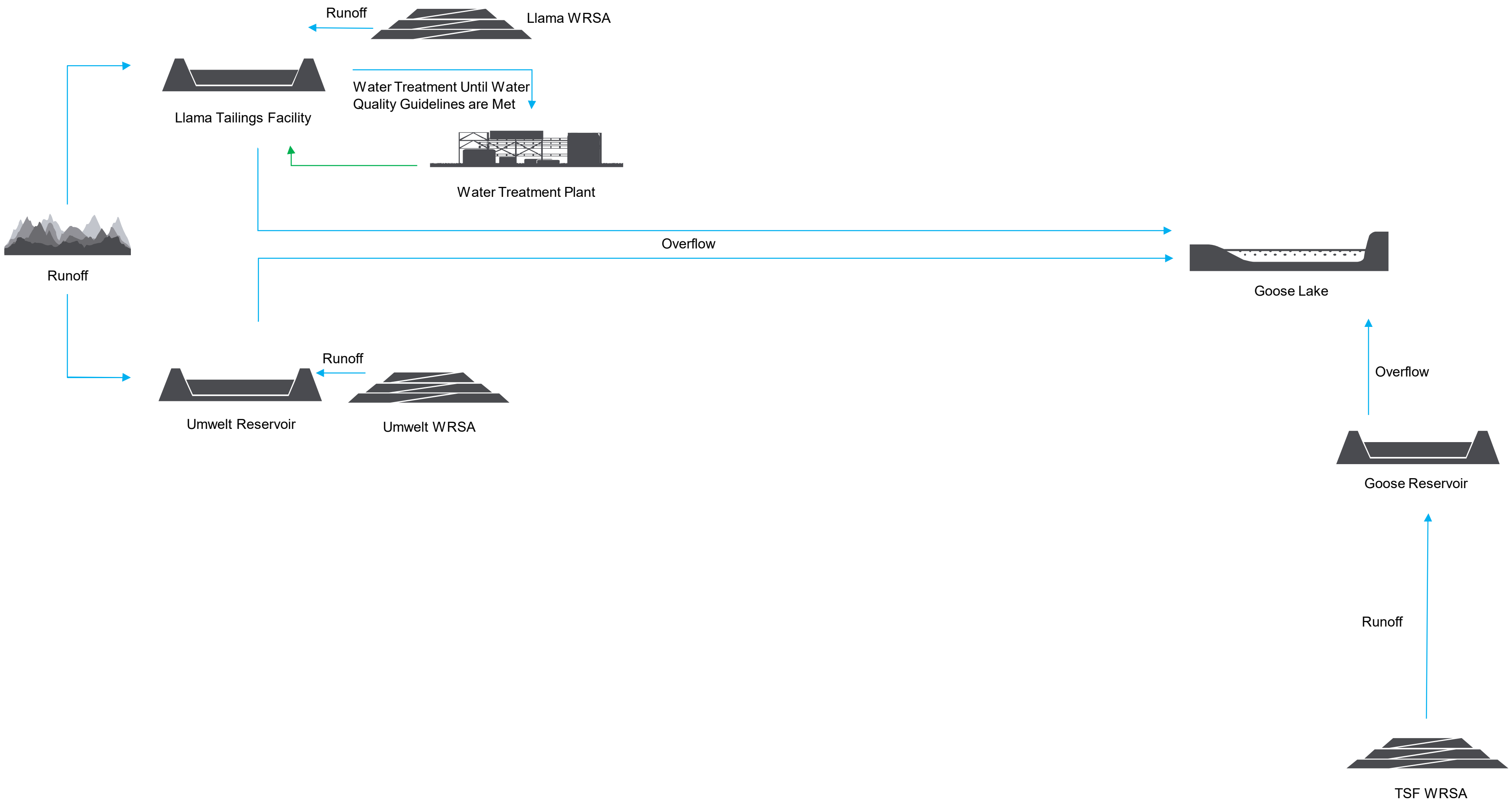
Back River

Date: 2019-05-03 | Approved: MGS | Figure: 7



Legend

- Contact Water
- Non-Contact Water
- Saline Water

srk consulting	Sabina	Water Management
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Job No: 1CS020.016 Filename: BackRiver_WaterMgmt_FlowDiagram.pptx	Back River	Date: 2019-05-03 / Approved: MGS / Figure: 8

Appendix E. Water and Load Balance Report

Back River Project
Water and Load Balance Report

Prepared for

Sabina Gold & Silver Corp.

Prepared by

srk consulting

SRK Consulting (Canada) Inc.
1CS020.018
June 2020

Back River Project
Water and Load Balance Report

June 2020

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Project No: 1CS020.018

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Executive Summary

SRK Consulting (Canada) Inc. was retained by Sabina Gold & Silver Corp. to develop a site-wide water and load balance model to evaluate water demands and predict water quality for the Back River Project (the Project), as part of the Project Type A Water License.

The Project is located in Nunavut, 160 km south of Bathurst Inlet, and is comprised of two distinct sites: The Goose Property and the Marine Laydown Area (MLA). Open pits and underground workings will be developed. The Goose Property includes three open pits and one underground development, and the Project has an estimated mine life of 12 years with a total production of 12.4 million tonnes (Mt) of ore. The focus of this report and the work completed is the Goose Property. The MLA is not included in this report.

Water and load balances were developed to optimize the water management strategy and tailings deposition schedule, and to evaluate water treatment needs during Construction, Operations, and Closure to meet water quality guidelines. The water and load balance model is based on mass balance principles, available hydrology inputs, mining and production schedules, water management plans, and updated water chemistry and source load inputs.

Water quality was predicted in all open pits, tailings facilities, and receiving water downstream of the Goose Property. The MLA was not included in the model. Results were compared to Metal and Diamond Mining Effluent Regulations (MDMER) water quality guideline and site specific limits.

Water quality predictions indicate that water treatment will be required for the Project to meet the anticipated discharge limits at Closure. With this proposed water treatment strategy, predicted water quality of Goose Lake inflows at Closure meets MDMER limits, and long-term water quality (Post-Closure) is expected to meet site specific water quality objectives for the Goose Property.

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1 Introduction

1.1 Background

SRK Consulting (Canada) Inc. was retained by Sabina Gold & Silver Corp. to develop a site-wide water and load balance model for the Back River Project (the Project). The model was designed to evaluate water management needs and predict water quality at the Project and its downstream receptors.

The Project is located in the territory of Nunavut, 160 km south of Bathurst Inlet. It is comprised of two distinct sites: The Goose Property and the Marine Laydown Area (MLA). The MLA is located approximately 130 km north of the Goose Property adjacent to Bathurst Inlet (Figure 1-1).

Mining will be completed using both open pit and underground methods at the Goose Property and the Project mine life is estimated to be 12 years, with a total of 12.4 million tonnes (Mt) of ore processed at a rate of 3,000 tpd.

1.2 Scope of Work

The scope of work for the water and load balance model is to develop a site wide model for the Project to evaluate water demands and provide water quality predictions. Other key objectives of the model were to optimize the water management plan, tailings deposition plan, and treatment requirements during Operations and Closure to meet water quality guidelines.

1.3 Report Layout

Section 2 of this report summarizes the mine infrastructure and Project timeline, and how they were incorporated in the model. Water balance and load model descriptions and inputs are presented in Sections 3 and 4, respectively. Section 5 summarizes the model implementation, including the structure and approach used in developing the water and load balance model. Section 6 and 7 provide a summary of water balance and water quality results for the Goose Property. Section 8 summarizes the model limitations.

2 Model Framework

2.1 Mine Infrastructure

2.1.1 General

The water and load balance model was developed for the Goose Property and MLA area. The Goose Property is composed of three open pits, one underground mine, three waste rock storage areas, two tailings deposition locations, an underground mining pad, an ore stockpile, camp, process plant, airstrip and roads. The MLA infrastructure is composed of only pads, an airstrip, and access roads.

The following sections provide a brief description of all reservoirs available to store water at the Goose Property that were included in the water and load balance model.

2.1.2 Primary Pond and Plant Site Pond

The Plant Site Pond will collect runoff from the ore stockpile from the beginning of operations until closure. The Primary Pond is constructed in Year -2, before waste rock placement from Umwelt Open Pit, and collects water from Llama waste rock storage area (WRSA) Pond, Umwelt WRSA, and pumped inflows from the Plant Site Pond and Umwelt Open Pit. Water from Primary Pond will be reclaimed in the mill until Umwelt Open Pit mining is complete in Year 2. Once Umwelt Open Pit mining is complete, the Primary Pond will be decommissioned and drained by gravity via culverts beneath the haul road to Umwelt Open Pit, which will become the Umwelt Reservoir. Primary Pond and Ore Stockpile Pond have total capacities of 2,500,000 m^3 and 49,800 m^3, respectively.

2.1.3 Tailings Storage Facility (TSF)

Based on the mine schedule (see Section 2.2), the Tailings Storage Facility (TSF) Main dam construction begins in Year -2, and the tailings deposition in this facility will last for approximately six years of the Project life (from Year -1 to Year 5), resulting in 8.3 Mm^3 of deposited tailings. In addition to the tailings volume, the TSF was designed to contain contact water and mill process water. Water in the TSF will be reclaimed after Year 2 for use by the mill when the Primary Pond is dewatered. The capacity of the TSF up to the full supply level (FSL) is 7.5 Mm^3.

The Goose Main Open Pit is located 2 km north, and downstream of the TSF. Development of the Goose Main Open Pit is scheduled to overlap for three months with active tailings deposition in the TSF. Waste rock from Goose Main Open Pit will be deposited on the tailings beaches and the upstream and downstream face of the TSF dam.

In the second quarter of Year 5, mining of Llama Open Pit will be complete and tailings deposition will stop the TSF and begin in Llama Tailings Facility (Llama TF). After tailings deposition in the TSF ceases, the available water storage up to the FSL level is 1 Mm^3. Reclaim water continues to be sourced from the TSF until the pond volume reaches a depth of 0.5 m in Year 12 under average hydrologic conditions, at which point reclaim of process water in the TSF is ceased. Reclaim water is then sourced from the Llama TF for the remainder of Goose Process Plant operations. The TSF dam is breached, allowing contact water runoff to flow by gravity into Goose Main Open Pit (renamed as Goose Main Reservoir in Year 8).

The closure plan for the TSF is to cover the exposed tailings and the containment dam with waste rock originating from the Goose Main open pit and convert the TSF into a waste rock storage area (TSF WRSA). This WRSA will in turn be covered with a 5 m cap of non-potentially acid generating (NPAG) waste rock.

2.1.4 Umwelt Open Pit and Umwelt Reservoir

The Umwelt Open Pit is the first pit to be mined at the Goose Property and is scheduled to start one year before milling begins (Year -1). Waste rock from Umwelt Open Pit is placed in the Umwelt waste rock storage area (Umwelt WRSA), and ore is placed in the Ore Stockpile. Contact water runoff from the Ore Stockpile is collected in the Plant Site Pond and pumped to the Primary Pond. Contact water runoff from the Umwelt WRSA flows by gravity to the Primary Pond.

Inflows to Umwelt Open Pit are dewatered to Primary Pond. Primary Pond is the source of reclaim water once milling operations begin in the last quarter of Year -1. After completion of Umwelt Open Pit mining at Year 2, the facility becomes the Umwelt Reservoir and will be used for storage of saline groundwater, originating from Llama Open Pit and the Umwelt Underground. At this stage, the Primary Pond is dewatered and drained via culverts beneath the haul road, by gravity into Umwelt Reservoir. The Umwelt WRSA is covered with NPAG waste rock and closed.

Based on available pit shell information, the estimated total storage capacity of the Umwelt Reservoir is 6.6 Mm^3, measured below the spill point elevation of 300 metres above sea level (masl). The Saline Water Pond is dewatered to the bottom of Umwelt Reservoir during the open water seasons of Year 3 and Year 4, creating a meromictic lake with saline water in the bottom, overlain by contact water from Primary Pond.

2.1.5 Llama Open Pit and Llama TF

Mining of Llama Open Pit begins in the third quarter of Year 1. Waste rock is placed in the Llama waste rock storage area (Llama WRSA). Contact water runoff from the Llama WRSA is collected in the Llama WRSA Pond and pumped to the Primary Pond. A diversion berm will be constructed around the extents of the open pit to reduce non-contact water inflows. Water collected upstream of the diversion berm may have high total suspended solids concentration and will be pumped to the Llama WRSA Pond.

The Llama Open Pit is the only pit on the Property that resides in an open talik. Groundwater inflows are expected to be encountered during mining in the talik. Groundwater inflows for the Property have high salinity and are managed separately from contact water. Additional information on groundwater inflows to the Llama Open Pit is described in Section 3.2.8 of this report and the Hydrogeological Characterization and Modeling Report (SRK 2015c). Saline groundwater inflows to Llama Open Pit are pumped to the Saline Water Pond.

In the second quarter of Year 5, mining of Llama Open Pit is complete and tailings deposition moves from the TSF to Llama TF. The containment dam for the Llama WRSA Pond is breached in Year 5, allowing contact water from the Llama WRSA to drain by gravity directly into Llama TF. Additional contact water inflows to Llama TF include runoff collected in the Plant Site Pond. The available storage capacity of the Llama TF below the spill point elevation of 302 masl is 11.6 Mm^3. Water in Llama TF is used for processing after the TSF is dewatered in Year 12.

2.1.6 Goose Main Open Pit and Goose Main Reservoir

Goose Main Open Pit mining begins in the fourth quarter of Year 3. As part of progressive reclamation, waste rock from Goose Main Open Pit is stored in the TSF, which becomes the TSF WRSA. The available storage capacity of the Goose Main Open Pit after development is 20.3 Mm^3 below a spill point elevation of 288 masl. Inflows to Goose Main Open Pit will be pumped to the TSF until mining is completed in the third quarter of Year 8, after which the pit becomes Goose Main Reservoir.

Diversions around the Goose Main Reservoir are breached at end of mining, allowing the reservoir to flood and eventually discharge to Goose Lake.

2.1.7 Llama Lake

Mining Llama Open Pit will require that the existing Llama Lake be fully dewatered in Year -1. Dewatering will occur during the open water season from July to September. Approximately 50% of the dewatered volume is assumed to be discharged directly to Umwelt Lake, which ultimately flows to Goose Lake. The remaining 50% of the volume is expected to have a high concentration of total suspended solids (TSS) and will be treated prior to discharge into Umwelt Lake.

2.1.8 Umwelt Lake and Saline Water Pond

During the development of Umwelt Underground and open pit mining at Llama Open Pit, groundwater will need to be managed because of open taliks (Section 8) and due to underground mining extending below the depth of basal permafrost. As chloride concentrations in the groundwater are expected to be high (Section 4.2.3), the groundwater from the underground workings needs to be separated from the site-wide contact and process water managed on site.

Umwelt Lake is downstream of Llama Lake and upstream of Goose Lake. Similar to Llama Lake, 50% of the Umwelt Lake water volume will be dewatered in Year -1 during the open water season from July to September, and the remaining 50% will be treated for TSS prior to discharge into Goose Lake.

The Saline Water Pond will be constructed around the footprint of Umwelt Lake, consisting of a downstream dam and ponded water levels above the existing invert of Umwelt Lake. Intercepted groundwater from underground development and Llama Open Pit will be stored in the Saline Water Pond until Umwelt Open Pit mining is complete and the Saline Water Pond is dewatered to Umwelt Reservoir. Based on available bathymetry, the Saline Water Pond will have a total capacity of 2.2 Mm^3 below the spill point elevation of 302.5 masl.

At Closure, once the Saline Water Pond is dewatered, surficial sediments within the previously ponded area will be tested to assess if it is necessary to remove. For modelling purposes, it was assumed that the first 2 m of sediments (approximately 773,817 m^3) would be excavated and transferred to the Llama TF.

2.1.9 Goose Lake

Goose Lake is the lake downstream of the Project. It is a freshwater source for the process plant and receives discharge from the Water Treatment Plant for lake dewatering and overflow from Llama TF, Umwelt Reservoir, and Goose Main Reservoir in closure. Based on available bathymetry, the Goose Lake has total capacity of 10.7 Mm^3.

2.1.10 Underground Workings

Underground mining will take place at Umwelt Underground from Years 1 to 9. Underground workings will be backfilled with waste rock during the mining process for stability reasons.

2.1.11 Camp and Sewage Treatment Plant

Sewage water is discharged overland to Goose Lake during construction at 154 m^3/d. During operations, sewage is discharged to TSF (Year 1) and the effluent rate becomes 87 m^3/d. The discharge then switches to Llama TF when it becomes active at Year 5, and finally overland discharge to Goose Lake after closure at 87 m^3/d.

2.2 Mine Schedule and Mine Phases

Water management throughout the mine life is represented by a series of phases and stages, as listed below:

- Phase 1: Construction
- Phase 2: Operations
- Phase 3: Closure

The Phase 2 Operation is divided into two stages characterized by the tailings deposition schedule. Tailings are deposited in two locations throughout the mine life. The sequence of operations for each tailings management facility represents the stage within the Operations phase as shown below:

- Phase 2, Stage 1: Tailings Storage Facility (TSF)
- Phase 2, Stage 2: Llama Tailings Facility (Llama TF)

Table 2-1 describes the phases and stages at the Goose Property with respect to water management, and a timeline of the key water management activities is summarized in Table 2-2.

Table 2-1: Summary of mining, dewatering and active ponds at the Goose Property

Phase	Year	Open Pits	UG Mines	Dewatering	Active Ponds
Phase 1: Construction (Year -3 to -1)	-2	n/a	n/a	-	Primary Pond
	-1	Umwelt	n/a	50% of Llama Lake to Goose Lake	Primary Pond Plant Site Pond

Phase	Year	Open Pits	UG Mines	Dewatering	Active Ponds
				50% of Umwelt Lake to Goose Lake	TSF
Phase 2, Stage 1 Operations: TSF (Year 1 to Year 5)	1	Umwelt Llama	Umwelt	-	Primary Pond Saline Water Pond Llama WRSA Pond Plant Site Pond TSF
	2	Umwelt Llama	Umwelt	Primary Pond dewatered to mill until breached to Umwelt Reservoir	Primary Pond Saline Water Pond Llama WRSA Pond Plant Site Pond TSF
	3	Llama Goose Main	Umwelt	Saline Water Pond to lower level of Umwelt Reservoir	Saline Water Pond Umwelt Reservoir Llama WRSA Pond Plant Site Pond TSF
	4	Llama Goose Main	Umwelt	Saline Water Pond to lower level of Umwelt Reservoir	Saline Water Pond Umwelt Reservoir Llama WRSA Pond Plant Site Pond TSF
	5	Llama Goose Main	Umwelt	-	Umwelt Reservoir Llama WRSA Pond Plant Site Pond Llama TF TSF
Phase 2, Stage 2 Operations: Llama TF (Year 5 to 12)	5	Llama Goose Main	Umwelt	-	Umwelt Reservoir Plant Site Pond Llama WRSA Pond Llama TF TSF
	6	Goose Main	Umwelt	-	Umwelt Reservoir Plant Site Pond Llama TF TSF
	7	Goose Main	Umwelt	-	Umwelt Reservoir Plant Site Pond Llama TF TSF
	8	Goose Main	Umwelt	-	Umwelt Reservoir Goose Main Reservoir Plant Site Pond Llama TF TSF
	9	End of Open Pit Mining	Umwelt	-	Umwelt Reservoir Goose Main Reservoir Plant Site Pond Llama TF TSF
	10	End of Open Pit Mining	n/a	-	Umwelt Reservoir Goose Main Reservoir Plant Site Pond Llama TF TSF
	11	n/a	n/a	-	Umwelt Reservoir Goose Main Reservoir Plant Site Pond Llama TF TSF
	12	n/a	n/a	-	Umwelt Reservoir Goose Main Reservoir Plant Site Pond

Phase	Year	Open Pits	UG Mines	Dewatering	Active Ponds
					Llama TF TSF
Phase 3: Closure and Post-Closure (Year 13 +)	13 +	n/a	n/a	-	n/a

Source: \\srk.ad\DFS\na\van\Projects\01_SITES\Back River\1CS020.017_2019 Water Mgmt & Earthworks Design\1100_Water_Load_Balance\Inputs\BackRiver_WLB_Model_Inputs_Compiled_20200607.xlsx

Table 2-2: Timeline of Water Management Activities

Phase	Activity	Year	Quarter
Phase 1	TSF Main Dam construction begins	-2 *	2
	Umwelt Open Pit predevelopment Waste rock runoff collected in Primary Pond Ore stockpile runoff collected in Plant Site Pond	-1	2
	Llama Lake Dewatered: 50% clean water via Umwelt Lake 50% high TSS water is treated Umwelt Lake dewatered, 50% clean water to Goose Lake Saline Water Pond is built	-1	3
	Goose Process Plant begins milling Freshwater is sourced from Goose Lake and Big Lake Reclaim water is sourced from the Primary Pond Tailings are deposited in the TSF	-1	4
Phase 2, Stage 1	Umwelt Underground mining begins	1	1
	Llama Open Pit mining begins Llama WRSA runoff collected in Llama WRSA Pond	1	3
	Primary Pond is dewatered via reclaim to Process Plant Primary Pond is breached Reclaim water is sourced from TSF Umwelt Open Pit becomes Umwelt Reservoir Saline Water Pond dewatered to Umwelt Reservoir	2	4
	Goose Main Open Pit development starts	3	4
Phase 2, Stage 2	Llama Open Pit mining is complete and tailings deposition transitions from TSF to Llama TF Llama WRSA Pond is breached to Llama TF Goose Main Pit inflows and Plant Site Pond are pumped to Llama TF	5	2
	Llama TF effluent is treated until copper and ammonia reach acceptable levels at Closure	6	1
	Goose Main Pit mining is complete and becomes Goose Main Reservoir TSF is dewatered via reclaim to Process Plant	8	3
	Reclaim water is sourced from Llama TF TSF is breached to Goose Main Pit Reservoir	12	1
	Milling ends	12	4
Phase 3	Umwelt Reservoir and Llama TF are allowed to fill and overflow to Goose Lake	11	2
	Goose Main Reservoir is allowed to fill and overflow to Goose Lake	13	3

* TSF construction potentially could be pushed to year -1 if completed in one year

Source: \\srk.ad\DFS\na\van\Projects\01_SITES\Back River\1CS020.017_2019 Water Mgmt & Earthworks Design\1100_Water_Load_Balance\Inputs\BackRiver_WLB_Model_Inputs_Compiled_20200607.xlsx

2.3 Conceptual Model

The water and load balance model was used as a tool to analyze water management options during the life of the Project. The management strategy is focused on managing the inventory of mine water stored on site, and maximizing the separation of saline, contact, and non-contact water. Where necessary, treatment and discharges of mine water were assessed to manage excess site-wide contact water and meet water quality guidelines downstream of discharge points from the Property.

A detailed description of the water management plan during the four phases of the Project can be found in the Sabina 2020 Modification Package.

Appendix A provides an overview of the timelines for the various water management elements. Appendix B of this document provides schematic (block flow diagrams) illustrating the conceptual water management plan that forms the basis of the water and load balance model. These figures illustrate inflows and outflows from key mine infrastructure at the Goose Property.

3 Water Balance Model Description

3.1 Water Balance Overview

The water balance tracks all inputs, outflows, and available storage at the site. The water balance can be represented in a simplistic form as follows:

$$Water\ Storage = Water\ Input - Water\ Output \qquad \text{(eq. 3a)}$$

Where the total water inputs to the site are groundwater from taliks and precipitation, as further described in this Section 3.2 of the report. The primary sources of storage available at the Goose Property are the open pits, TSF and tailings pores. Water outputs from the Property are discharges such as treated effluent, pit and TSF overflows to downstream receptors, evaporation, and seepage. Figure 1 shows a schematic of the open pit and WRSA water balances included in the water and load balance model.

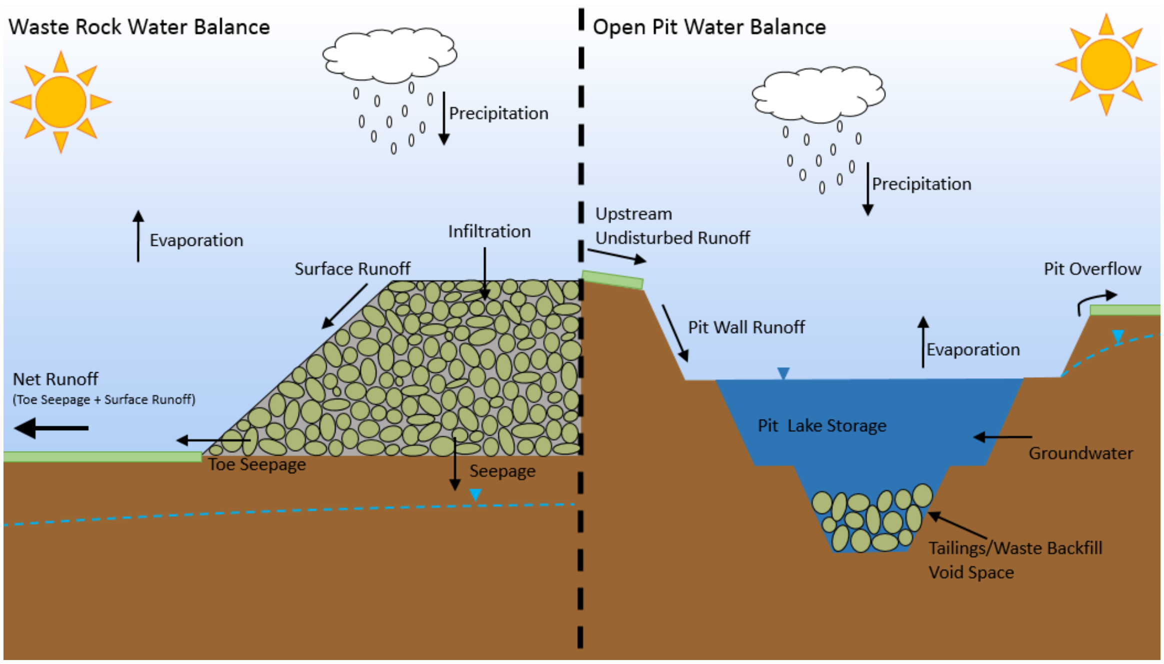


Figure 1: Water Balance Schematic

The open pit water balance illustrates inflows, outflows, and available storage accounted for in the model. Undisturbed runoff and pit wall runoff are modelled as a function of precipitation, where the runoff coefficient accounts for losses such as evaporation and infiltration. In general terms, runoff and direct precipitation on ponded areas can be represented as follows:

$$Surface\ Runoff = Area\ \times Precipitation\ \times\ Runoff\ Coefficient \qquad \text{(eq. 3b)}$$

$$Direct\ Precipitation\ Rate = Pond\ Area \times Precipitation\ Release\ Rate \qquad \text{(eq. 3c)}$$

The modelling of the WRSAs was simplified in the water balance. A runoff coefficient was applied to estimate the runoff at the toe of a WRSA. This runoff coefficient accounts for all losses such as evaporation, seepage to the groundwater table, and loss of storage in the waste rock voids. As such, runoff from a waste rock surface area was evaluated using equation 3b.

3.2 Water Balance Inputs

3.2.1 General

There are a number of inputs used to calculate water volumes in the site wide water balance. Precipitation and groundwater are the key inputs at the Property. Other important inputs include catchment areas, available storage capacities, and volumes of solids to be stored.

Table 3-1 summarizes the required inputs to the water balance model, which are further discussed in the following sections.

Table 3-1: Inputs Required for Water Balance Model

Water Balance Component	Input Required
Surface Runoff and Direct Precipitation	Annual runoff and precipitation volumes Open water evaporation rates Ice thickness Temperature Climate change data Snow melt rates Catchment areas Runoff coefficients Typical monthly hydrograph
Groundwater	Open talik inflows Through talik inflows
Water Storage	Open pit volumes Pond volumes Tailings deposition volumes (voids)
Milling	Water content in ore Reclaim demand Freshwater requirement
Water Released to Downstream Receptors	Calculated by the water balance model

3.2.2 Hydrology

Hydrological inputs for the water balance model are based on the hydrology analysis for the Project (SRK 2015e). Site-specific precipitation data was analyzed along with regional data to estimate annual precipitation at the Property. An average annual precipitation undercatch factor was estimated for the Project based on factors published by Environment Canada for the region (SRK 2015e). The correction for undercatch is important in the Arctic as precipitation measurements are typically affected by systematic errors, in particular snowfall measurements, leading to an underestimation of actual precipitation. The mean annual precipitation (MAP) for the Project was estimated to be 413 mm/year.

Runoff is calculated as a function of rainfall and snowmelt. A simple snowpack model was applied to calculate snowmelt using the temperature index method (USACE 1998). Air temperature at site was available for 2004 – 2019. The snowpack begins to develop if the average air temperature is below 0°C and begins to melt if the temperature is above 0°C. A melt rate coefficient of 3.3 mm/°C was calibrated to match the snowpack depth as estimated by MERRA (SRK 2015e). A value of 3.3 mm/°C is suitable for unforested areas (USACE 1998). The undisturbed mean annual runoff (MAR) for the Project was estimated to be 149 mm/year.

The mean annual lake evaporation was determined to be 324 mm/year using Morton's WREVAP program and site-specific data. Table 3-2 summarizes the monthly distribution of runoff, precipitation, evaporation, and temperature estimated for the Project. Table 3-3 summarizes the frequency analysis of annual runoff and precipitation used to evaluate water volumes for a range of hydrological conditions (i.e. wet and dry year events). Results reflect baseline conditions from statistical analysis on historical data. Climate change adjustments were also applied in the model and are described in Section 3.2.3.

Table 3-2: Summary of Mean Hydrologic Inputs

Month	Runoff		Total Precipitation (mm)	Evaporation		Air Temperature (°C)
	Distribution (%)	Mean (mm)		Distribution (%)	Mean (mm)	
January	0.0%	0.0	26.9	0.0%	0	-29.1
February	0.0%	0.0	22.5	0.0%	0	-28.7
March	0.0%	0.0	29.2	0.0%	0.1	-26.1
April	0.0%	0.0	27.8	1.8%	5.9	-16.4
May	1.9%	2.9	28.9	8.0%	25.8	-5.3
June	66.3%	98.6	39.5	29.8%	96.4	6.1
July	10.1%	15.0	41.7	33.0%	106.7	12.5
August	14.8%	22.1	61.1	20.3%	65.8	10.0
September	6.8%	10.2	40.3	6.9%	22.4	2.6
October	0.0%	0.0	39.3	0.1%	0.4	-6.7
November	0.0%	0.0	29.7	0.0%	0	-19.9
December	0.0%	0.0	25.1	0.0%	0	-25.7
Annual	100.0%	149	413	100.0%	324	-10.5

Source:\\srk.ad\DFS\na\van\Projects\01_SITES\Back River\1CS020.017_2019 Water Mgmt & Earthworks Design\1100_Water_Load_Balance\Inputs\BackRiver_WLB_Model_Inputs_Compiled_20200607.xlsx

Table 3-3: Summary of Runoff Frequency Analysis

Hydrological Condition	Return Period	Annual Runoff (mm)	Annual Precipitation (mm)
Wet	200	269	658
	100	258	632
	50	245	603
	20	227	562
	10	210	527
	5	190	487
Average	-	151	413
Dry	5	112	344
	10	92	311
	20	75	284
	50	56	256
	100	44	238
	200	32	221

Source: \\srk.ad\DFS\na\van\Projects\01_SITES\Back River\1CS020.017_2019 Water Mgmt & Earthworks Design\1100_Water_Load_Balance\Inputs\BackRiver_WLB_Model_Inputs_Compiled_20200607.xlsx

3.2.3 Climate Change

Climate change projections over the Project life were developed in SRK (2015h) and represent rates of change on an annual basis. While most surface water management infrastructure will have a short lifespan and be breached as soon as their effective use has been fulfilled, waste rock storage areas and pits will remain in perpetuity. The effects of climate change need to be evaluated for its long-term effects on water storage in the pits.

The long-term air temperature and precipitation trends are compared to a baseline set in 1979 – 2005 and provided in Table 3-4. Precipitation values in the model were calculated by multiplying the historical value by the rate of change presented in Table 3-4. Temperature values in the model were calculated by adding the rate of change presented in Table 3-4 to the historical value. The values used in the model were interpolated linearly centred on 2025, 2055, and 2085 for the 2020s, 2050s, and 2080s periods, respectively. Climate beyond 2085 was assumed to remain constant.

Table 3-4: Long-Term Air Temperature and Precipitation Projections

Period	Change Over Baseline (1979 – 2005)	
	Mean Annual Air Temperature	Total Annual Precipitation
2020s (2011 – 2040)	+2.0°C	+6%
2050s (2041 – 2070)	+3.7°C	+11%
2080s (2071 – 2100)	+5.3°C	+16%

Source: \\srk.ad\DFS\na\van\Projects\01_SITES\Back River\1CS020.017_2019 Water Mgmt & Earthworks Design\1100_Water_Load_Balance\Inputs\BackRiver_WLB_Model_Inputs_Compiled_20200607.xlsx

Temperature variations from climate change affect the snowpack and snowmelt timing therefore affecting the runoff distribution presented in Table 3-2. Warmer air temperatures will shift freshet earlier in the year and extend the runoff period.

3.2.4 Catchment Delineation

Mine infrastructure and upstream catchments were delineated for the Project using AutoCAD based on existing topography, final footprints of mine infrastructure, and the water management plan. In the water and load balance model, mine infrastructure such as pits and pads reach their final footprint as soon as the facility becomes active according to the Project schedule.

Figure 3-1 illustrates the catchment delineations for the Goose Property and Table 3-5 summarizes total catchment delineations and associated infrastructure areas. A total of 10 prediction nodes were included in the water balance to describe the hydrology and water quality effects from the Project. Figure 3-2 illustrates the location of the 10 prediction nodes that were included in the water and load balance model.

The total area of mine infrastructure to be developed at the Goose Property is 4.71 km^2, which consists of 6% of the total Goose Lake watershed. Area impacted by the Project will change depending on the phase of the Project. The maximum extent of impacted area will occur during pit filling when diversions are breached, and upstream catchment areas are used to fill the pits.

Table 3-5: Goose Property Catchment Areas

Catchment ID	Description	Total Area (m^2)	Infrastructure Area (m^2)
PN01	Prediction Node 01	6,486,915,430	-
PN02	Prediction Node 02	108,970,650	-
PN03	Prediction Node 03	10,495,032	-
	Total road area (PN03)		87,929
PN04	Prediction Node 04	15,750,496	-
UW	Total area from Umwelt WRSA	332,900	282,305
UCP	Total area from Umwelt Contact Water	763,500	
UP	Total area to Umwelt open pit	250,200	163,546
UU	Umwelt underground pad	101,900	96,889
GooStock	Total area from Ore Stockpile	142,600	135,805
GooMA*	Total from Goose mill area	459,500	453,523
SWP	Total Area to Saline Water Pond	1,546,000	
	Total road area (PN04, PN10)	214,373	162,955
PN05	Prediction Node 05	2,651,984	-
PN06	Prediction Node 06	27,543,514	-
GD	Upstream diversion of Goose Main open pit	33,209,472	-
GP	Total area to Goose Main open pit	307,100	211,532
TSF	Total area to TSF (tailings and WRSA)	1,976,000	1,235,798**
	Total road area (PN06)		28,532
PN07	Prediction Node 07	35,266,907	-
PN08	Prediction Node 08	1,794,654	-
PN09	Prediction Node 09	1,517,465	-
	Total road area (PN09)		13,315
PN10	Prediction Node 10	10,858,440	-
LD1	Upstream Llama Lake diversion	523,000	-
LD2	Upstream Llama Lake diversion	300,300	-
LL	Total area to Llama Lake	372,700	-
LP	Total area to Llama open pit	231,700	167,939
LW	Total area from Llama WRSA	490,962	429,200

Source: \\srk.ad\DFS\na\van\Projects\01_SITES\Back River\1CS020.017_2019 Water Mgmt & Earthworks Design\1100_Water_Load_Balance\Inputs\BackRiver_WLB_Model_Inputs_Compiled_20200607.xlsx

Notes:

Total Areas presented for the prediction nodes are total cumulative upstream areas (i.e.PN04 in Table 3-5 = PN10 + PN04 from Figure 3-2)

* Total mine facility area includes plant and camp areas.

** Footprint of the TSF WRSA.

3.2.5 Site Specific Hydrology

As described in the Hydrology Report (SRK 2015e), it was found that a number of local hydrometric stations installed at the Goose Property experienced significantly higher unit flows than other watersheds monitored on the Goose Property. ERM provided an explanation for this variance (Rescan ERM 2015), including the fact that due to minimal topography, the catchment boundaries are not well defined in some areas with some watersheds spilling over into adjacent watersheds during high flows.

PN06 and PN05 overflows are contained by Llama and Goose Diversions once these are built, and PN10 overflows to PN04 during high flows. Llama and Goose Diversions are shown in Figure 3-2. Non-contact flows to Llama Diversion areas LD1 and LD2 are pumped to Llama WRSA pond and flows to Llama Lake (LL) are diverted to Umwelt Lake. Flows to Goose Diversion are diverted to Goose Lake.

Figure 3-2 illustrates the identified watersheds experiencing site specific conditions and Table 3-6 provides a summary of the equivalent area transferred from one watershed to the adjacent watershed.

Table 3-6: Site Specific Hydrology Inputs

Flows from	Transferred to	Equivalent Area Transferred
PN10	PN04	2.2 km^2
PN06	PN04	2.2 km^2
PN05	PN08	3.1 km^2

Source: \\srk.ad\DFS\na\van\Projects\01_SITES\Back River\1CS020.017_2019 Water Mgmt & Earthworks Design\1100_Water_Load_Balance\Inputs\BackRiver_WLB_Model_Inputs_Compiled_20200607.xlsx

3.2.6 Runoff Coefficients

Runoff coefficients were used in the water balance to describe precipitation losses for catchment and infrastructure surfaces, including evapotranspiration, soil storage, and infiltration for different surface types. Specific runoff coefficients were assigned to each area depending on land use and surface cover characteristics (Table 3-7).

The Property is located in a continuous permafrost zone. Waste rock will be deposited on permafrost and, over a period of time, is expected to develop a permafrost layer within its core. Based on the available data and literature, the hydrological behaviour of a WRSA placed on permafrost is expected to change over time. During the initial wet-up period, while waste rock is actively being placed, greater losses are expected. Once the permafrost layer is fully developed within the WRSA, losses are found to be less significant, generating a larger amount of runoff at the toe of the waste rock storage area. Appendix E provides a detailed literature review of the hydrological behaviour of waste rock in northern climates and justification of runoff coefficients applied to WRSAs for the Project. For the purpose of predicting runoff volumes from WRSAs, a runoff coefficient of 0.3 was applied during the wet-up period (i.e. during active waste rock placement) and a coefficient of 0.6 was applied during steady state frozen conditions (i.e. after waste rock placement is complete).

Table 3-7: Runoff Coefficients

Land Use	Runoff Coefficient Value		Comment
Undisturbed Area	0.36		Based on hydrology analysis (SRK 2015e). Accounts for losses due to evapotranspiration, infiltration, and storage.
Waste Rock Storage Area	Unfrozen	0.30	Assumed value to account for losses due to evapotranspiration and storage in WRSAs and pads constructed of waste rock.
	Frozen	0.60	
Pit Walls	0.80		Assumed value applied to open pit areas. Accounts for losses due to evapotranspiration and storage.
Tailings Beach Area	0.80		Assumed value to account for losses due to evaporation
Underground/Industrial Pads	0.30		Value applied to pad surfaces due to evaporation and infiltration.
Road Surface Area	0.30		Value applied to road surfaces due to evaporation and infiltration.
Ponded Area	1.00		Value applied to water surfaces to account for direct precipitation.

3.2.7 Milling Quantities and Freshwater Demand

The tailings production rate for the Project will be approximately 3,000 tpd over the 12-year life of mine, with a ramp up period over the first year of operations. Table 3-8 illustrates the ramp-up schedule included in the water balance and Table 3-9 summarizes the parameters used to calculate water lost to tailings voids, reclaim demand, and storage capacity occupied by tailings solids.

Table 3-8: Ramp-Up Production Schedule

Start	Production Rate (tpd)	Percent of Target Rate
Yr-1, Q4	1,095	37%
Yr1, Q1	1,916	64%
Yr1, Q2	2,326	78%
Yr1, Q3	2,600	87%
Yr1, Q4	3,000	100%

Source: \\srk.ad\DFS\na\van\Projects\01_SITES\Back River\1CS020.017_2019 Water Mgmt & Earthworks Design\1100_Water_Load_Balance\Inputs\BackRiver_WLB_Model_Inputs_Compiled_20200607.xlsx

Table 3-9: Milling Rates and Parameters

Parameter	Value
Average Production Rate	3,000 tpd
Specific Gravity of Tailings solids	2.88
Tailings Dry Density	1.20 t/m^3
Void Ratio*	1.40
Slurry Percent Weight Solids	47%
Ore Moisture Content	3%
Average Reclaim Rate	2,100 m^3/d
Process Freshwater Demand	900 m^3/d
Water Loss to Voids	1,460 m^3/d

Source: \\srk.ad\DFS\na\van\Projects\01_SITES\Back River\1CS020.017_2019 Water Mgmt & Earthworks Design\1100_Water_Load_Balance\Inputs\BackRiver_WLB_Model_Inputs_Compiled_20200607.xlsx

Note: * The void rate was calculated based on material properties.

Based on the tailings properties, the slurry discharge will consist of 3,400 m^3/d of water and 2,500 m^3/d of solids. The volume of water entrained in tailings voids is a function of the void ratio and tailings density and is equal to 1,458 m^3/d based on the average tailings disposal rate.

Table 3-10Table 3-10 summarizes freshwater consumption requirements of the Project where freshwater for Project use will be sourced from Goose Lake and Big Lake. The maximum water consumption from Goose Lake is 1,500 m^3/d and 1,900 m^3/d during the winter and summer, respectively. The maximum water consumption from Big Lake is 750 m^3/d year-round.

Table 3-10: Water Supply Locations and Volumes

Water Source	Total Water Use as per 2020 Modification Package Type A Water Licence Amendment (m^3/yr)
Total Water Use: Goose Lake [a]	608,700
Total Water Use: Big Lake [b]	273,750
Total Water Use: MLA [c]	110,000
Total Water Use: Dewatering [d]	1,400,000
Total Water Use: Winter Ice Road [e]	2025 m^3/km

Source: provided by Sabina
Table References:

a Proposed change to 2AM-BRP1831, Part E, Item 3a.
b Proposed change to 2AM-BRP1831, Part E, Item 3b.
c Proposed change to 2AM-BRP1831, Part E, Item 3c.
d Proposed change to 2AM-BRP1831, Part E, Item 4.
e Proposed change to 2AM-BRP1831, Part E, Item 5.

3.2.8 Permafrost and Groundwater

The Property is located in the continuous permafrost region of the Canadian Arctic. Although permafrost may extend in excess of 400 metres below the ground surface (mbgs), it is expected that some of the underground development may extend below the permafrost layer into unfrozen soil and rock referred to as taliks. In addition, both open pit and underground development extend underneath or in close proximity to lakes associated with taliks. As such, groundwater inflows are expected during open pit and underground mining.

Figure 2 illustrates a representation of the permafrost and possible groundwater sources from taliks for the Property. As part of the Project, a groundwater prediction model was completed to estimate potential groundwater inflows during mining at the Goose Property. A more detailed description of the groundwater prediction model and results can be found in the Hydrogeological Characterization and Modelling Report for the Project (SRK 2015c).

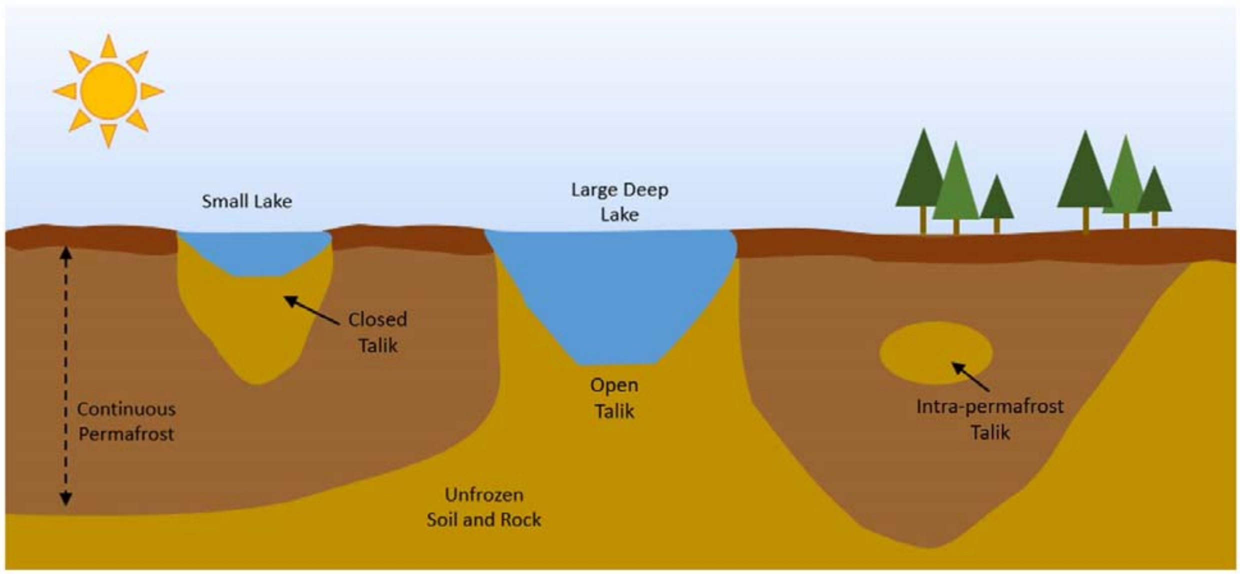


Figure 2: Permafrost and Taliks

At the Goose Property, the developments which were determined to capture groundwater inflows are Umwelt Underground and Llama Open Pit.

Llama Open Pit mining will be developed below Llama Lake through talik that is connected to the groundwater system. The Umwelt Underground stopes will likely intercept the groundwater system below the permafrost layer. In the water balance model, average annual groundwater inflows were included. Table 3-11 summarizes groundwater inflows at the Goose Property.

Table 3-11: Goose Property Groundwater Inflows

Mine Year	Flow in m³/d	
	Umwelt Underground	Llama Open Pit
-2	0	0
-1	0	0
1	373	615
2	804	290
3	715	360
4	628	220
5	653	185
6	489	0
7	425	0
8	0	0
9	0	0
10	0	0
11	0	0
12	0	0

Source: \\srk.ad\DFS\na\van\Projects\01_SITES\Back River\1CS020.017_2019 Water Mgmt & Earthworks Design\1100_Water_Load_Balance\Inputs\BackRiver_WLB_Model_Inputs_Compiled_20200607.xlsx

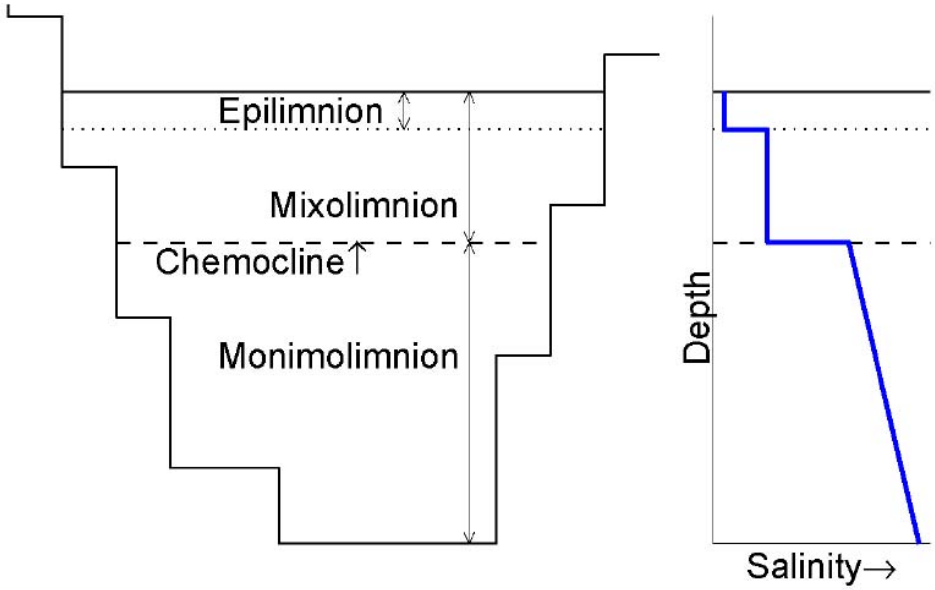
3.2.9 Meromictic Lake

Under certain conditions lakes can be meromictic, meaning they can be permanently stratified and never mix completely. Meromixis occurs when salinity stratification successfully resists wind mixing. Pit lakes are predisposed to meromixis because they are deep, have a relatively small surface area, and can contain relatively saline (dense) water.

For the purpose of this water and load balance, the Umwelt Reservoir is stratified. The bottom of Umwelt Reservoir will be filled with a combination of intercepted talik groundwater and excess contact water to form a lower layer of high chloride concentration (dense layer), capped by an upper less dense layer of fresher water.

A detailed description of the stratification assessment was conducted by Pieters and Lawrence (2015, Appendix F).

A schematic of the layers in a meromictic lake is show in Figure 3.



Schematic of a meromictic lake showing: the surface layer or **epilimnion** which is less saline as a result of ice-melt and freshet runoff; the **mixolimnion** which mixes seasonally; the **chemocline** where the largest step in salinity occurs and which resists further mixing; and the **monimolimnion** which is relatively isolated.

Figure 3: Schematic of a meromictic lake from Pieters and Lawrence (2015, Appendix F).

4 Load Balance Model Description

4.1 Load Balance Overview

The load balance for the Project was developed to evaluate the potential effects of mass loadings from mine components on water quality in downstream receiving waters. The load balance and water quality predictions were also used as a tool to optimize the water management and treatment requirements during Operations and Closure.

The load balance is based on conservation of mass. Concentrations (source terms) were estimated for each mine component, and loading rates were generated for each corresponding inflow of the water balance. Mass loading rates were also estimated from reagent addition rates in the mill and the use of drilling brine in the underground mine. There are two types of loading rates included in the load balance model:

- Direct loadings based on a defined input source term; and
- Linked loading from reservoirs (i.e. open pits or lakes).

The majority of the loading rates are calculated based on the concentrations of source terms (eq. 4a) but can also be based on loading per unit volumes (eq. 4b).

$$Inflow\ Loading\ Rate = Inflow \times Source\ Term\ Concentration \qquad \text{(eq. 4a)}$$

$$Inflow\ Loading\ Rate = Load\ per\ Unit\ Volume \times Rock\ Volume\ Flooded \times Flush\ Factor \qquad \text{(eq. 4b)}$$

Linked inflow loading rates (eq. 4c) from another facility are calculated based on the concentration (eq. 4d) in the upstream facility and associated inflow from the water balance.

$$Inflow\ Loading\ Rate = Inflow \times Calculated\ Concentration \qquad \text{(eq. 4c)}$$

$$Concentration = \frac{LMass\ (M)}{Volume\ (V)} \qquad \text{(eq. 4d)}$$

4.2 Load Balance Inputs

4.2.1 General

Table 4-1 summarizes geochemical source terms developed for the Project. Each source term represents an estimate of runoff water quality (mg/L) or parameter loadings (mg/year) contributed by a Project component. The following sections describe the source terms included in the load balance.

Table 4-1: Summary of Load Balance Source Terms

Source Term	Units	Applies to
Background Surface Concentrations	mg/L	Undisturbed catchments, initial water quality in lakes and non-contact runoff
Groundwater Concentration	mg/L	Groundwater inflows from open pit and underground mining
Ore Stockpile Concentration	mg/L	Stockpile areas (pre-operation, operation and closure)
Waste Rock Concentration	mg/L	Waste rock surface areas
Pit Wall Concentration	mg/L	Pit wall area below overburden elevation
High Wall Concentration	mg/L	Pit wall area above overburden elevation
Industrial Pad Concentration	mg/L	Mill area, roads, dykes and underground pads
Tailings Beach Concentration	mg/L	Tailings beach surface area from subaerial deposition
Tailings Slurry Concentration	mg/L	Tailings slurry supernatant (i.e. process water)
Blasting Residue	mg/year	Ore, WRSA, underground pads and roads
Brine Residue	mg/year	Underground waste rock and ore

Source: \\srk.ad\DFS\na\van\Projects\01_SITES\Back River\1CS020.017_2019 Water Mgmt & Earthworks Design\1100_Water_Load_Balance\Inputs\BackRiver_WLB_Model_Inputs_Compiled_20200607.xlsx

4.2.2 Background Water Quality

Water quality data collected at the Property dated from 2011 to 2018 were analyzed and compiled by Golder (2019). Stream water quality data were collected during freshet and the remaining open water season. The water quality median values for the Goose Lake outlet were used as inputs in the load balance model. The freshet values were applied for April through June and the open water season values were applied to all other months. Any measurement below the detection limit was taken to be equal to the detection limit. Appendix C summarizes the water quality data used in the load balance model.

4.2.3 Groundwater Inflows

Groundwater quality included in the load balance is based on results from the Westbay well (13-GSE-319) installed adjacent to the Umwelt deposit at the Goose Property. Data from the well was corrected for the concentrated calcium chloride drilling brine used to avoid freezing during drilling. For the purpose of this analysis, an average from Westbay well Zone 3 and Zone 5 concentrations was applied in the model. Table 4-2 summarizes the average groundwater quality expected during mine operations.

Table 4-2: Groundwater Water Quality Parameters

Parameter	Concentration (mg/L)	Parameter	Concentration (mg/L)	Parameter	Concentration (mg/L)
Sulphate	50	Beryllium	0.001	Nickel	0.011
Alkalinity	13.3	Bismuth	0.04	Potassium	244
Chloride	depth dependent	Boron	3.94	Selenium	0.009
Nitrate as N	0.5	Cadmium	0.001	Silicon	0.6
Nitrite as N	0.1	Calcium	16,333	Silver	0.001
Ammonia as N	0.201	Chromium	0.006	Sodium	6,770
TDS	depth dependent	Cobalt	0.009	Strontium	326
Total CN as N	0	Copper	0.008	Tellurium	0
WAD as CN	0	Iron	3.81	Thallium	0.004
CNO as N	0	Lead	0.004	Thorium	0
SCN as N	0	Lithium	7.06	Tin	0.009
Hardness	44,889	Magnesium	1018	Titanium	0.1
Aluminum	0.08	Manganese	2.87	Vanadium	0.03
Antimony	0.004	Mercury	0.00001	Zinc	0.30
Arsenic	0.0071	Phosphorus	3.3	Zirconium	0
Barium	6.11	Molybdenum	0.0424	-	-

Source: \\srk.ad\DFS\na\van\Projects\01_SITES\Back River\1CS020.017_2019 Water Mgmt & Earthworks Design\1100_Water_Load_Balance\Inputs\BackRiver_WLB_Model_Inputs_Compiled_20200607.xlsx

Groundwater inflows for the Property are expected to be more saline than sea water (salinity of 57 to 76%), where calcium chloride and sodium chloride are the dominant salts. Based on collected data, it is also expected that salinity concentrations will increase with depth.

Table 4-3 summarizes the total dissolved solids and chloride concentrations of groundwater inflows assuming 60% of measured total dissolved solids (TDS) is composed of chloride. It was found that the estimated salinities used in the model are of similar concentrations to those reported for other sites situated in continuous permafrost environments (e.g. Meliadine[1], Hope Bay[2]) (SRK 2015c).

[1] Meliadine Gold Project, Agnico Gold, Nunavut, Advanced Exploration
[2] Hope Bay, TMAC, Nunavut, Historical Drilling / Advanced Exploration

Table 4-3: Goose Property Groundwater TDS and Chloride Concentrations

Year No.	Umwelt Underground		Llama Open Pit	
	TDS (mg/L)	Chloride (mg/L)	TDS (mg/L)	Chloride (mg/L)
-2	0	0	0	0
-1	0	0	0	0
1	0	0	8,758	5,255
2	32,157	19,294	10,888	6,533
3	40,901	24,540	12,000	7,200
4	49,820	29,892	12,000	7,200
5	58,826	35,296	12,000	7,200
6	57,571	34,543	12,000	7,200
7	58,198	34,919	12,000	7,200
8	58,919	35,351	12,000	7,200
9	59,681	35,809	12,000	7,200
10	60,224	36,135	12,000	7,200
11	0	0	0	0
12	0	0	0	0

Source: \\srk.ad\DFS\na\van\Projects\01_SITES\Back River\1CS020.017_2019 Water Mgmt & Earthworks Design\1100_Water_Load_Balance\Inputs\BackRiver_WLB_Model_Inputs_Compiled_20200607.xlsx

4.2.4 Geochemical Source Terms

Source concentrations (dissolved) for water in contact with the tailings facilities, exposed mine workings and other earthworks that are part of the Project were developed by SRK for use in the load balance model (SRK 2015f). Source concentrations for water in contact with WRSAs were revised by Golder (2020) and were then used as input for SRK's final geochemical modelling.

The approach used to predict the source concentrations was based on a combination of scale-up calculations, geochemical modelling, and extrapolation of monitoring data from geologically similar mine sites in the area. The hydrological inputs for these predictions were based on an average hydrological year and assumed infiltration rate.

The additional geochemical modelling to the waste rock source terms developed by SRK aimed to balance ion charges and reflect regional limits. The modelling details are summarized as follows:

- Trace elements that were not compounds of interest were excluded from the PHREEQC modelling, as well as Na, K, F, Cl which are not related to sulphide oxidation/carbonate neutralization processes within the waste rock dumps.
- Inputs were adjusted as follows:
  - Calcium and alkalinity were set to zero.

  - Magnesium was left at original mass balance result (for an upper case) and set to a value that results in the Ca/Mg molar ratio after equilibration being roughly equivalent to the initial Ca/Mg molar ratio in the mass balance calculation (base case).
  - Fe(II) was set at value required to balance SO_4 on the basis that prior to neutralization, iron would be released in proportion to SO_4 and the HCT results reflect conditions after buffering – not initial release.

- The solutions were allowed to equilibrate with calcite at atmospheric pCO_2 values of -3.5 and -1.5 (-3.5 is approximately atmospheric and -1.5 reflects elevated pCO2 which is often present within buffered waste rock pore space).
- The outputs from PHREEQC were then further adjusted to reflect the regional limits – with base case regional limits applied to the base-case results, and upper bound regional limits applied to the upper-case results. No limits were applied to major ions. If equilibrium modelling resulted in lower concentrations than regional limits, the regional limits were applied – otherwise, the highest regional limit, pCO2 -3.5 and pCO2 -1.5 were applied – except for major ions where the pCO2 -1.5 limits were used.

The results for the base case were notably lower than earlier Golder results – largely because Na was not introduced to balance the solutions and because of the Mg adjustment which brought the counterion concentrations down. As per Golder's recommendation, an upper bound scenario that uses the original Mg values was carried.

Total concentrations were determined by calculating suspended solids based on the MDMER limit for TSS of 15 mg/L and the metal composition of a mixture of rock types from the Environmental Impact Statement (EIS). Table 4-4 summarizes the sulphate, chloride, arsenic and copper concentrations for the new source terms included in the model. A summary of all parameters is included in Appendix C.

Table 4-4: Summary of Geochemical Source Terms (2020)

Source Term	Descriptor	Sulphate (mg/L)	Chloride (mg/L)	Arsenic (mg/L)	Copper (mg/l)
Ore Stockpile	Pre-Operation	492	32.2	0.145	0.0118
	Operation	1,885	0	0.268	0.0118
	Post-Operation	247	16.2	0.145	0.0118
Waste Rock (unfrozen)	Umwelt	2,143	0	0.268	0.0119
	Llama	2,080	0	0.220	0.0118
	Goose	2,170	0	0.219	0.0118
Waste Rock (frozen)	Umwelt	210	16.0	0.097	0.0119
	Llama	206	16.0	0.097	0.0119
	Goose	247	16.2	0.096	0.0119
Pit Wall	Umwelt	53	6.1	0.231	0.0118
	Llama	56	5.9	0.164	0.0118
	Goose	40	3.4	0.184	0.0118
High Wall	Umwelt	23	1.1	0.054	0.0118
	Llama	4	1.0	0.0022	0.0022
	Goose	4	1.0	0.0010	0.0022
Industrial Pads/Roads/Dykes		36	0	0	0.0036
Tailings Beach		1,055	5.1	5.1	0.38

Source: \\srk.ad\DFS\na\van\Projects\01_SITES\Back River\1CS020.017_2019 Water Mgmt & Earthworks Design\1100_Water_Load_Balance\Inputs\BackRiver_WLB_Model_Inputs_Compiled_20200607.xlsx

4.2.5 Process Water Effluent

Table 4-5 summarizes the process water chemistry included in the load balance. These parameters represent the process water chemistry after a single pass through the Goose Process Plant. As water is reclaimed from the TSF and reused in the plant, constituents will accumulate, and concentrations will increase. Concentrations will increase up to their solubility limit. The arsenic, copper, sulphate, ammonia and chloride concentrations in the process water 0.025 mg/L, 0.059 mg/L, 1055 mg/L, 51.1 mg/L and 92.4 mg/L, respectively. Further details on metallurgical data and the analysis conducted to develop process water chemistry can be found in the Geochemical Characterization Report (SRK 2015f).

Table 4-5: Process Water Chemistry

Parameter	Concentration (mg/L)	Parameter	Concentration (mg/L)	Parameter	Concentration (mg/L)
Sulphate	1055	Beryllium	0.000025	Nickel	0.00152
Alkalinity	79	Bismuth	0.00025	Potassium	77.9

Parameter	Concentration (mg/L)	Parameter	Concentration (mg/L)	Parameter	Concentration (mg/L)
Sulphate	1055	Beryllium	0.000025	Nickel	0.0021
Alkalinity	79	Bismuth	0.00027	Potassium	77.98
Chloride	92.4	Boron	0.07	Selenium	0.0036
Nitrate as N	0.13	Cadmium	0.000026	Silicon	6.64
Nitrite as N	0.14	Calcium	178	Silver	0.000069
Ammonia as N	51.1	Chromium	0.0035	Sodium	338
TDS	1900	Cobalt	0.06	Strontium	0.72
Total CN as N	0.59	Copper	0.059	Tellurium	0.00037
WAD as CN	0.2	Iron	3.68	Thallium	0.00002
CNO as N	20	Lead	0.0029	Thorium	0.00011
SCN as N	22.74	Lithium	0.01	Tin	0.001
Hardness	617	Magnesium	47	Titanium	0.026
Aluminum	1.34	Manganese	0.16	Vanadium	0.0079
Antimony	0.002	Mercury	0.00346	Zinc	0.0042
Arsenic	0.0736	Phosphorus	0.3	Zirconium	0.0009
Barium	0.0418	Molybdenum	0.082	-	-

Source: \\srk.ad\DFS\na\van\Projects\01_SITES\Back River\1CS020.017_2019 Water Mgmt & Earthworks Design\1100_Water_Load_Balance\Inputs\BackRiver_WLB_Model_Inputs_Compiled_20200607.xlsx

4.2.6 Sewage Treatment Plant (STP) Treated Effluent Water

Concentrations of treated effluent discharged to TSF, Llama TF and Goose Lake during Construction, Operations and Closure are based on typical performance estimates from packaged sewage treatment plants (PJ Equipment Sales Corp., SRK 2011).

Table 4-6 provides the estimated parameter concentrations applied to the domestic demand from the start of Construction (Year -2) to start of Closure (Year 12).

Table 4-6: Treated Sewage Effluent Water Quality Input

Parameter	Concentration (mg/L)	Parameter	Concentration (mg/L)
Ammonia as N	10	Iron	0.014
Nitrate as N	1.0	Lead	0.0001
Nitrite as N	30	Molybdenum	0.0001
Aluminum	0.021	Nickel	0.0004
Arsenic	0.0001	Phosphorus	1.0
Cadmium	0.0001	Uranium	0.0001
Chromium	0.0001	Zinc	0.002
Copper	0.0024	-	-

Source: \\srk.ad\DFS\na\van\Projects\01_SITES\Back River\1CS020.017_2019 Water Mgmt & Earthworks Design\1100_Water_Load_Balance\Inputs\BackRiver_WLB_Model_Inputs_Compiled_20200607.xlsx

4.2.7 Blasting Residuals

Modelled blasting residues (ammonia, nitrite, and nitrate) applied to blasted rock placed as backfill or in WRSAs were derived from the methods described by Ferguson and Leask (1998). The following equation (eq. 4e) and input parameters (Table 4-7) were included in the load balance to evaluate nutrient loading from blasting.

$$NH_4NO_3 - N = Wr * Pf * ANc * Nc * Rf \qquad \text{(eq. 4e)}$$

Where:

NH_4NO_3 – N (kg of ANFO / day) = annual release of total ammonium nitrate as nitrogen

Wr (tonne rock / day) = Waste rock production rate

Pf (kg ANFO / tonne rock) = powder factor

ANc (constant) = fraction of ammonium nitrate in ANFO

Nc (constant) = fraction of nitrogen content in ammonium nitrate

Rf (%) = residual nitrogen remaining

Table 4-7: Blast Residue Assumptions

Parameter	Label	Value
ANFO : NH_4NO_3	Anc	1 : 0.94
NH_4NO_3 : NH_4NO_3 as N	Nc	1 : 0.35
Surface Rock Powder Factor	Pf	0.26 kg ANFO / tonne rock
Underground Powder Factor	Pf	0.74 kg ANFO / tonne rock
Residual ANFO Factor*	Rf	5%
Annual Flush Rate		40%

Source: \\srk.ad\DFS\na\van\Projects\01_SITES\Back River\1CS020.017_2019 Water Mgmt & Earthworks Design\1100_Water_Load_Balance\Inputs\BackRiver_WLB_Model_Inputs_Compiled_20200607.xlsx

Note: * The residual ANFO factor (1%) specified by Furguson and Leask (1998) was increased by a factor of five.

The total nitrogen was split into ammonia, nitrate, and nitrite according to the speciation of nitrogen in the blast residues: 37% ammonia, 60% nitrate, and 3% nitrite for surface rock; and 43% ammonia, 53.5% nitrate, and 3.5% nitrite for underground rock (Morin and Hutt, 2009).

The model does not account for which portion of the material is placed as infrastructure fill or in WRSAs. Pads made of fill (i.e. underground pads and roads) were based on a 2-m thickness and total surface area as described in Section 3.2.4. The annual nutrient loads were distributed monthly based on the annual hydrograph (Table 3-2) and assuming that 40% of the residue would be flushed annually. Loadings from all WRSAs, ore stockpile area, road, dykes, and underground pad were included in the model.

4.2.8 Degradation Reactions

SRK derived degradation rates for total cyanide (TCN), cyanate (OCN^-), thiocyanate (SCN^-), and ammonia (NH_4^+). There are four relevant degradation reactions for these species, which are summarized in Table 4-8.

Table 4-8: Degradation Reactions and Relevant Species

No.	Degradation Reaction	Losing Species	Gaining Species
1	TCN degrades to OCN-	TCN	OCN-
2	OCN^- degrades to NH_4^+	OCN^-	NH_4^+
3	SCN^- degrades to NH_4^+	SCN^-	NH_4^+
4	NH4+ is transformed to a variety of other forms of nitrogen	NH_4^+	Various N forms

SRK used mass balance data from the Colomac Mine[3] to estimate both natural and enhanced degradation rates. The masses of TCN, cyanate, thiocyanate, and ammonia in the Colomac tailings lake had been calculated periodically before adding nutrients (2000 and 2001) and after adding nutrients (2002 and 2003). The net change in mass for each of these species over the open water season was estimated (SRK 2004).

To determine degradation rates, SRK performed the following calculations:

- The masses of TCN, cyanate, thiocyanate, and ammonia from the Colomac dataset were converted to an equivalent mass on a nitrogen basis (e.g., TCN as N) to easily track mass changes between species.
- The total change in mass (on a nitrogen basis) for each species was calculated for each of the four years of data. The losses of TCN and thiocyanate were straightforward, but cyanate and ammonia are both degradation products from other species and are themselves degraded.
- The total mass change for each species was divided by the duration to calculate daily rates of mass change (in tonnes as N per day), which were then converted to daily rates of mg/m^2/day using the area of the Colomac tailings lake.
- The lowest degradation rates were extracted for use in the water and load balance model (Table 4-9**Error! Reference source not found.**).

Table 4-9: Summary of Degradation Rates

Parameter	Degradation Rate	Units
TCN-N	-218	mg/m^2/day
CNO-N	-300	mg/m^2/day
SCN-N	-674	mg/m^2/day
NH_4^+-N	-249	mg/m^2/day

Source: \\VAN-SVR0\Projects\01_SITES\Back River\1CS020.006_FS_Study\!020_Project_Data\010_SRK\Water Balance\WaterQuality\Ndegradation rates 20141230 for use in Back River_LMC.xlsx

[3] Colomac Mine, Closed Mine (1997), Northwest Territories

4.2.9 Brine Residuals

Calcium chloride will be required for mining Umwelt Underground. Brine loadings were calculated based on Hope Bay[4] (SRK, 2015) values derived from shake flask tests and runoff monitoring data from waste rock pile for drilling in permafrost. It was assumed that 780 mg of chloride would be required per one kilogram of rock, and a 50% reduction was applied to ore in permafrost (Table 4-10**Error! Reference source not found.**). The brine residues were assumed to be flushed out overtime at a rate of 40% per year, and the brine mass on ore was assumed to be 100% flushed upon entering the mill. The calcium addition was calculated based on the respective chloride loads.

Table 4-10: Brine addition details

Material	Location	Cl Load (mg/kg)
Underground Waste Rock (on surface)	Permafrost	780
Underground Ore	Permafrost	390

Source: \\srk.ad\DFS\na\van\Projects\01_SITES\Back River\1CS020.017_2019 Water Mgmt & Earthworks Design\1100_Water_Load_Balance\Inputs\BackRiver_WLB_Model_Inputs_Compiled_20200607.xlsx

4.2.10 Mill Outflow Water Quality

The mill outflow water quality was determined by the reclaimed water concentrations from Goose Lake, TSF, Primary Pond and Llama TF, as well as the additional load from the pore water, species released in the water from the ore dissolution, brine and ANFO flush, and the mill reagent addition for gold cyanidation and products of cyanide destruction.

The mill reagent addition rates are based on the test work from JDS (2015). The total nitrogen generated by the cyanide addition was determined by the WAD cyanide concentration in the carbon adsorption tanks that reports to cyanide destruction. The nitrogen speciation was derived from the proportion of the cyanide breakdown products in the process water source terms. Sulphate generated in the cyanide destruction was calculated by the SO_2 (g): CN_WAD (g) ratio of 5.5. Reagent loads were determined by multiplying the reagent concentrations by the mill inflow rate.

Solubility limits were applied to the following metals to account for precipitation in the mill circuit: aluminum, cadmium, copper, iron, lead, cobalt, magnesium, manganese, mercury, nickel, silver and zinc. Sulphate concentrations were determined considering calcium concentrations and calcite precipitation, as well as sodium concentrations and sodium sulphate generation. Table 4-11 summarizes the mill reagent information.

[4] Hope Bay, Doris North Project – Water and Load Balance

Table 4-11: Summary of mill reagent addition used in load balance

Reagent dose (kg/tonne)	
NaCN	1.4
$Na_2S_2O_5$	1.5
Species addition (g/tonne)	
NH_3 (53.8%)	53.15
NO_3 (21.1%)	0.14
NO_2 (24.0%)	0.15
CNO^- (21.1%)	20.80
SCN^- (24.0%)	23.65
CN_T (0.6%)	0.62
CN_WAD	183.33
Na	1010
SO_4 (5.5g SO_2/ g of WAD CN)	1540

Source: \\srk.ad\DFS\na\van\Projects\01_SITES\Back River\1CS020.017_2019 Water Mgmt & Earthworks Design\1100_Water_Load_Balance\Inputs\BackRiver_WLB_Model_Inputs_Compiled_20200607.xlsx

4.2.11 Cryoconcentration

The model conservatively assumes that there will be 100% exclusion of parameters from the lake ice, resulting in higher concentrations in the underlying water. Cryoconcentration was applied to water bodies modelled as reservoirs in the load balance (i.e. lakes and open pit reservoirs, including Goose Main Reservoir, Llama TF, Umwelt Reservoir, Saline Water Pond, TSF, Primary Pond and Goose Lake).

A maximum ice thickness of 2.0 m was applied to water bodies modelled. Ice was assumed to form in October to a maximum depth in February, receding to a zero-ice thickness by the start of the open water season in July. Table 4-12 summarizes ice thickness in the model. These assumptions are based on observations recorded during the freshwater baseline study performed by Rescan ERM (2012).

Table 4-12: Ice Thickness Input

Day of the Year	Average Ice Thickness (m)
1	0.8
31	1
60	1
180	0
274	0
366	0.8

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5 Model Implementation

A simplified overview of the main water and load balance stages and phases are presented in Appendix A. Appendix B of this document provides schematics illustrating the conceptual water management plan that forms the basis of the water and load balance model. These figures illustrate inflows and outflows from key mine infrastructure at the Goose Property.

5.1 Model Version

The water and load balance model for the Project was developed using the GoldSim software package (version 12.1.3) (GoldSim Technology Group 2019).

5.2 Modelling Approach

5.2.1 Time Step

The model is run on a daily time step. Although the input data for several parameters are on a monthly time step. Daily values are calculated by dividing monthly values by the number of days in a month.

The model runs from Year -3 to Year 47. This duration was chosen because it is the time until steady-state conditions are reached in pit lakes and downstream receptors.

5.2.2 Stochastic Water Balance Model

Water balance results were generated by running the model as a Monte Carlo simulation. Monte Carlo simulations are well suited for situations where the actual value of a key input is not known, but where its distribution (how it may vary) is known or can be adequately estimated. Total annual precipitation for the Project is an example of such a variable. Although it is not possible to know the annual precipitation in any given year, it is possible to estimate it from a probability distribution function.

The model randomly selects a value of annual precipitation from the probability distribution developed for the Project (Table 3-3). Runoff volumes are then calculated by multiplying the annual precipitation by the average monthly runoff distribution according to the typical hydrograph, a runoff coefficient based on the surface type and the catchment area (Section 3.2.2). The model uses a randomly generated precipitation depth for each year. All results were recorded and stored by the model. A total of 100 model runs were completed using this approach. At the end of 100 model runs, all results were compiled, and probability distributions of the results were generated (i.e. 5^{th}, 50^{th} and 95^{th} percentiles).

5.2.3 Deterministic Load Balance Model

Water quality predictions were also made in deterministic model runs (i.e., a single run with no probabilistic elements) and average hydrological conditions. In these cases, the mean annual precipitation (413 mm) was applied. This approach was taken to be consistent with the source terms, which were derived based on average hydrological conditions.

5.3 Water Quality Objectives

Predictions were evaluated in pit lakes and reservoirs at the Property as well as downstream prediction nodes. Figure 3-2 illustrates the selected downstream prediction nodes for the Goose Property. The prediction nodes were chosen to assess the flow and water quality effects from Project infrastructure and to optimize the required water treatment to meet water quality objectives.

Results were compared to Metal and Diamond Mining Effluent Regulations (MDMER) and site-specific objectives developed by ERM Rescan (Sabina 2015). The site-specific water quality objectives (SSWQOs) limit for arsenic and copper were committed to by Sabina at 0.01 mg/L and 0.0042 mg/L, respectively. The model compares water quality predictions at the following locations for compliance:

- PN-04 must meet MDMER limits.
- Goose Main Reservoir must meet MDMER limits.
- PN-03 must meet SSWQO limits.

5.4 Water Treatment

The water and load balance model was used to evaluate water treatment needs. Water quality predictions indicate that water treatment will be required to treat Llama TF effluent during Operations for the Project to meet MDMER discharge limits for total ammonia (15 mg/L) at PN04 when Llama TF overflows and site-specific limits for copper (0.0042 mg/L) at PN03.

Treatment will begin once tailings deposition starts at Llama TF and will continue until Llama TF overflows (Years 5 to 12). The treatment is proposed to be year-round at a flow rate of 8,500 m^3/day, and the WTP effluent will discharge at Llama TF.

Note that the water treatment plants during Construction, Operations, and Closure are modular, can be relocated, and combined as necessary to achieve the appropriate water treatment at different phases of the Project.

Table 5-1 summarizes the required treatment for the Goose Property during Construction, Operations, and Closure.

Table 5-1: Goose Property Treatment Summary

Phase	From	To	Start	End	Flow Rate (m^3/d)	Primary Constituent	Comment
Construction	Llama Lake	Goose Lake	Yr-1, Q3	Yr-1, Q3	13,000	TSS	Treat final 50% of Llama Lake volume. Open Water Season.
Construction	Umwelt Lake	Goose Lake	Yr-1, Q3	Yr-1, Q3	13,000	TSS	Treat final 50% of Umwelt Lake volume. Open Water Season.
Operations	Llama TF	Llama TF	Yr5, Q1	Yr11, Q2	8,500	Ammonia	Year-Round Treatment.
Operations	Llama TF	Llama TF	Yr10, Q1	Yr11, Q2	8,500*	Copper	Year-Round Treatment.

*In Goldsim, the model flow rates as low as 5,500 m^3/day used with an allowance of up to 8,500 m^3/day; although this upper end was not allowed to be utilized in the latest water and load balance runs, i.e. Copper did not need to be treated in model for that long / at those upper rates.

Source: \\srk.ad\DFS\na\van\Projects\01_SITES\Back River\1CS020.017_2019 Water Mgmt & Earthworks Design\1100_Water_Load_Balance\Inputs\BackRiver_WLB_Model_Inputs_Compiled_20200607.xlsx

6 Water Balance Results

6.1 Context

As described in Section 5.2, water balance results were generated by running the model as a Monte Carlo simulation. Results are presented for the 5th, 50th and 95th percentiles, where the 50th percentile represents the median of all outcomes. The median values represent the results that are most likely to occur, (i.e. which have the highest probability of occurrence). During Operations, when water storage is a key element, the median water volumes summarized represent several consecutive years of average precipitation or alternating dry and wet years. Only when several wet years occur in succession (which is relatively improbable) does the model produce results that show greater than median water volumes in pits and tailings storage facilities. For facilities with relatively short durations, as with some of the facilities modelled, consecutive wet years may be a likely occurrence that could have a significant impact on the operation of the facility. Consequently, the Monte Carlo simulation is an effective tool for simulating the effects of variable hydrology on a given facility.

Figures B-1 to B-7 presented in Appendix B illustrate water balance results for an average hydrological year during the four identified phases of the Project. These figures illustrate the water management strategy that was implemented for the Project, cumulative volumes and change in storage over the period of a specified Project phase.

The following sections provide a summary of water balance results using a stochastic approach. The results presented in the water balance schematics are based on a deterministic model run where it is expected that the 50th percentile result would be different than the average used in the deterministic model run.

6.2 Tailings Storage Facility

Tailings will be deposited in the TSF for a total of 6 years beginning Yr-1, Q4 of the Project. The Process Plant will take approximately 12 months to reach a steady state mill operation. At steady state, slurry will be pumped to the TSF with a composition of 2,500 m^3/d of solids and 3,400 m^3/d of process water. At the end of tailings deposition in the TSF, the total volume of solids deposited was 3.7 Mm^3 at a settled density of 1.2 tonne/m^3. Based on milling requirements, water will be reclaimed at an average rate of 2,100 m^3/d and 1,460 m^3/d will be lost to tailings voids. Contact water will continue to go to the TSF once Llama TF is active during a five-year period.

The water balance for the TSF was determined to be positive where water will be accumulated during the deposition period. Figure 6-1 illustrates the total volume in the TSF at end of deposition under stochastic conditions. Maximum total volumes are summarized in Table 6-1. The total solids volume deposited is 3.5 Mm^3.

Table 6-1: TSF Max Storage Volumes

Facility	Maximum Volume: 7,576,524 m^3		
	5th Percentile	50th Percentile	95th Percentile
Tailings Storage Facility	2,706,000 m^3	3,431,000 m^3	4,018,000 m^3

Source:\\srk.ad\dfs\na\van\Projects\01_SITES\Back River\1CS020.018_Type A Water License Water Mgmt\400_W&LBM\20_Appendices\Back River Water Balance Results_20200607_lmp.xlsx

Once deposition is complete, water will continue to be reclaimed in the TSF until the facility is dewatered to depth of 1.0 m in Year 12 and reclaim is switched to Llama TF.

These water balance results do not account for the co-disposal of the waste rock in terms of volumes in the TSF. Once waste rock begins to be placed on the TSF facility, beach runoff becomes waste rock runoff.

The TSF dam is breached approximately at Year 12, allowing WRSA runoff to flow by gravity into Goose Main Reservoir.

6.3 Saline Water Pond

Total inflows to the Saline Water Pond include groundwater from Umwelt Underground, groundwater and surface runoff in Llama Open Pit, and direct precipitation and natural runoff from within the Saline Water Pond catchment area.

Umwelt Lake, which will comprise a portion of the total Saline Water Pond footprint, has an initial volume of 240,000 m^3 and will be fully dewatered at a rate of 14,433 m^3/d prior to receiving saline water inflow.

Table 6-2 provides a summary of maximum volume of water within the Saline Water Pond for the 5th, 50th and 95th percentile water balance results.

Table 6-2: Saline Water Pond Maximum Storage Volumes

Facility	Maximum Volume 2,171,236 m^3		
	5th Percentile	50th Percentile	95th Percentile
Saline Water Pond	1,085,000 m^3	1,255,000 m^3	1,473,000 m^3

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The Saline Water Pond minimum design volume was selected as the 95th percentile result from the water balance.

6.4 Umwelt Open Pit and Umwelt Reservoir

Stripping the Umwelt Open Pit will begin in Year -1. After completion of the pit mining at Year 2, the facility becomes the Umwelt Reservoir and will be used to store saline groundwater inflows from Llama Open Pit and saline water from the Umwelt Underground. The Primary Pond is dewatered and breached, and contact water will drain by gravity to Umwelt Reservoir. Saline Water Pond is dewatered to the bottom of Umwelt Reservoir during the open water seasons of Year 3 and Year 4 at a rate of 13,000 m^3/day. A meromictic (non-mixing) lake is created with dense saline water at the base, overlain by less dense contact water.

Table 6-3**Error! Reference source not found.** summarizes total saline water pumped to Umwelt Reservoir and Figure 6-2 illustrates the total water volume (saline + freshwater) in the facility.

Table 6-3: Pumped Saline Water Volumes to Umwelt Reservoir

Result	5th Percentile	50th Percentile	95th Percentile
Total Saline Volume (m^3)	2,848,000	3,216,000	3,486,000

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6.5 Llama Open Pit and Llama TF

Llama Lake will be fully dewatered before being mined as an open pit. The initial 728,000 m^3 will be dewatered to Umwelt Lake and the final 243,000 m^3 will be dewatered to the Primary Pond due to high TSS. Mining of Llama Open Pit begins in the third quarter of Year 1, and saline groundwater inflows to Llama Open Pit are pumped to the Saline Water Pond.

In the second quarter of Year 5, mining of Llama Open Pit is complete and tailings deposition is transitioned from the TSF into Llama TF. The total amount of tailings solids deposited in Llama TF over seven years will be approximately 6 Mm^3. The containment dam for the Llama WRSA Pond is breached in Year 5, allowing contact water from the Llama WRSA to drain by gravity directly into Llama TF.

Additional contact water inflows to Llama TF include runoff collected in the Plant Site Pond. Reclaim water is sourced from Llama TF in Year 12 after TSF is dewatered in Year 12, Q2. Year-round water treatment in Llama TF is expected to be completed in Year 11, Q2, based on a rate of 8,500 m^3/d. Should water quality objectives not be met at this time, then water treatment in

Llama TF would be continued during open water season until ammonia and copper reach acceptable levels.

Figure 6-3 presents the total volume in Llama TF over time.

6.6 Goose Main Open Pit and Goose Main Reservoir

Goose Main Open Pit mining begins in the fourth quarter of Year 3, and pit dewatering flows will be pumped to the TSF, until mining is completed. Goose Main Open Pit becomes Goose Main Reservoir. Diversions around Goose Main Open Pit are breached once mining is complete.

Figure 6-4 presents the total volume in Goose Main Reservoir over time.

6.7 Primary Pond and Plant Site Pond

As previously stated, from the beginning of operations until closure, the Plant Site Pond will collect runoff from the ore stockpile. The Primary Pond is constructed in Year -2 to collect water across the site, including flows collected in the Llama WRSA Pond, runoff from the Umwelt WRSA, and pumped inflows from the Plant Site Pond and Umwelt Open Pit. The collected water is reclaimed to the Process Plant. The Primary Pond will be decommissioned once Umwelt Open Pit mining is complete, and the contact water will drain by gravity to Umwelt Reservoir.

Figure 6-5 presents the total volume in Primary Pond over time. Maximum total volumes are summarized in Table 6-4Table 6-1.

Table 6-4: Primary Pond Maximum Storage Volumes

Facility	Maximum Volume: 2,448,118 m^3		
	5th Percentile	50th Percentile	95th Percentile
Primary Pond	359,047 m^3	428,534 m^3	601,885 m^3

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6.8 Goose Lake

Freshwater for domestic use begins to be sourced from Goose Lake and Big Lake at the start of Year -3, and freshwater required for the Goose Process Plant starts to be pumped from Goose Lake at Year -1. During Llama Lake and Umwelt Lake dewatering, Goose Lake receives the total dewatered volume. Goose Lake continues to be pumped for mill make-up water during operations, and at closure, it receives the overflow from Llama TF, Umwelt Reservoir, and Goose Main Reservoir.

Figure 6-6 compares monthly average pre- and post-mining water levels in Goose Lake.

6.9 Summary of Pit Filling Times

Table 6-5 summarizes the time to fill pits and reservoirs at the Goose Property after mining operations are completed (Yr12, Q3). The timing of tailings deposition in the Llama TF and the overtopping timeline of this facility will be intrinsically linked. The Llama TF, as shown in the current model overtops in Year 11 Q2, based on average hydrological conditions, as it continues to receive tailings from the Process Plant until the fourth quarter of Year 12.

Based on site data and ongoing monitoring collected during Operations, adjustments may be required by Sabina to the site water management strategy in this area to ensure the Llama TF supernatant meets water quality objectives for reconnection to the receiving environment. The most logical adjustment identified, which will be confirmed during operations data collection, would be maintaining the contact and non-contact water infrastructure around the Llama Pit to reduce the amount of natural recharge collecting in the Llama TF, or pumping a portion of the Llama TF supernatant water volume to Goose Main reservoir. Any approach would be done while ensuring that MDMER results are being met and would be supported with the circular water treatment strategy being used during Operations at this mined out pit.

Table 6-5: Reservoir Fill Time

Facility	Result	5th Percentile	50th Percentile	95th Percentile
Llama TF	Fill Date	Yr11, Q2	Yr11, Q2	Yr11, Q1
	No. days	-386*	-339*	-301*
Umwelt Reservoir	Fill Date	Yr12, Q2	Yr11, Q2	Yr11, Q2
	No. days	-343*	-301*	2
Goose Main Reservoir	Fill Date	Yr14, Q2	Yr13, Q3	Yr13, Q2
	No. days	805	478	427

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*Note: negative values indicate that pit fills before Closure.

6.10 Prediction Nodes

In order to assess the effect of the Project to baseline hydrology, the change in monthly flows at each prediction node and water levels for Goose Lake, the 5th, 50th and 95th percentile water balance predictions are required. The percent change over baseline was calculated on an annual basis for each node for each year of the mine life, and for the long-term steady-state condition (see Figures 6-7 through 6-16).

Impacts to each node are:

- The prediction node PN01 has negligible effects from the Project as it includes a large catchment area compared to the Project infrastructure. PN02 and PN03 are located at the outlet of Propeller Lake and Goose Lake, respectively. These prediction nodes illustrate that during Operations and Closure, downstream flows are reduced as water is used on site for processing and pit filling. During Post-Closure, flows are greater than baseline as runoff coefficients from the Property infrastructure (i.e., frozen WRSA) are greater than natural conditions. Maximum change over baseline occurs in Year 9 when the pit lakes are being flooded.

- PN04 illustrate flows downstream of Llama and Umwelt Open Pits. Flows during Operations are lower than baseline because water from Project infrastructure is captured and used for Operations. Maximum change over baseline occurs in Year 11 when Llama TF overflows.
- PN07 flows are directed towards PN05 during Construction, Operation, Closure and Post-Closure. This is due to the Goose Main open pit being located immediately upstream of PN07 cutting off flows to PN07. PN05 receives the runoff flow from PN07 and represents discharge from Goose Main Open Pit. A portion of PN05 catchment spills to PN08 once the Goose Diversion is built and flows are diverted to Goose Main Pit once mining is complete. As expected, flows during Operations are lower than baseline as water from Project infrastructure is captured and used for Operations.
- PN06 is located at the outlet of Giraffe Lake and receives undisturbed and road runoff. PN06 catchment flows spill over PN04.
- PN08 is located at the Gander outlet. PN08 project flows are greater than baseline due to the spill flow from PN05 after Goose Diversion is built.
- PN09 is located at C4 culvert and PN10 is located at the Mam Lake outflow. Both nodes receive undisturbed and road runoff and change over baseline remains relatively constant throughout operations. PN10 project flows are greater than baseline because a portion of PN10 catchment spills over PN04 during high flows.

7 Water Quality Results

7.1 Goose Property Water Quality Predictions

Monthly average water quality predictions for total metal concentrations were evaluated for all open pits and downstream prediction points to understand the required water treatment and assess the parameters that are predicted to be elevated in comparison to MDMER and site-specific limits.

The predicted water quality concentrations are based on a deterministic modelling approach, assuming average hydrological conditions. This approach is consistent with the derivation of source terms, which are developed based on average hydrology. The predicted water quality under these conditions provides the most likely results to occur.

Table 7-1 summarizes the parameters modelled in the load balance model. Water quality predictions summarized in the following sections are presented only for the parameters of concern: ammonia, chloride, sulphate, arsenic and copper. Water quality predictions for remaining parameters and for all the facilities and nodes are included in Appendix D.

Table 7-1: Parameters Modelled in the Load Balance

TDS	Nitrite as N	Bismuth	Mercury	Thallium
Free CN as N	Alkalinity	Boron	Molybdenum	Thorium
Total CN as N	Ortho Phosphate	Cadmium	Nickel	Tin
WAD as CN	Phosphate	Calcium	Phosphorus	Titanium
CNO as N	TOC	Chromium	Potassium	Uranium
SCN as N	Hardness	Cobalt	Selenium	Vanadium
Sulphate	Aluminum	Copper	Silicon	Zinc
Chloride	Antimony	Iron	Silver	Zirconium
Ammonia as N	Arsenic	Lead	Sodium	
Nitrate as N	Barium	Lithium	Strontium	
Nitrate as N	Beryllium	Manganese	Tellurium	

7.2 Long-Term Steady State Predictions for Open Pit and TF Overflows

PN04 is located at the neck of Goose Lake, downstream of Llama TF and Umwelt Reservoir, and receives the flow from these facilities when flooding occurs.

Figure 4 to Figure 8 present the average monthly concentrations at PN04 for ammonia, chloride, sulphate, arsenic and copper. PN04 must meet MDMER limits for ammonia, arsenic and copper, although the prediction results show that MDMER limit for ammonia is exceeded after Llama TF overflows in the second quarter of Year 11.

Treatment for ammonia is proposed to begin at the operations phase, as soon as Llama TF starts to have tailings deposition. Treatment is expected to last for approximately 6 years at 8,500

m^3/day. The influent rate of the water treatment system will be optimized in subsequent engineering studies.

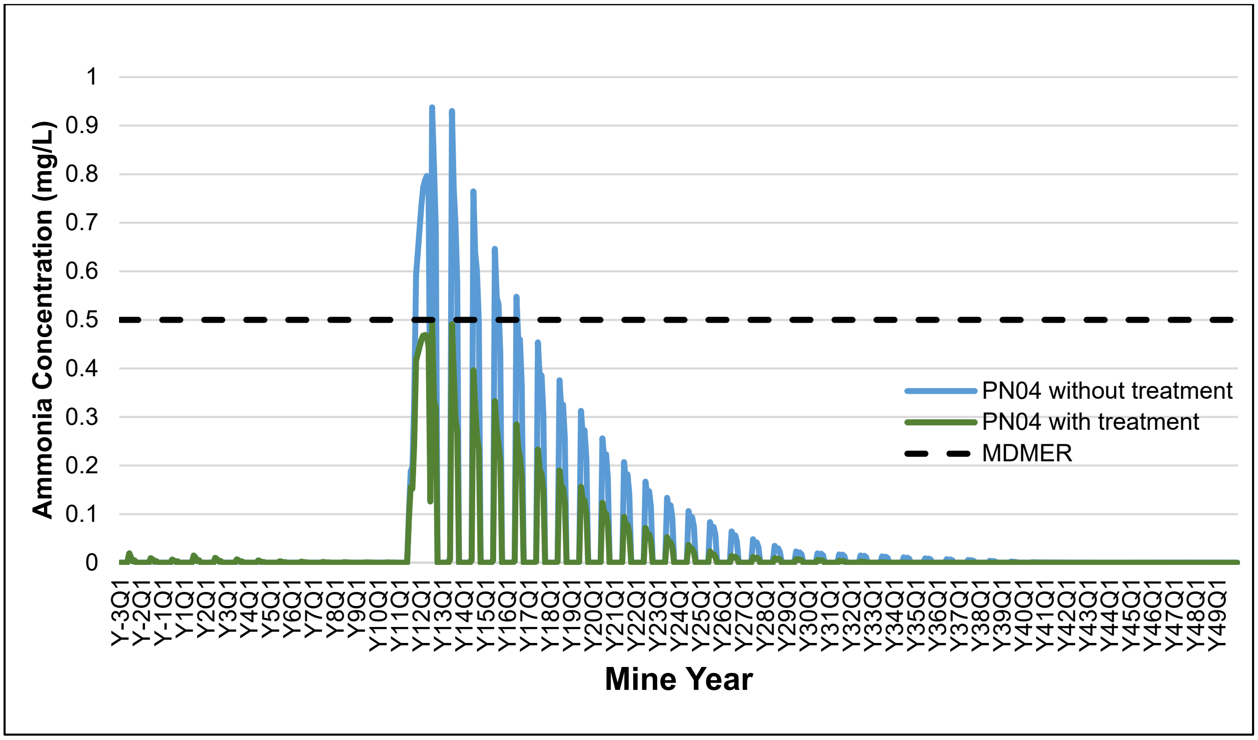

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Figure 4: Ammonia -nitrogen prediction at PN04

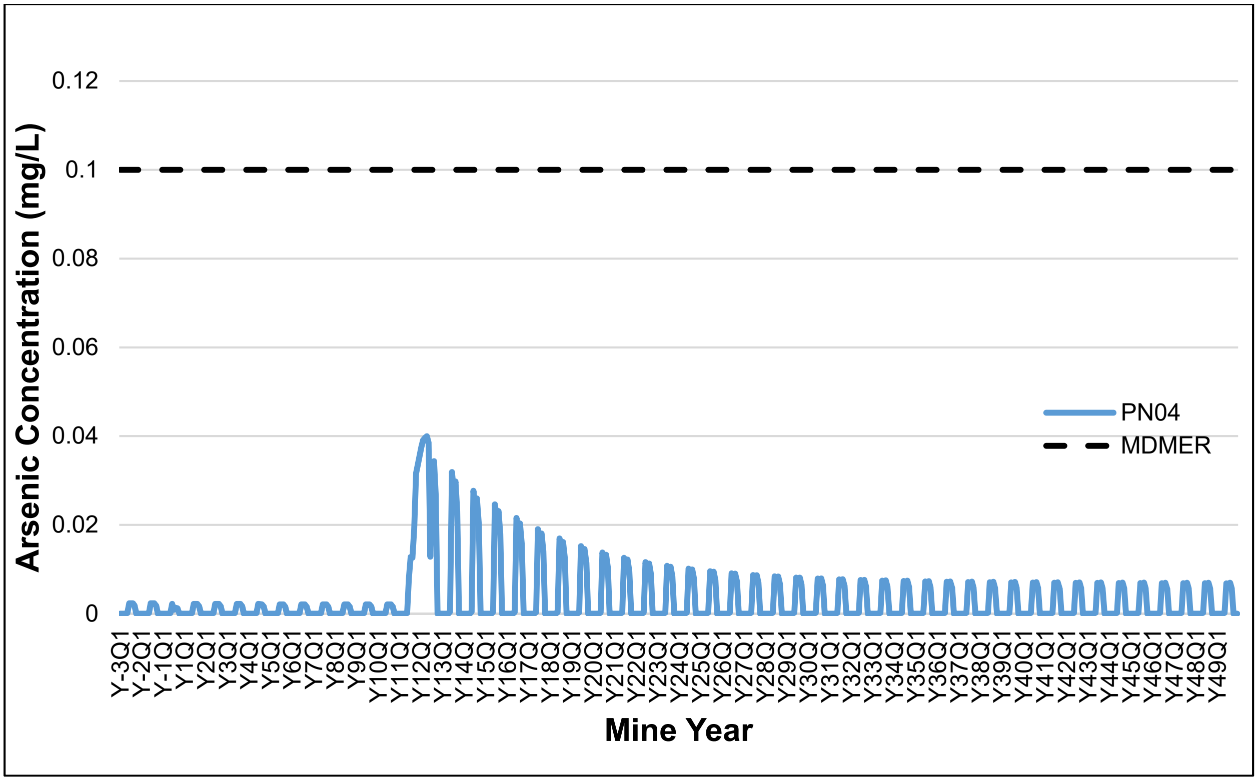

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Figure 5: Arsenic prediction at PN04

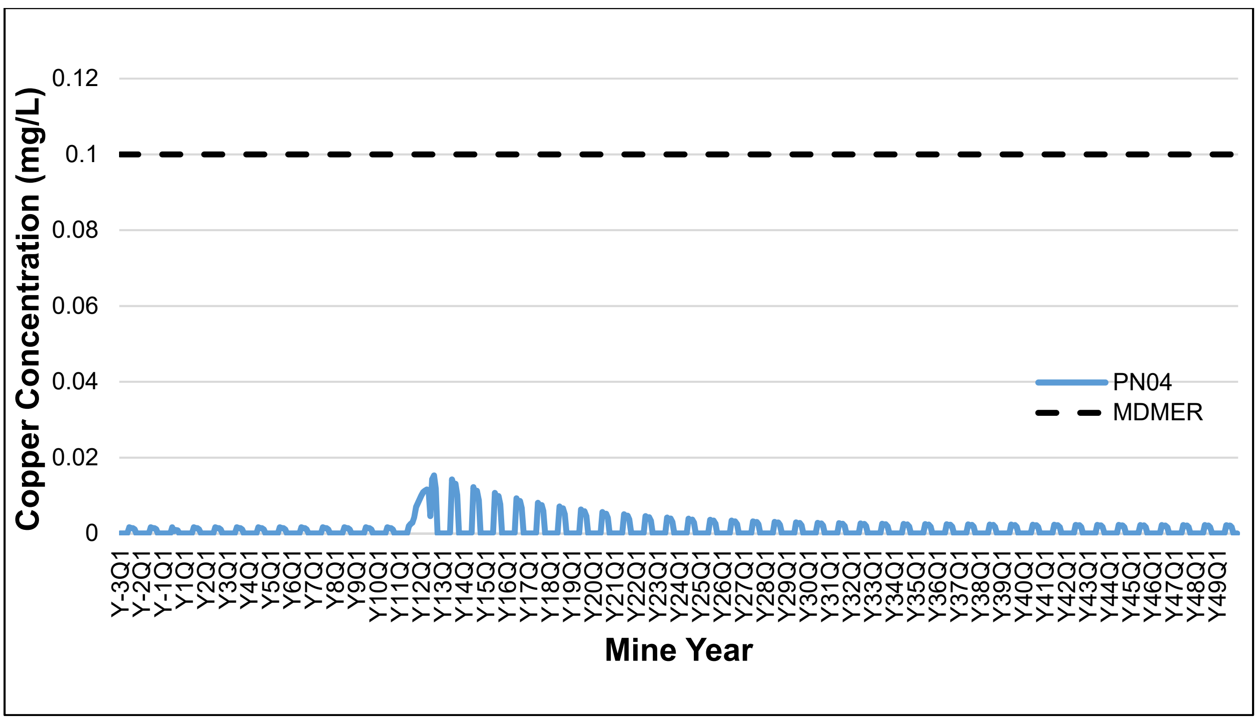

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Figure 6: Copper prediction at PN04

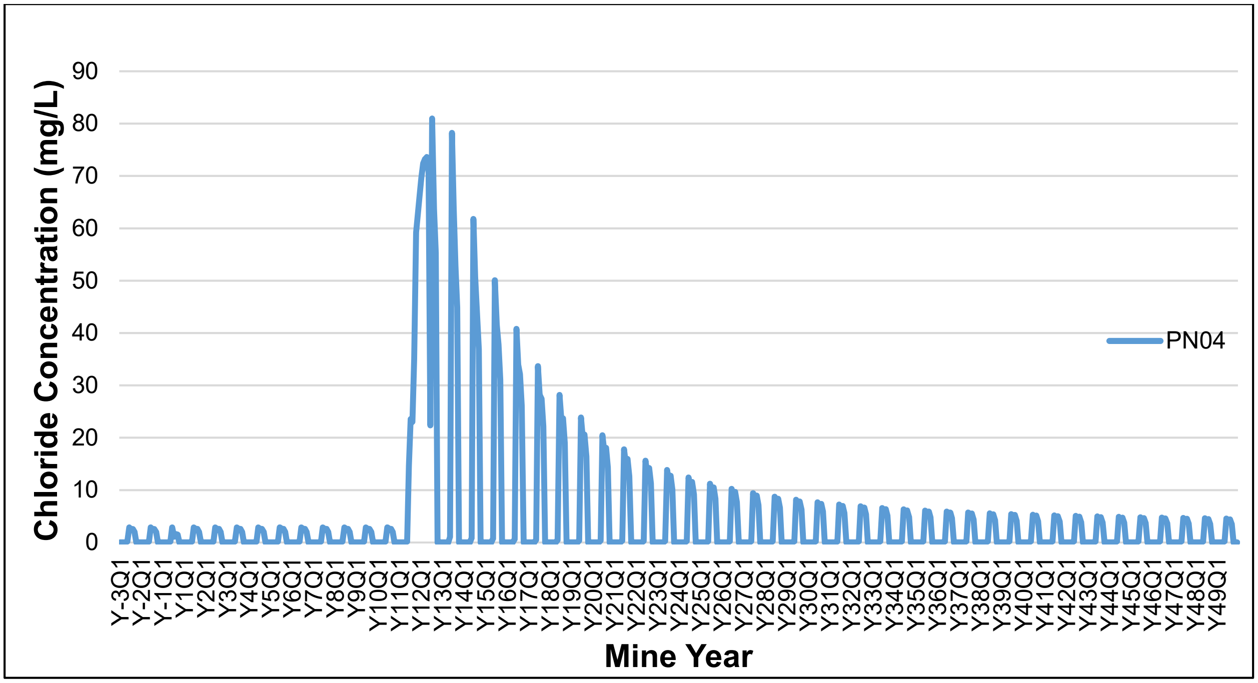

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Figure 7: Chloride prediction at PN04

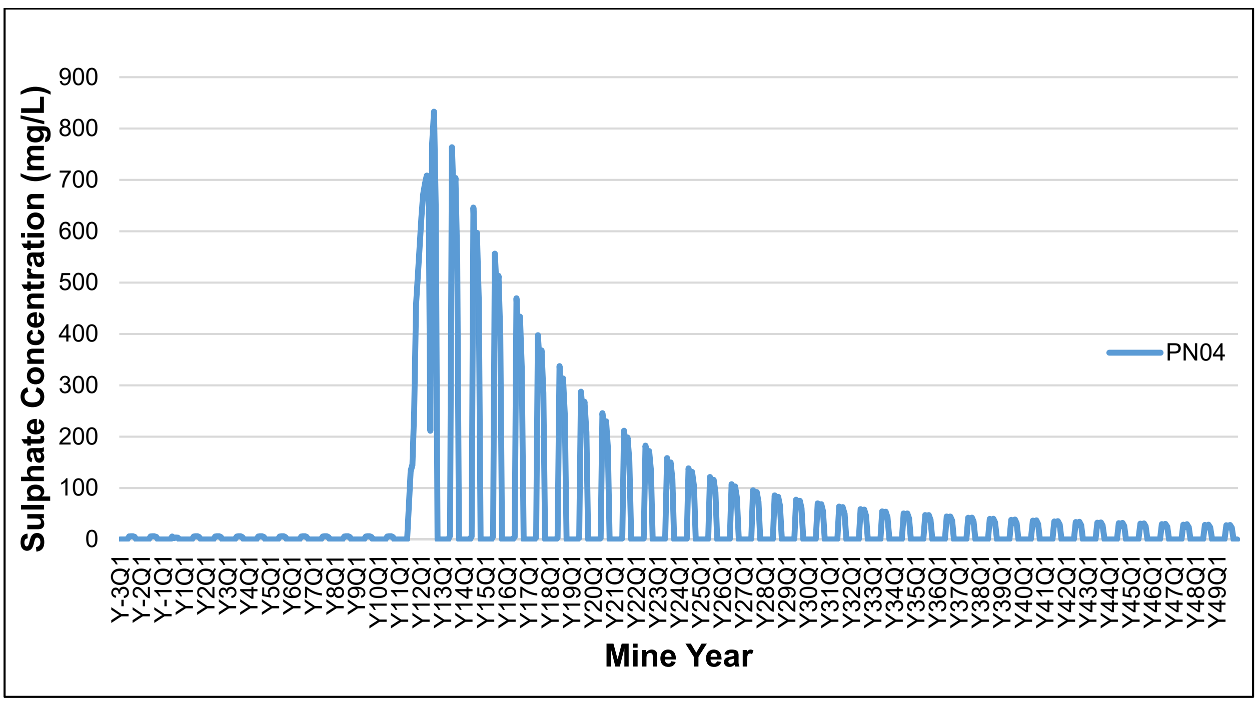

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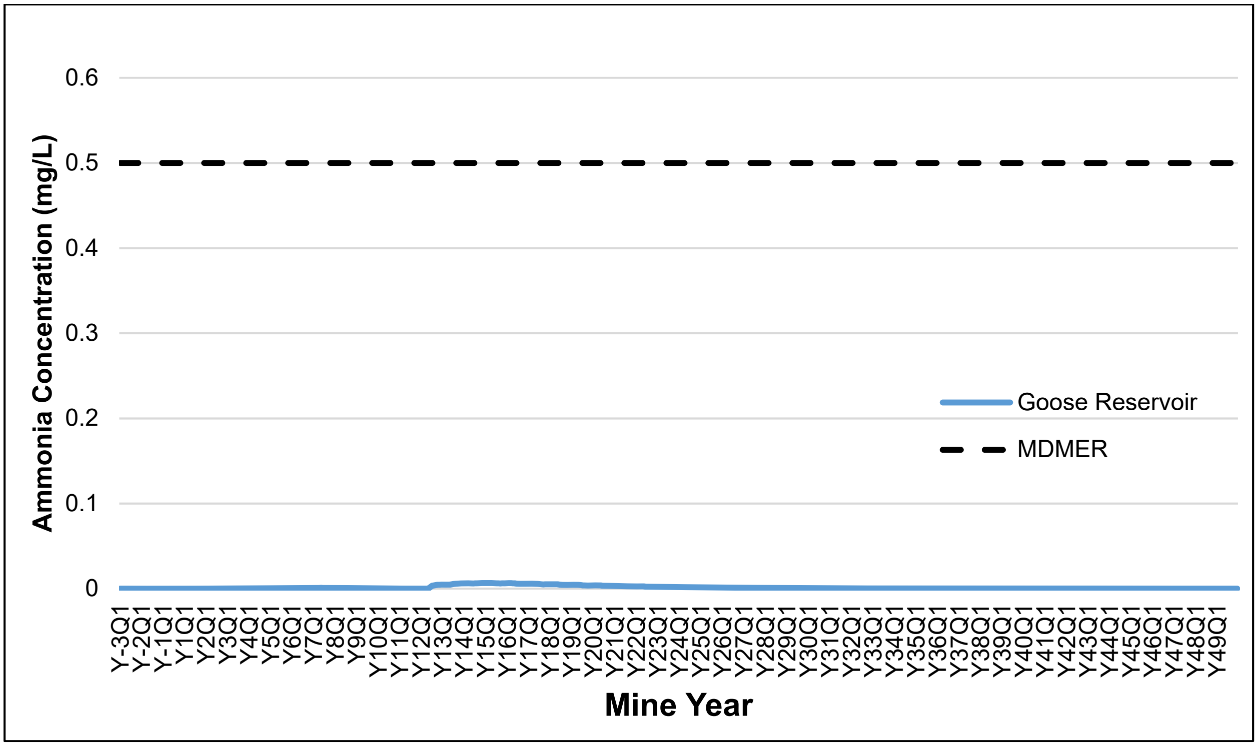
Figure 8: Sulphate prediction at PN04

Goose Reservoir is the facility upstream of the PN05 node, which is at the Goose Lake inlet. Therefore, Goose Reservoir also must meet MDMER limits for ammonia, arsenic and copper when it overflows in the second quarter of Year 13. The predictions for these parameters shown at Figure 9 to Figure 13 indicate that these are well below MDMER limits.



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Note: Total Ammonia limit calculated based on the average monthly MDMER limit of 0.5 mg/L of un-ionized ammonia, a pH of 8.1 and a temperature of 15C.

Figure 9: Ammonia prediction at Goose Reservoir

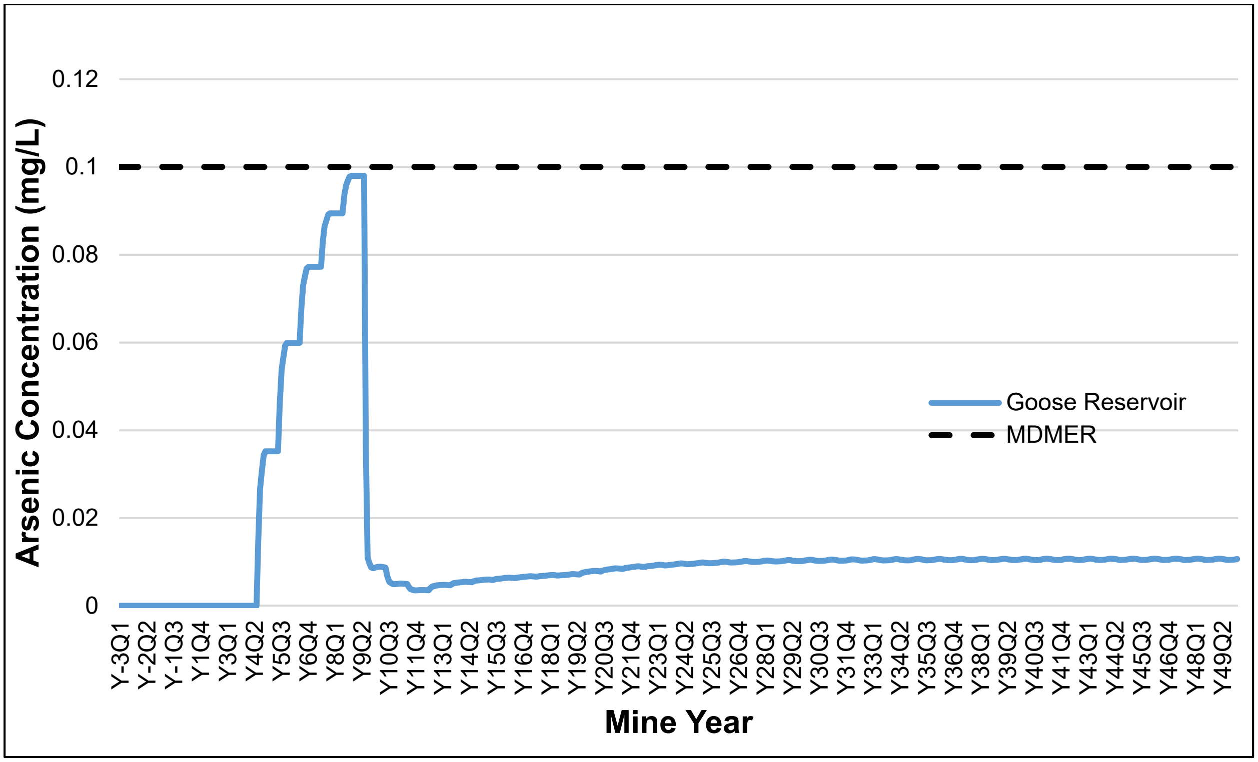

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Figure 10: Arsenic prediction at Goose Reservoir

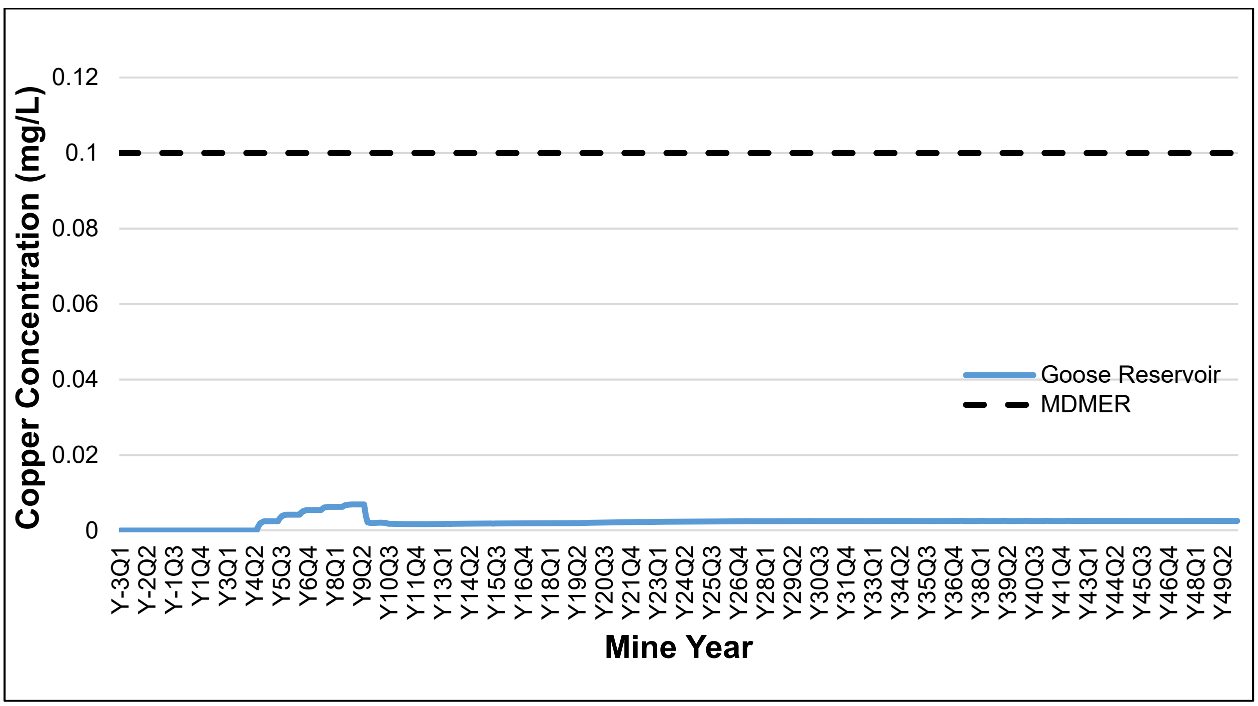

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Figure 11: Copper prediction at Goose Reservoir

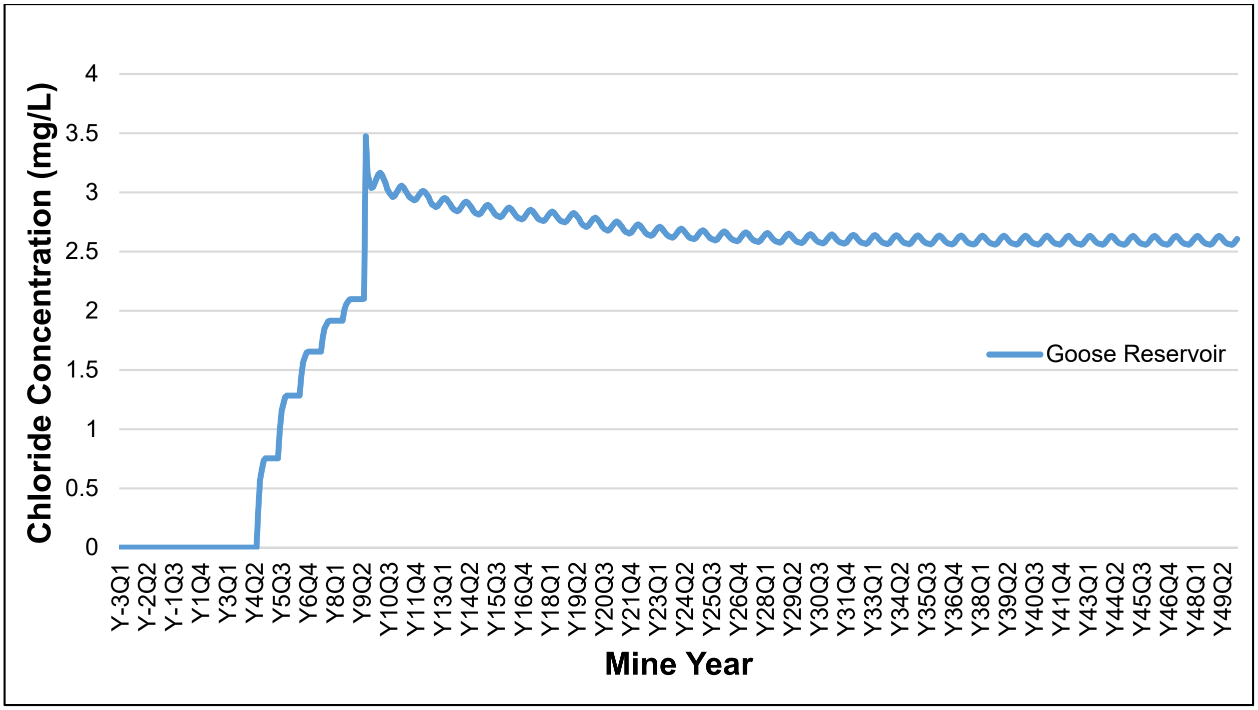

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Figure 12: Chloride prediction at Goose Reservoir

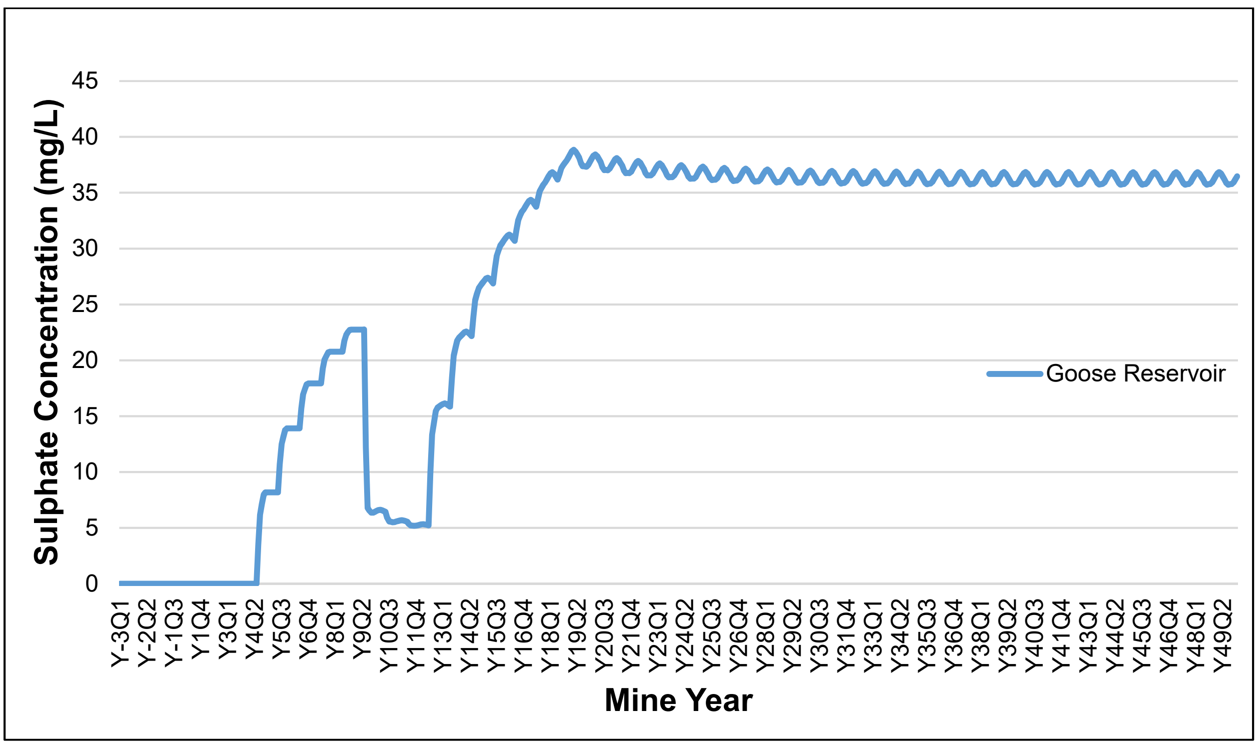

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Figure 13: Sulphate prediction at Goose Reservoir

7.3 Goose Property Downstream Water Quality Predictions

PN03 node is located at the outflow of Goose Lake towards Propeller Lake. Site specific limits were applied to this node. Figure 14 to Figure 18 present the average monthly concentrations at PN03 for ammonia, chloride, sulphate, arsenic and copper. Water quality predictions show that arsenic meets site specific limit at PN03, however copper exceeds the 0.042 mg/L limit in the third quarter of Year 13 and will require treatment. Ammonia concentrations at PN03 are lowered because of treatment.

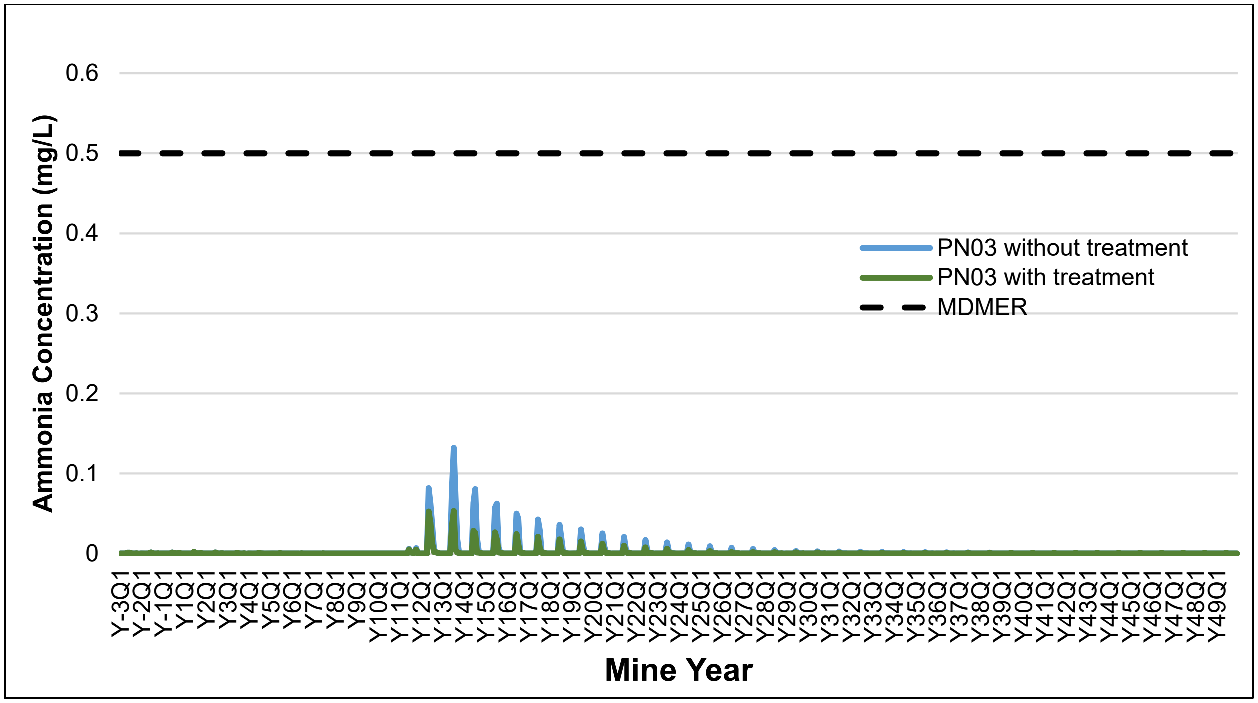

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Figure 14: Ammonia-nitrogen prediction at PN03

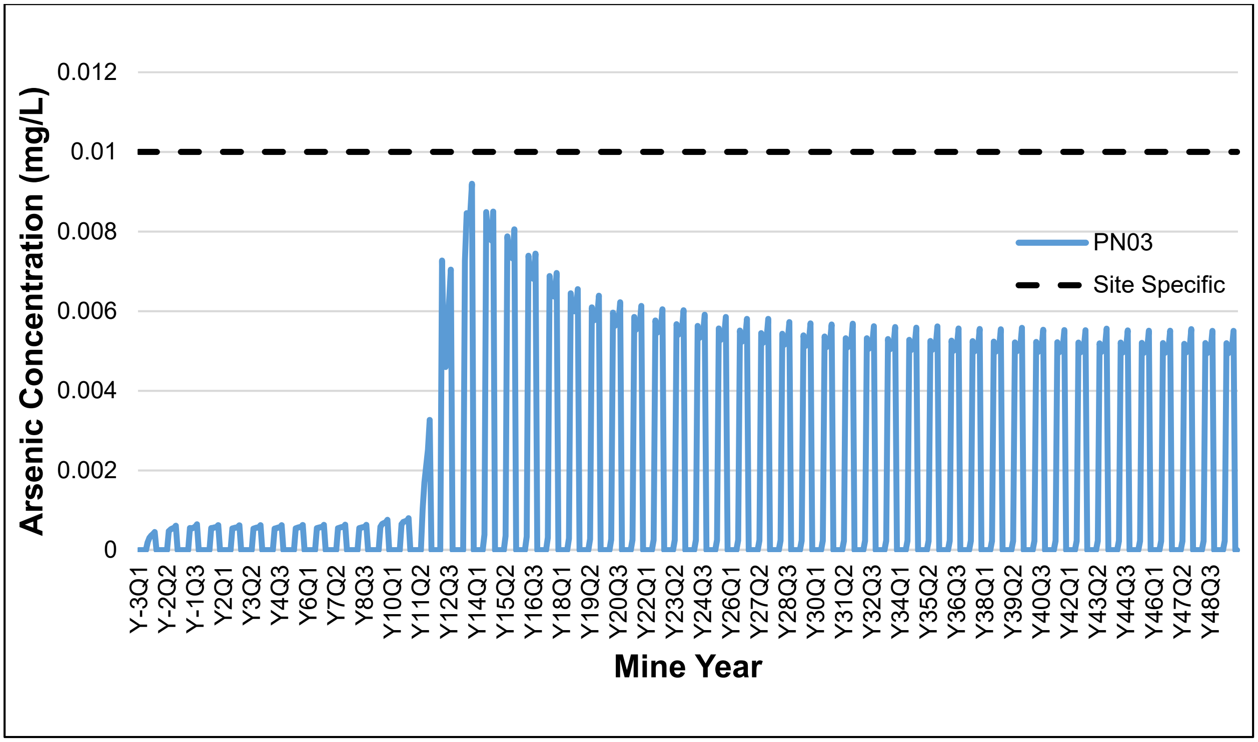

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Figure 15: Arsenic prediction at PN03

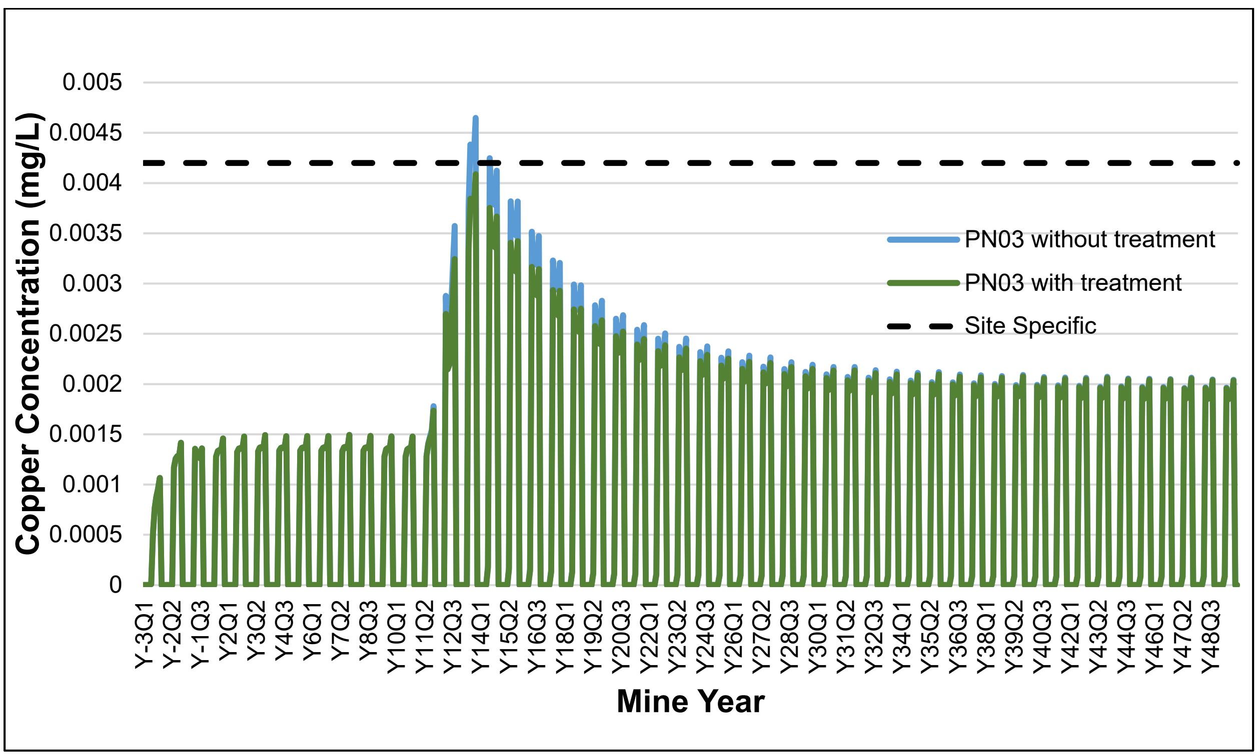

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Figure 16: Copper prediction at PN03

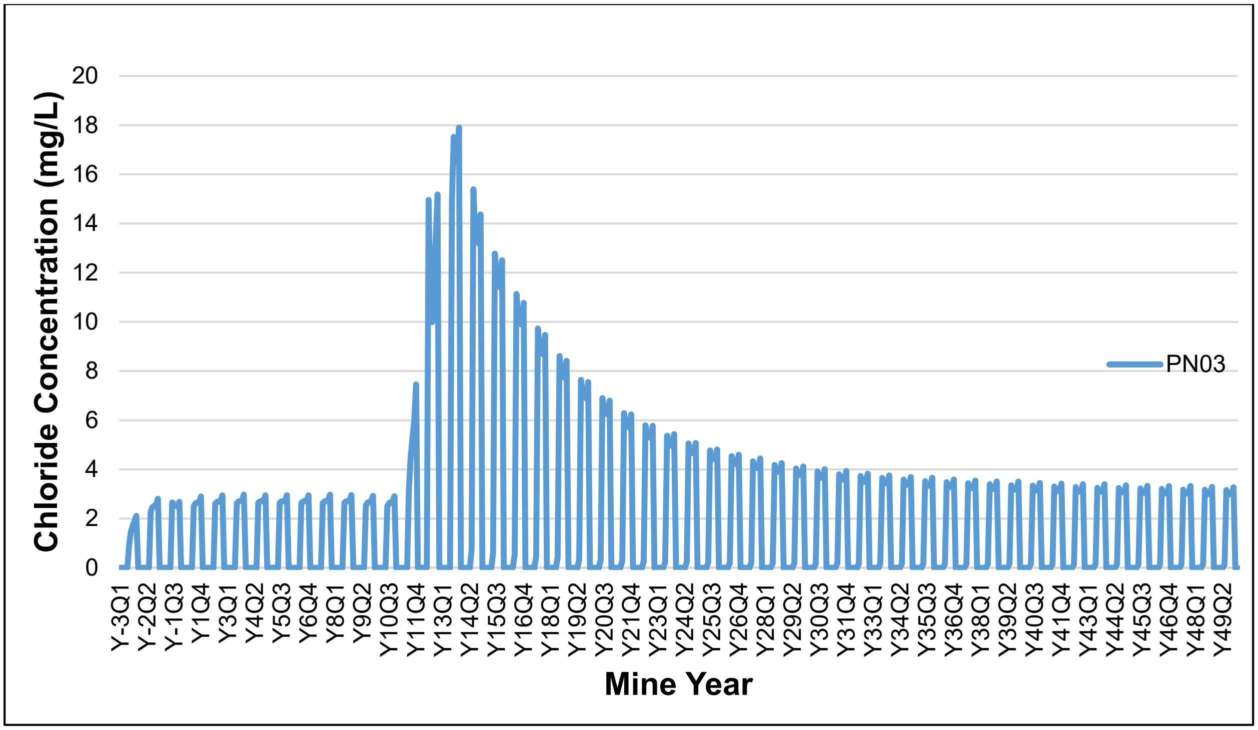

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Figure 17: Chloride prediction at PN03

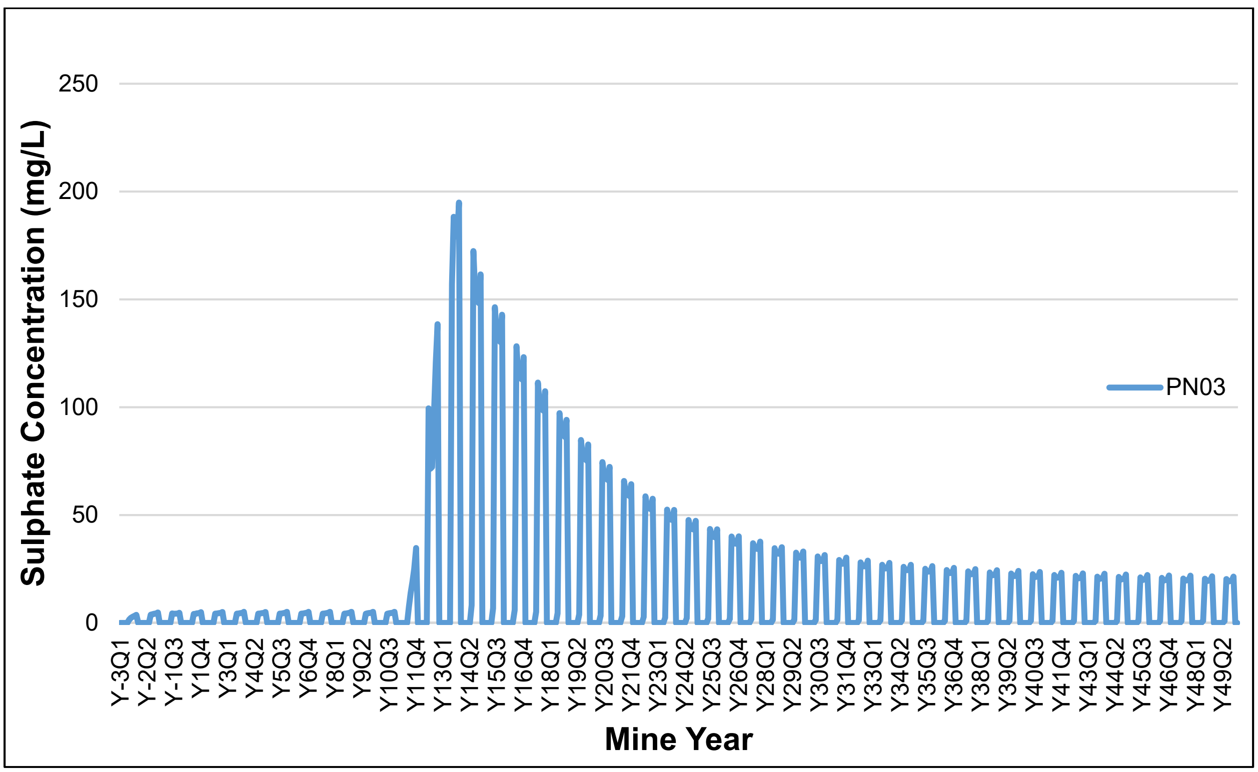

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Figure 18: Sulphate prediction at PN03

8 Limitations of the Water and Load Balance Model

8.1 Context

The model results presented in this report are based on the mine timeline, water management plans and best available input data. As with any model representing a complex system, there are a number of uncertainties associated with inputs and modelled processes. For most cases, uncertainties are accounted for by incorporating conservative assumptions. The following sections describe uncertainties that may affect the accuracy of the model results.

8.2 Hydrology Inputs

Hydrology inputs such as annual runoff, precipitation, evaporation, and monthly distributions were evaluated based on available local and regional data. Multiplying annual precipitation depths by a fixed monthly distribution does not reflect the true behaviour of hydrological systems. In some cases, a wetter year could occur based solely on a larger than average freshet with average or below average runoff during other months. This could lead to underestimates in required storage capacities during wetter years and in water supply requirements during dryer years.

In addition, the impacts of climate change on flow seasonality, including timing of freeze-up as well as thickness of lake ice, have not been fully captured in the constant runoff distribution. The following notes summarize potential impacts of this assumption to the model results:

- Shorter winter period could result in smaller snowpacks and therefore reduced snowmelt magnitude. However, the intensity of snowmelt may increase as a result of higher temperatures. These changes will be captured in the sizing of containment infrastructure.
- Thinner ice on lakes would result in a reduced effect of cryoconcentration. Current assumptions of thicker ice conditions are more conservative in terms of pond water quality predictions.
- The total monthly and annual volumes of water produced on site from precipitation may increase, which has been addressed through incorporation of climate change rates of change.

8.3 Runoff Coefficients

The undisturbed runoff coefficient of 0.36 is based on calibrated regional data. All other runoff coefficients for mine facilities were based on professional judgement and available documentation.

Two different runoff coefficients were applied to waste rock to illustrate the change in runoff from an unfrozen and frozen WRSA. As a conservative approach, SRK chose to apply a waste rock runoff coefficient of 0.3 and 0.6 for an unfrozen and frozen WRSA, respectively. A lower runoff coefficient would result in less water stored during Operations. In addition, a lower waste rock runoff coefficient for a frozen WRSA would result in longer pit filling times.

The model currently assumes runoff from the WRSA facilities will be collected at the toe of the dumps at the same timestep as the precipitation event, which does not account for temporary storage within the waste rock voids. Water collected in the downstream ponds is more likely to occur as a steady stream of seepage from the toe of the dumps, similar to baseflow in a stream. This may change pumping requirements from the ponds, but the total volume collected at the toe should remain the same.

8.4 Groundwater Inflows

Groundwater inflows are highly sensitive to assumptions relating to the hydraulic conductivity and permafrost. Further details on the assumptions used to evaluate groundwater flows and quality (TDS) profiles with depth are described in the Hydrogeological Characterization Report (2015b). A change in groundwater inflows during underground development could affect the sizing of the Saline Water Pond and total volumes pumped to the Umwelt Reservoir.

8.5 Geochemical Factors

A number of geochemical factors that are not reflected in the model, such as attenuation of parameters along surface and subsurface flow paths, tailings diffusion, and removal of chemical loads in open pits and tailings storage facilities, may affect the total loads included in the model and the water quality predictions presented in this report.

The model accounts for solubility controls in process water and waste rock and ore runoff.

8.6 Dry Bulk Density of Tailings

A 1.2 tonne/m^3 bulk density was applied to tailings deposited in the TSF and Llama TF. Variations in the placed density of tailings will affect the volume of water stored in the tailings pore space and the remaining capacity of the facilities modelled. Depending on the potential discrepancy between actual and modelled densities, water quality loadings and volumes of water to be managed during Operations could be overestimated or underestimated.

8.7 Water Treatment

Final rates for water treatment will be determined based on the detailed design and actual water treatment systems purchased by Sabina. When additional clarity is known on these treatment rates (specifically for ammonia and TSS treatment) then updates to the water and load balance would be expected to be required. At this time, when additional clarity on treatment systems is know, then the assumptions on the treatment processes and rates presented in this water and load balance, along with the associated timelines, can be re-examined.

8.8 Fully Mixed Conditions and Cryoconcentration

In order to simplify the model, water quality predictions were evaluated assuming completely mixed systems. This may not reflect the true behaviour of parameters flowing through the system. In some cases, flows may not fully mix in a lake, causing higher than predicted concentrations at the outlet.

During under-ice conditions, the model conservatively assumes that there will be 100% exclusion of parameters from the ice, resulting in higher concentrations in the water bodies. The majority of available baseline water quality data for the Project are during the summer season. However, available datasets for April and May do not exhibit increased concentrations as the modelled cryoconcentration suggests. Water quality predictions during under-ice conditions may be overestimated.

8.9 Ammonia Load Prediction

The main sources of ammonia in Back River are the ammonium nitrate used for blasting and the sodium cyanide used in the leach circuit. The previous version of the model did not for accumulation of soluble constituents in process water as the water is recycled through the mill. Accounting for ammonia accumulation results in concentrations exceeding guidelines at discharge if no treatment is pursued.

Ammonia generated in the mill was calculated assuming that the total nitrogen concentration after the leach circuit was the total nitrogen in WAD cyanide concentrations reported on the test work from JDS (2015). The ammonia fraction of WAD-N was determined by the breakdown of the cyanide degradation products developed for the process water source terms. If the processing of the ore is changed, ammonia predictions may also change.

9 Conclusions

The water and load balance model for the Project was created to provide water quantity and quality estimates based on the mine and production schedule and water management plans. The model was created to optimize the water management strategy and tailings deposition schedule, and to evaluate water treatment needs during Construction, Operations, and Closure to meet water quality guidelines. Water quality predictions were evaluated in all open pits, tailings facilities, and predefined locations downstream of the Goose Property. Results were compared to Metal and Diamond Mining Effluent Regulations (MDMER) and site-specific water quality objectives developed by ERM Rescan (Sabina 2015).

Water quality predictions indicate that treatment during specific periods of Construction, Operations, and Closure will be required to meet MDMER discharge limits and site-specific guidelines in the downstream environment. At the Goose Property, discharges during Construction will be treated for TSS. During Operations, water from the underground development of Umwelt and the Llama open pit will be intercepted, stored in the Saline Water Pond and pumped into Umwelt Reservoir once the open pit development is completed. In order to lower ammonia and copper concentrations prior to end of Operations, year-round treatment will be required during Llama TF deposition to meet MDMER limit for ammonia at PN04 and site-specific criteria for copper at PN03.

This report, “Back River Project Water and Load Balance Report”, was prepared by SRK Consulting (Canada) Inc.

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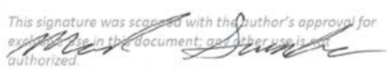
Staff Consultant



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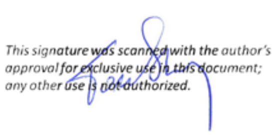
and reviewed by:

Samantha Barnes, PEng
Consultant



Tom Sharp, PhD, PE, PEng
Principal Consultant

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.

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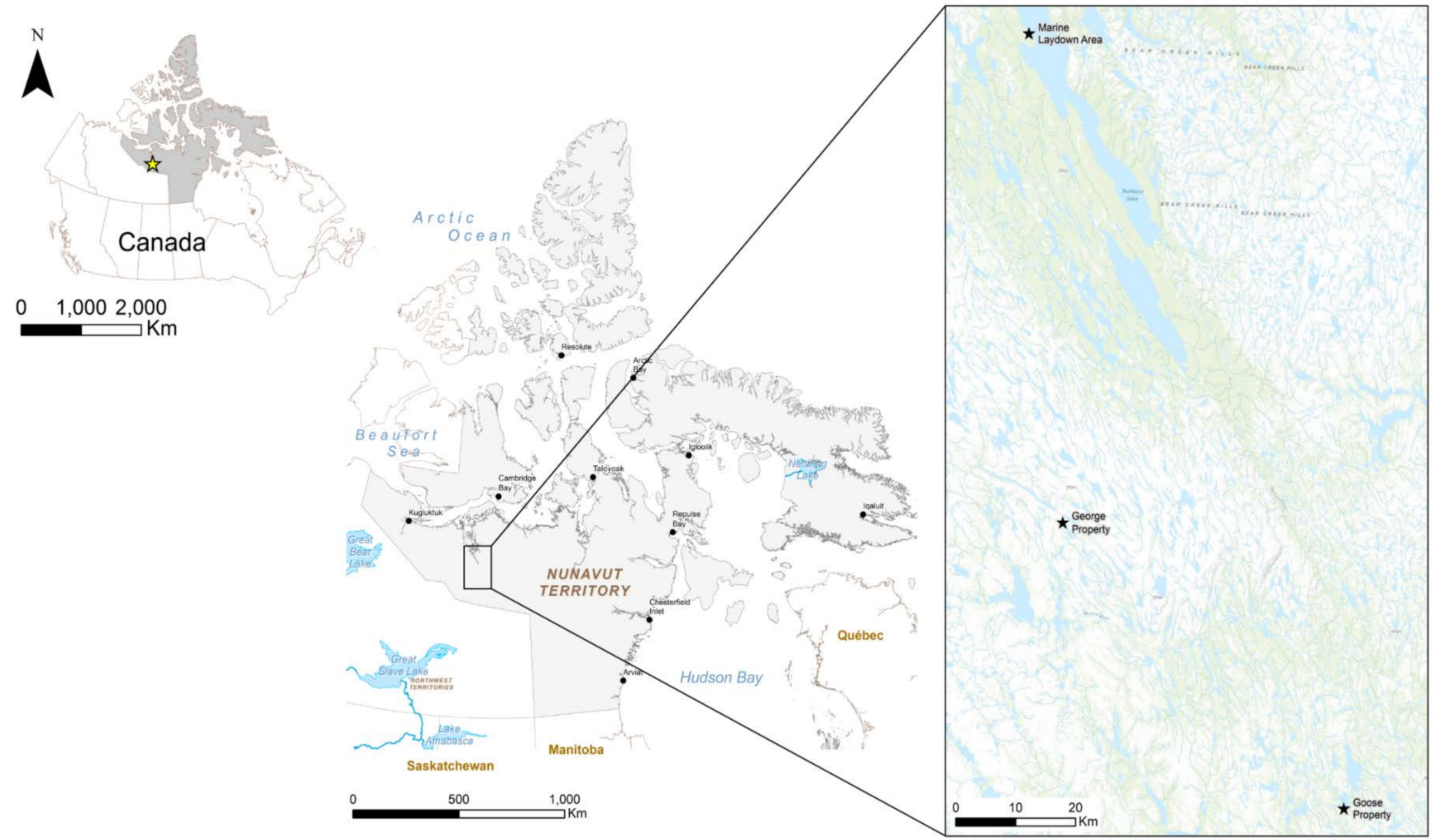
Figures Attachment



Coordinate System: NAD 1983 UTM Zone 13N

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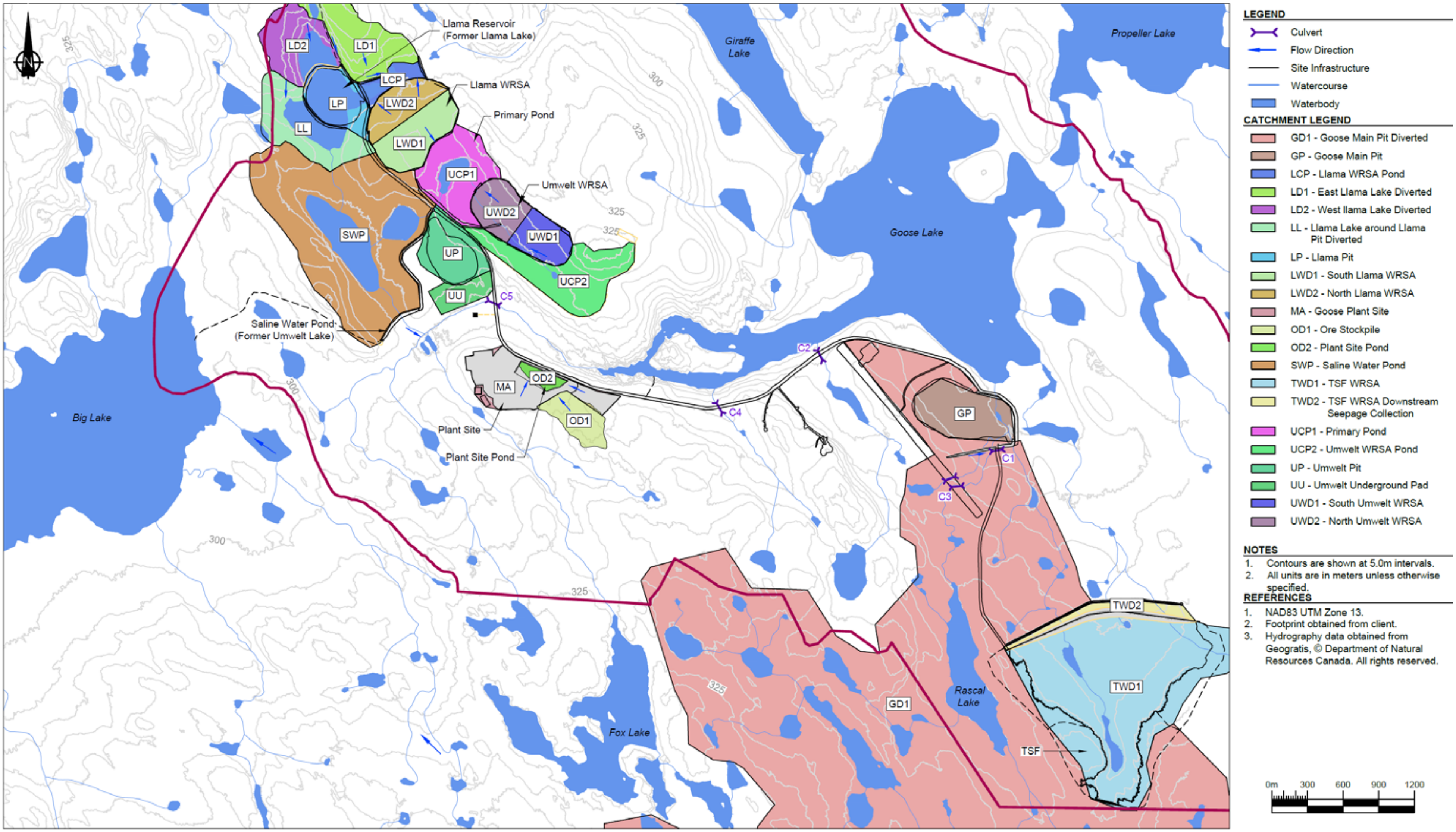
srk consulting	Sabina GOLD & SILVER CORP.	Water and Load Balance Report **Site Location Plan**
Job No: 1CS020.018 Filename: Figures_WLB_Report.pptx	Back River Project	Date: June 2020 | Approved: JBK | Figure: **1-1**



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Water and Load Balance Report

Goose Property

Job No: 1CS020.018

Filename: Figures_WLB_Report.pptx

Back River Project

Date: June 2020

Approved: JBK

Figure: 3-1

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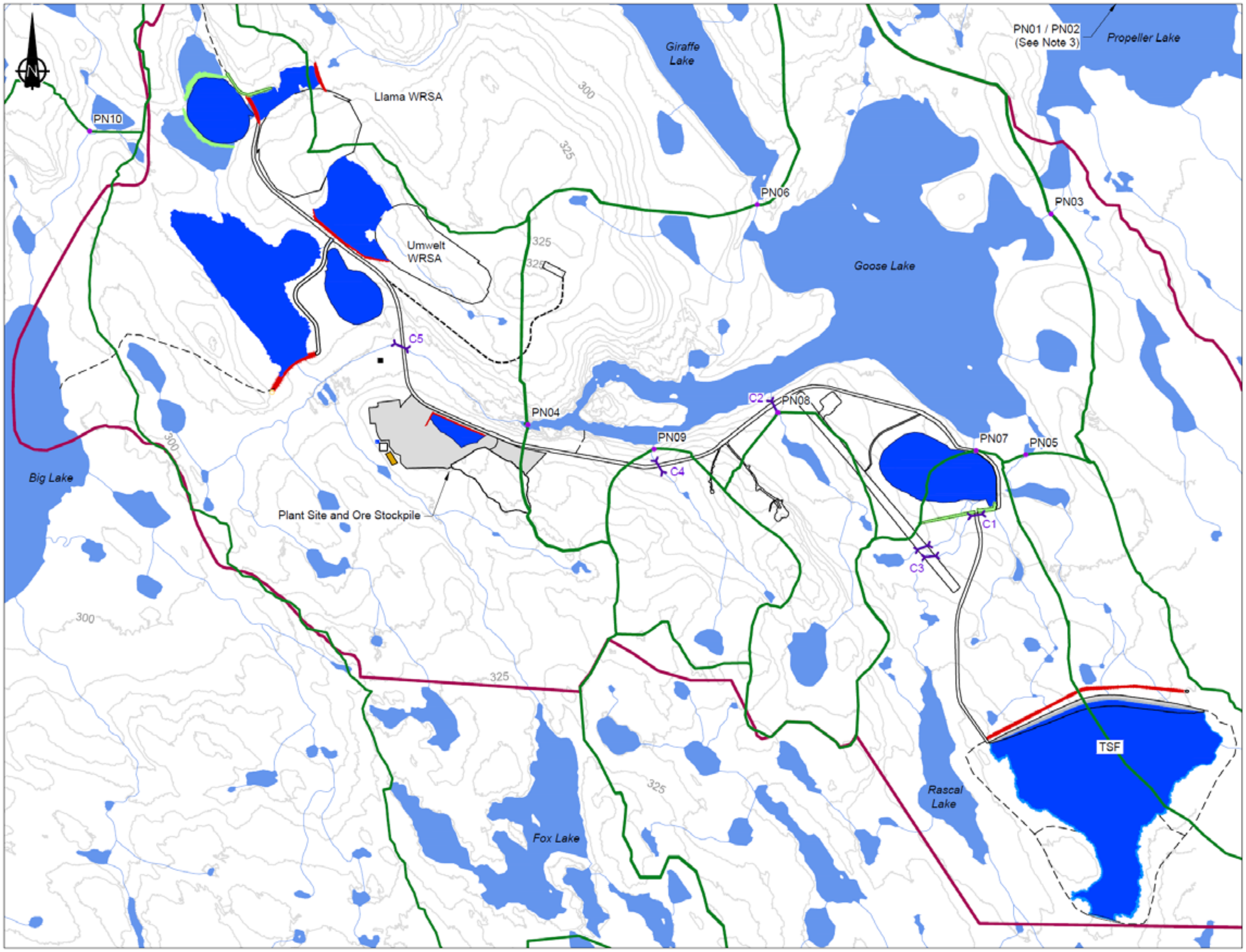

LEGEND

- Prediction Note (W&LB)
- Culvert
- Site Infrastructure
- Watercourses
- Pre-mining Catchments
- Contact Water Containment Dam(Lined)
- Non-contact Water Diversion Berm(Unlined)
- Landfarm
- Pond / Sump Location
- Potential Development Area
- Waterbody

NODE LEGEND

Node ID	Easting	Northing	Name
PN01	492324	7341050	Ellice River at RDA (See note 3)
PN02	435853	7479860	PL-H1 Propeller Outflow (See note 3)
PN03	434920	7271480	CP4 Goose Outflow
PN04	431063	7269930	CP1 Goose Inflow – Goose Neck
PN05	434733	7269710	CP3 – East of Goose Pit
PN06	432754	7271550	Giraffe Outflow
PN07	434367	7269740	CP3a Downstream of Goose Pit Diversion
PN08	432907	7270020	GL-H3 Gander Outflow
PN09	431994	7269750	CP2 Echo Outflow
PN10	427834	7272090	Mam Lake Outflow

NOTES

1. Contours are shown at 5.0m intervals.
2. All units are in meters unless otherwise specified.
3. PN02 located at Propeller Lake outlet, PN01 is downstream of Propeller Lake outlet.

REFERENCES

1. NAD83 UTM Zone 13.
2. Footprint obtained from client.
3. Hydrography data obtained from Geogratis, © Department of Natural Resources Canada. All rights reserved.

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Water and Load Balance Report

Water and Load Balance Prediction Nodes and Catchment Areas

Job No: 1CS020.018

Filename: Figures_WLB_Report.pptx

Back River Project

Date: June 2020

Approved: JBK

Figure: **3-2**

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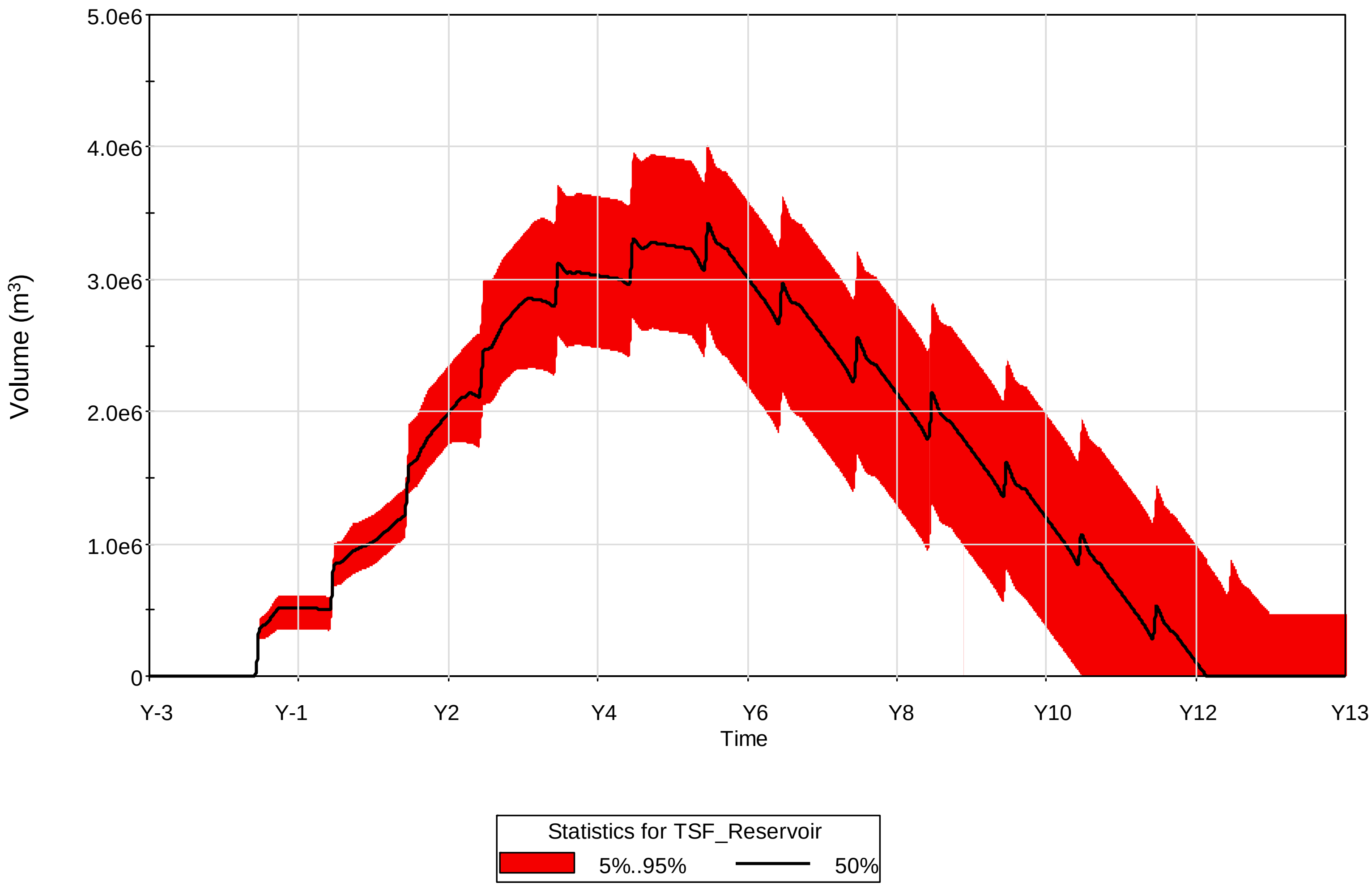

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Water and Load Balance Report

TSF Storage Volume

Job No: 1CS020.018

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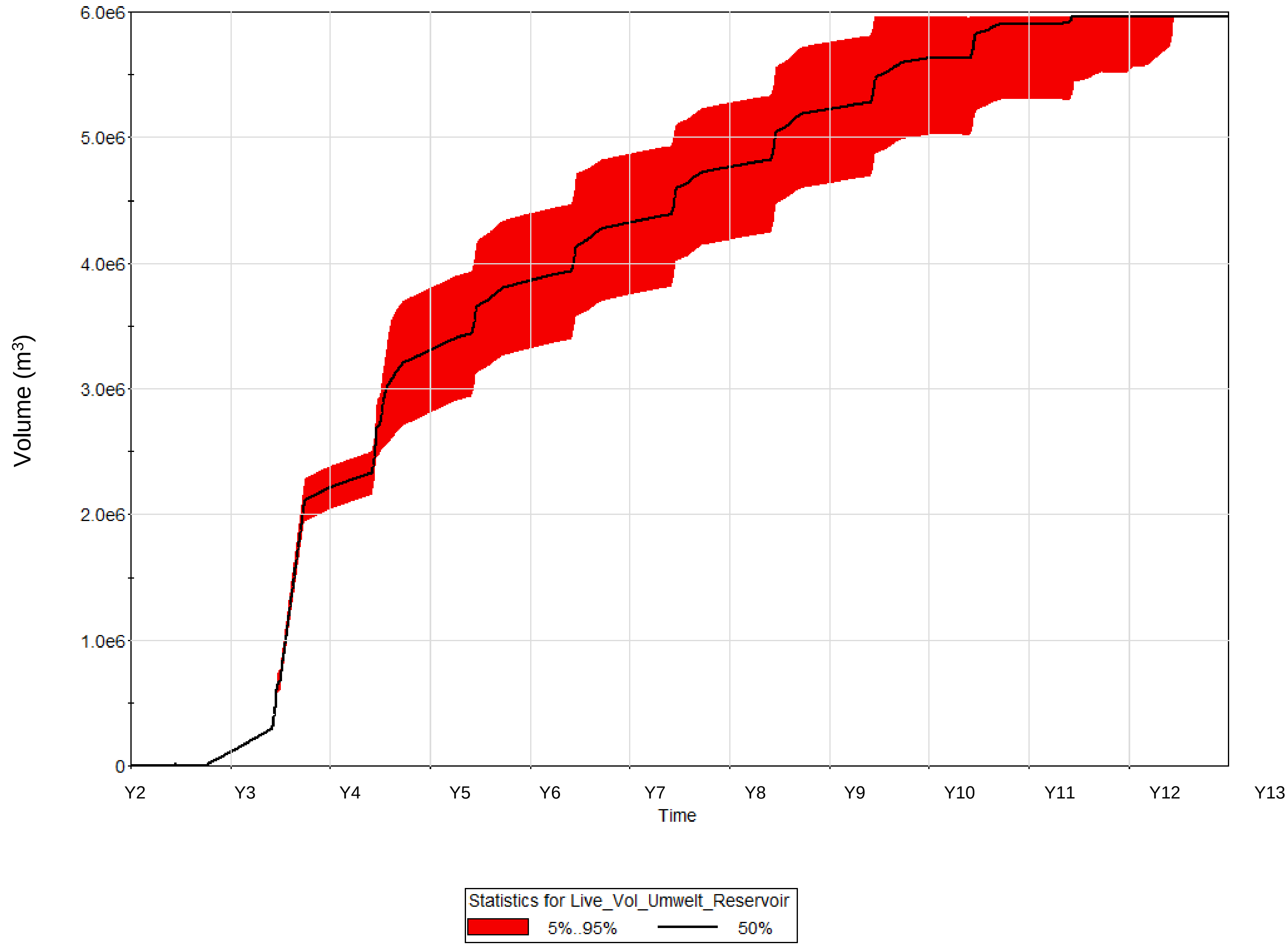
Back River Project

Date: June 2020

Approved: TRS

Figure: **6-1**



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Water and Load Balance Report

Umwelt Reservoir Storage Volume

Job No: 1CS020.018

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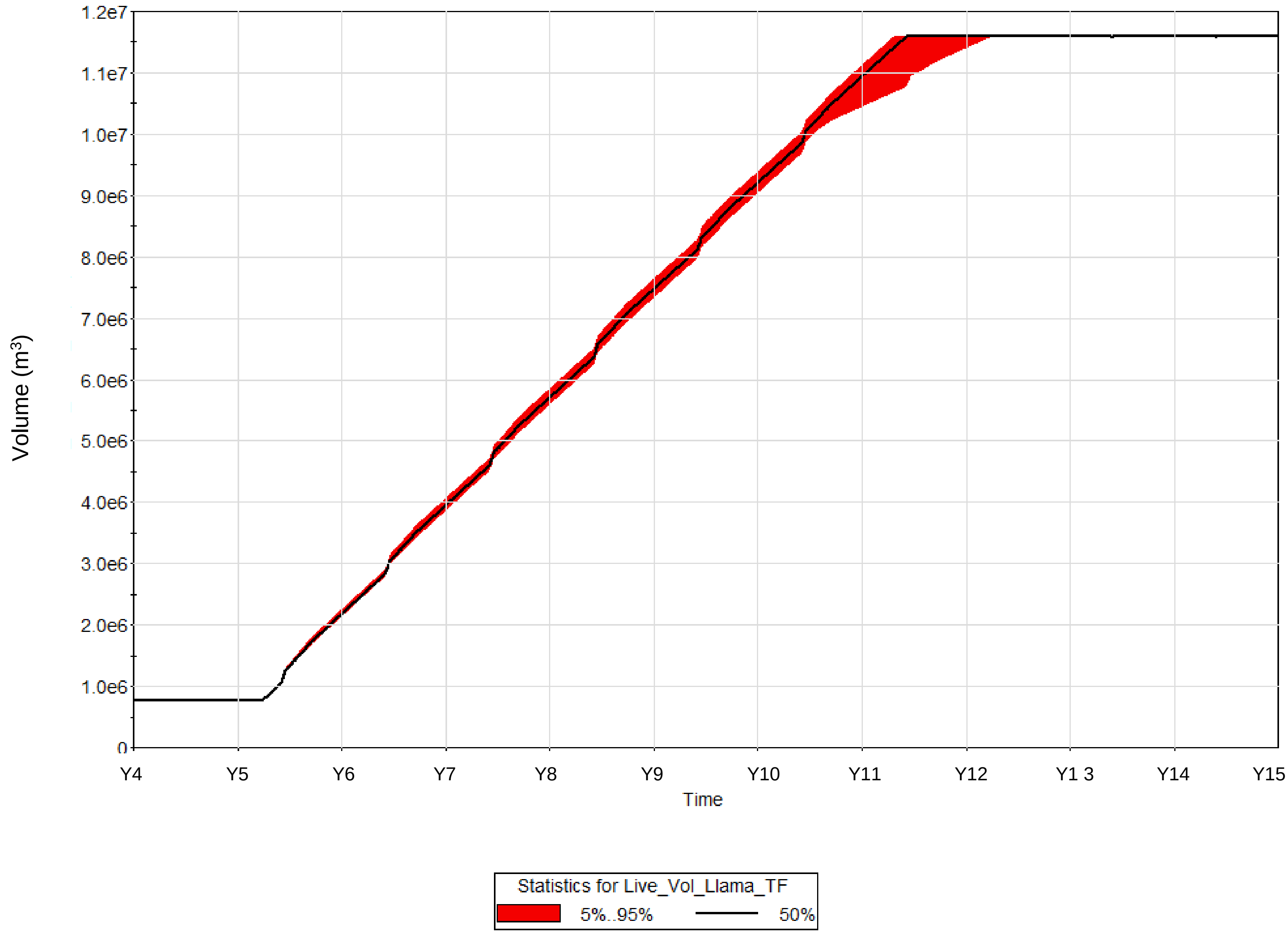
Back River Project

Date: June 2020

Approved: TRS

Figure: **6-2**



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Water and Load Balance Report

Llama TF Storage Volume

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Back River Project

Date: June 2020

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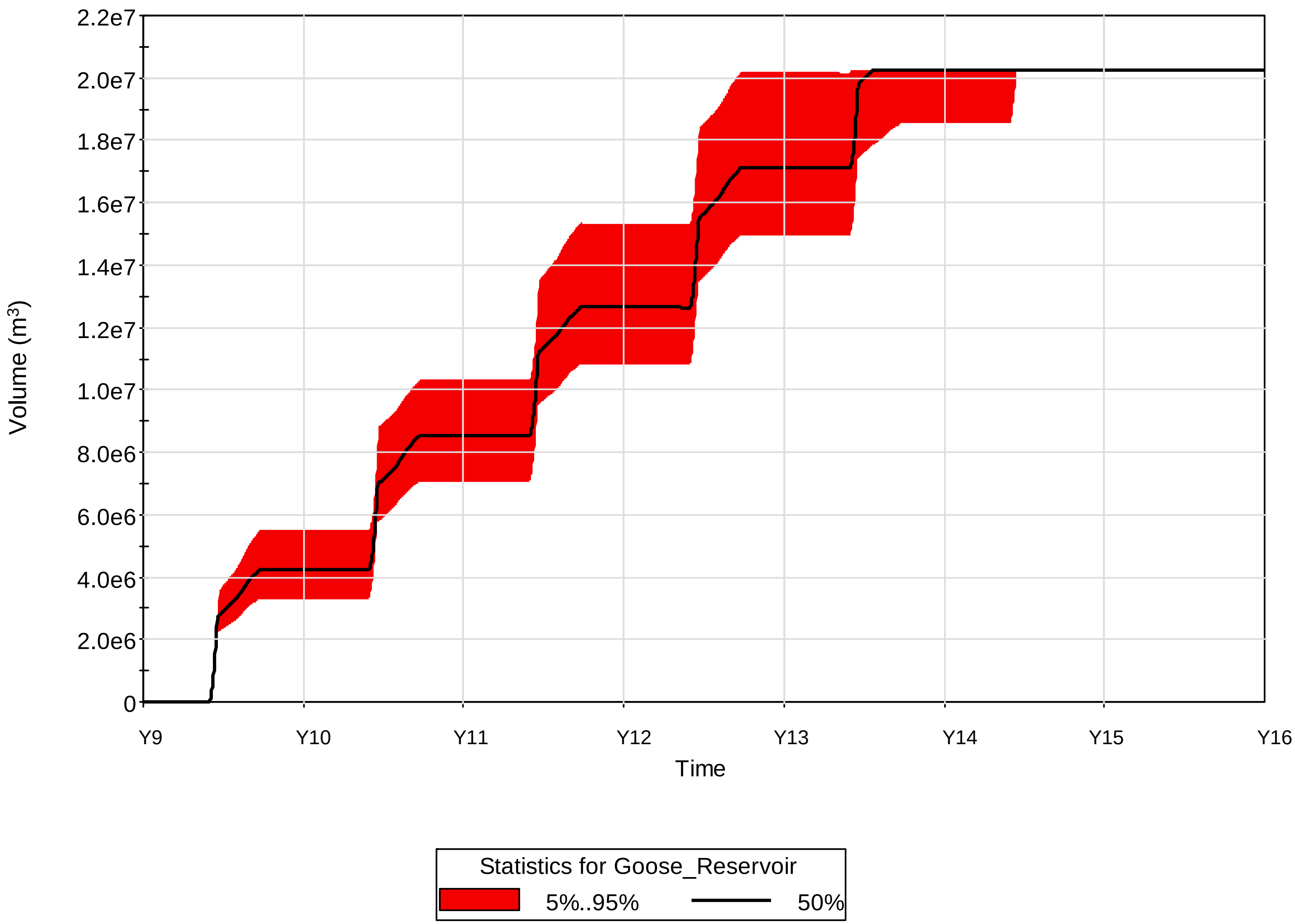
Figure: **6-3**



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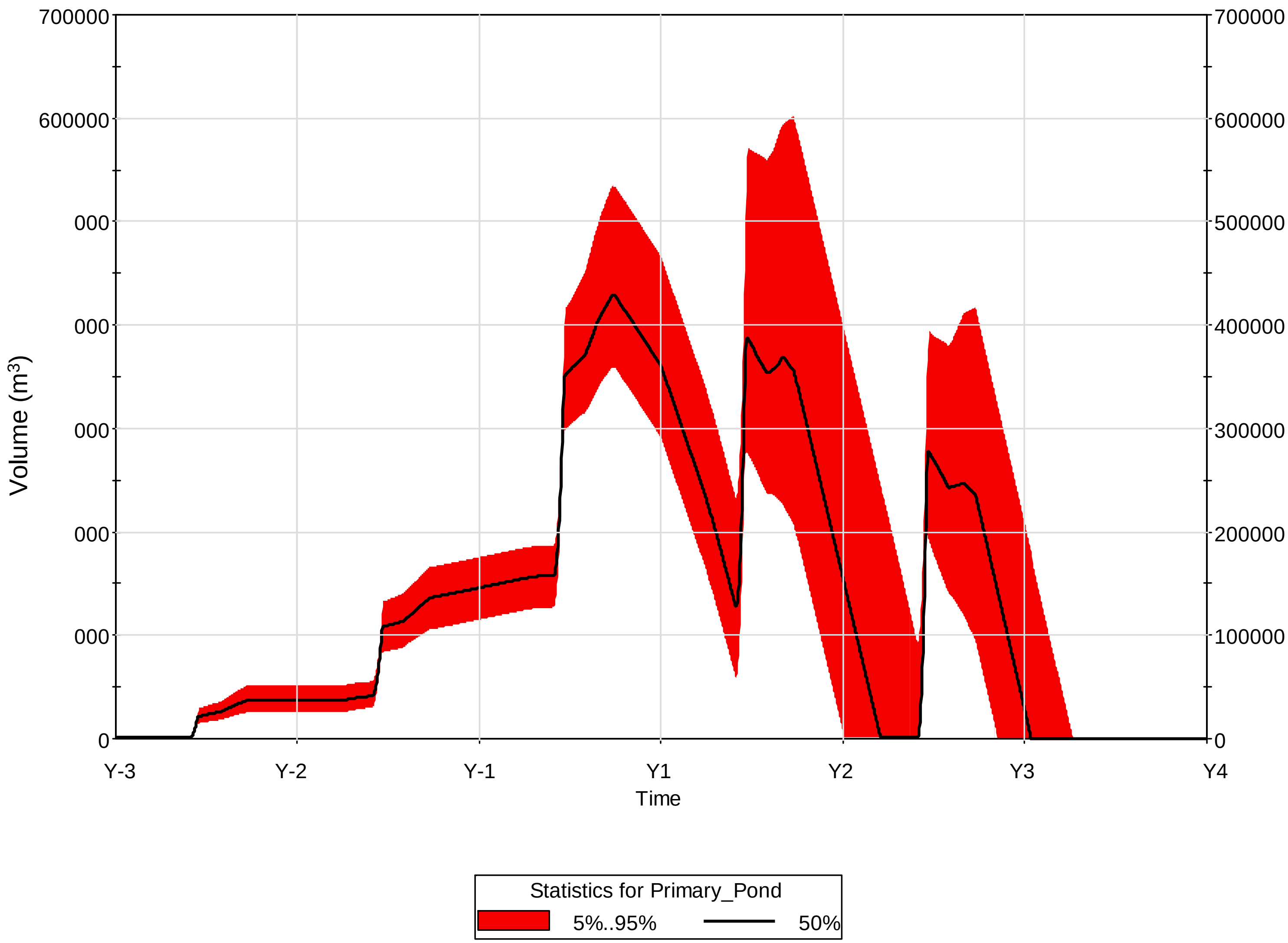
		Goose Main Pit Storage Volume
Job No: 1CS020.018 Filename: Figures_WLB_Report.pptx	Back River Project	Date: June 2020	Approved: TRS	Figure: **6-4**



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Water and Load Balance Report

Primary Pond Storage Volume

Job No: 1CS020.018

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Back River Project

Date: June 2020

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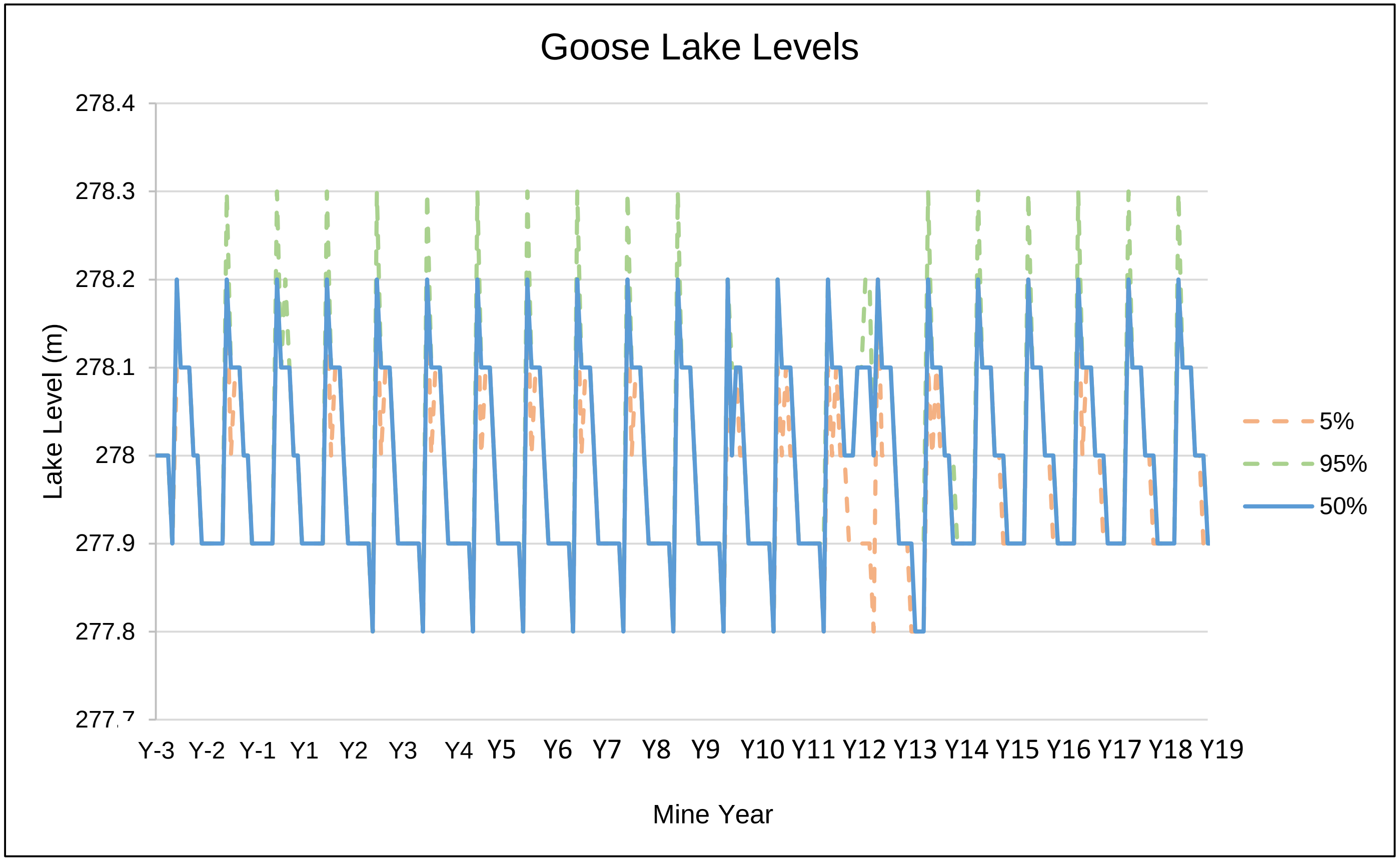
Figure: **6-5**



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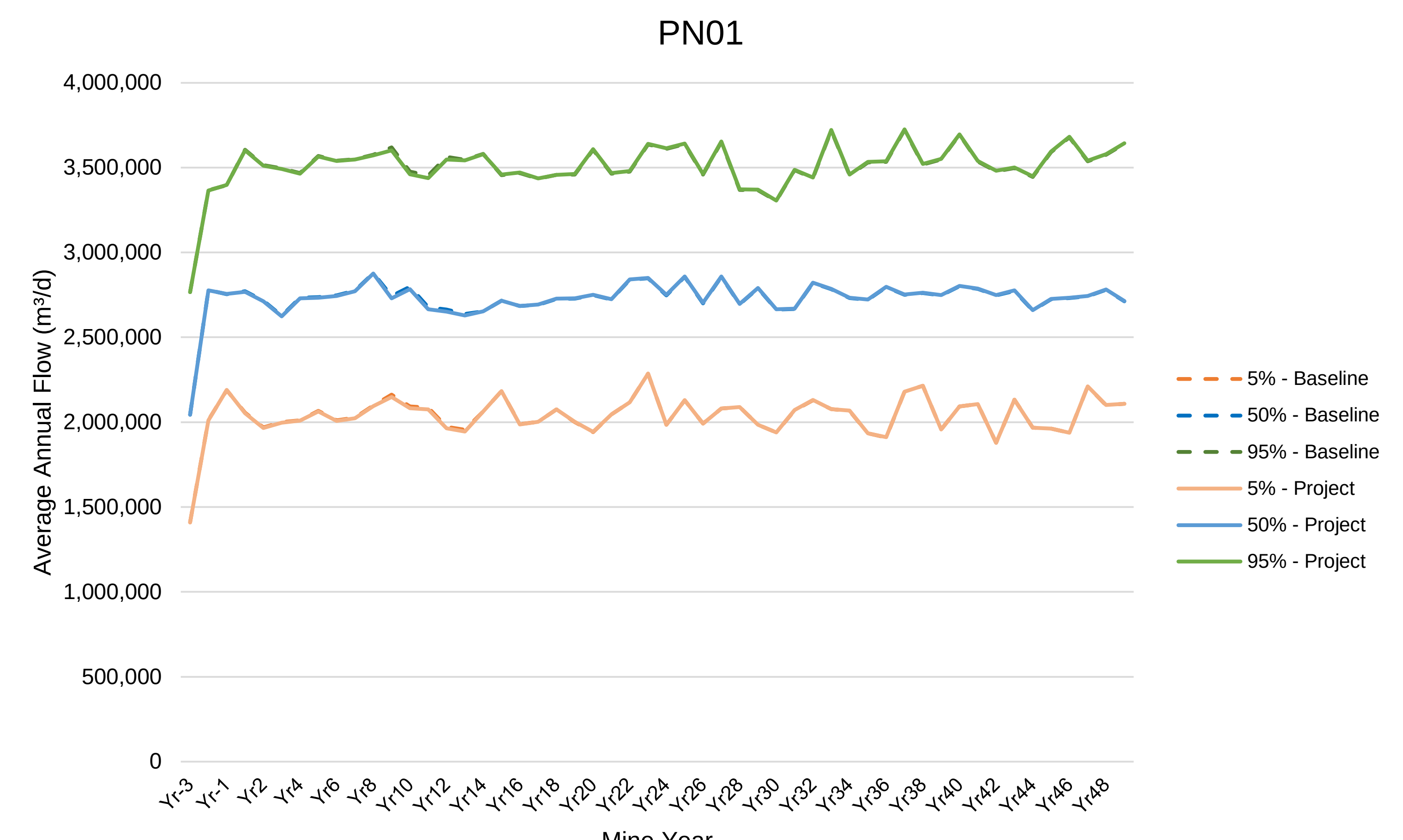
Water and Load Balance Report

Goose Lake Average Monthly Water Levels

Job No: 1CS020.018
Filename: Figures_WLB_Report.pptx

Back River Project

Date: June 2020
Approved: TRS
Figure: **6-6**



Note: PN01 baseline and project flows overlap.

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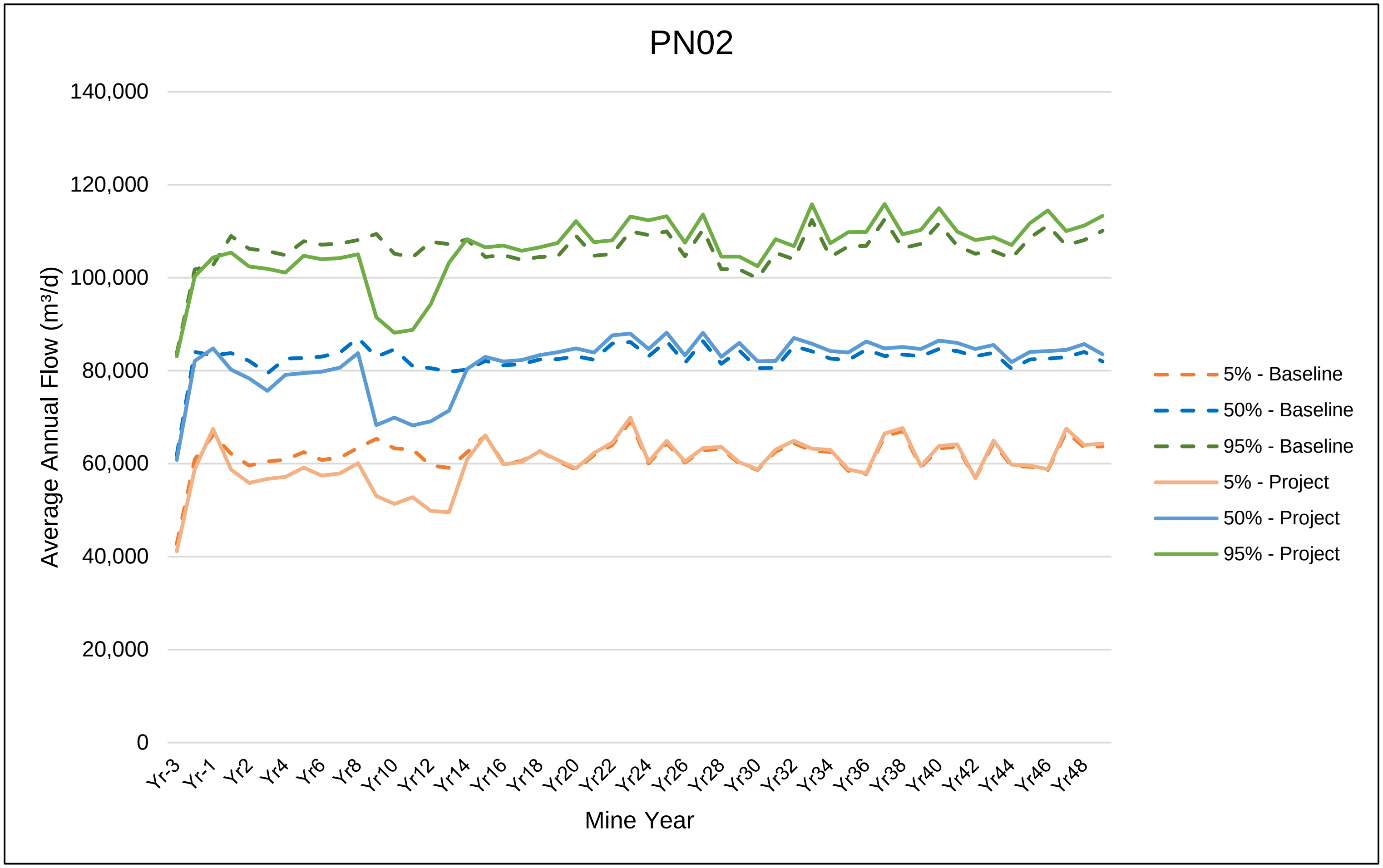
		Project and Baseline Average Annual Flow at PN01
Job No: 1CS020.018 Filename: Figures_WLB_Report.pptx	Back River Project	Date: June 2020 — Approved: TRS — Figure: **6-7**



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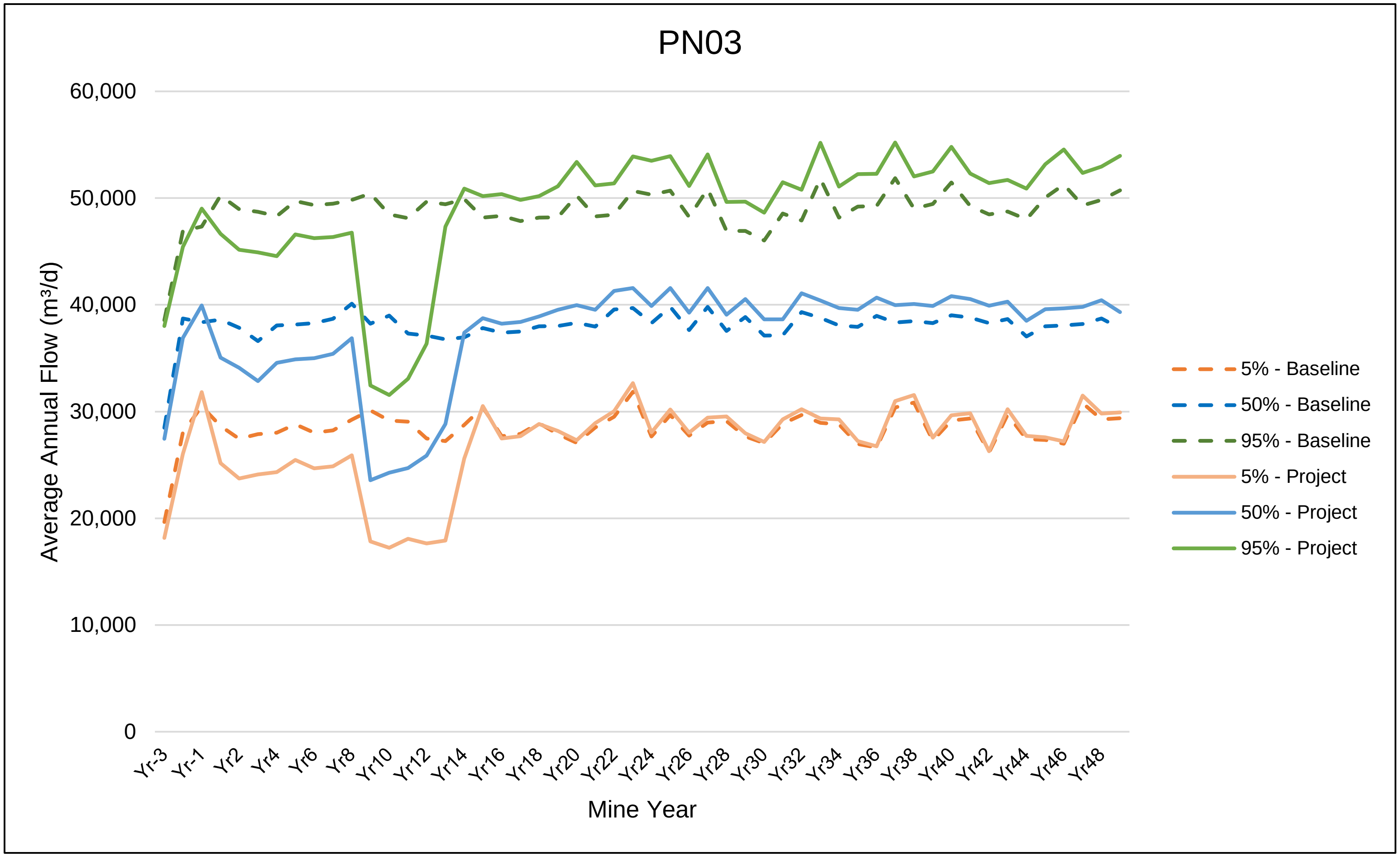
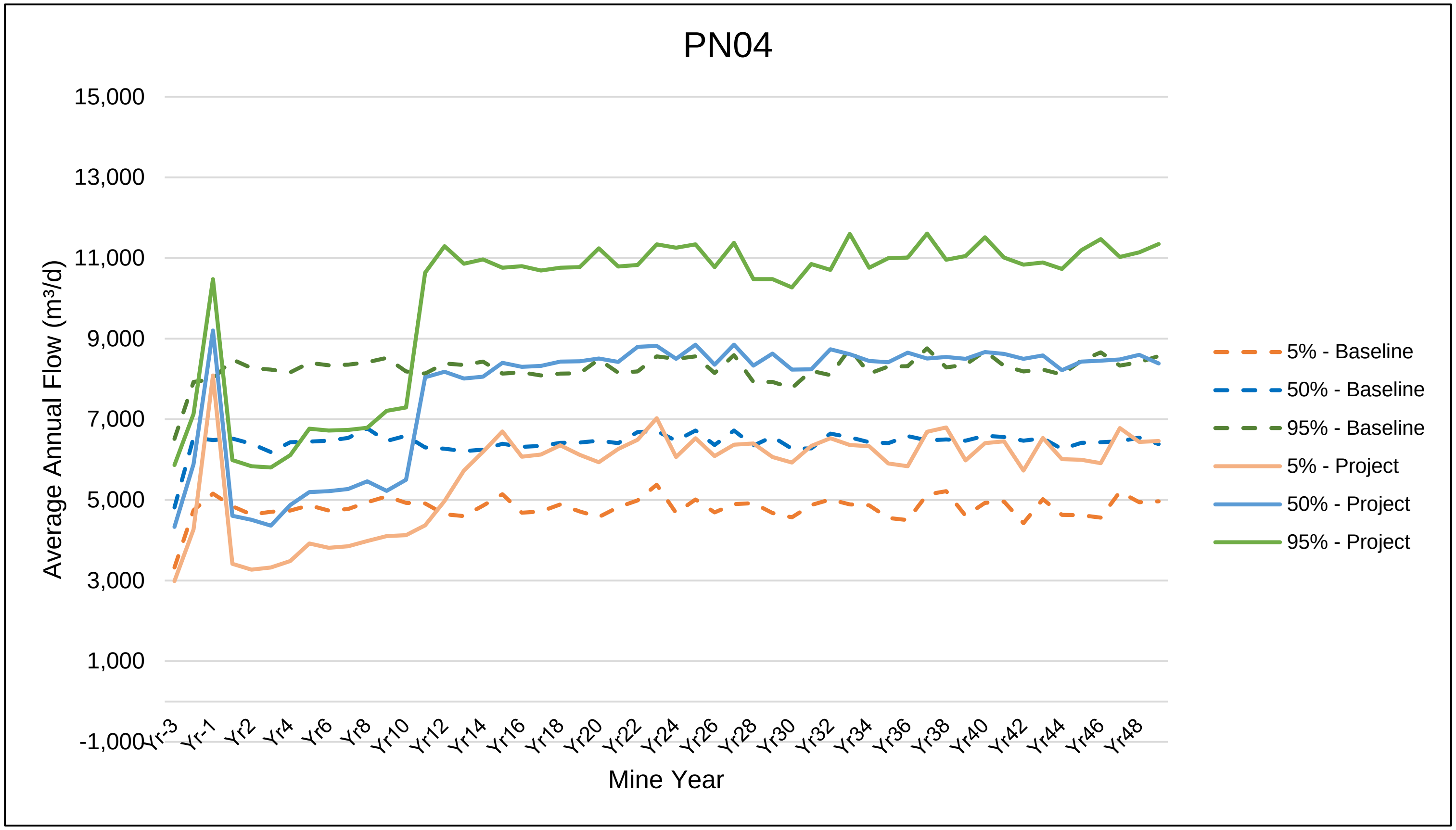
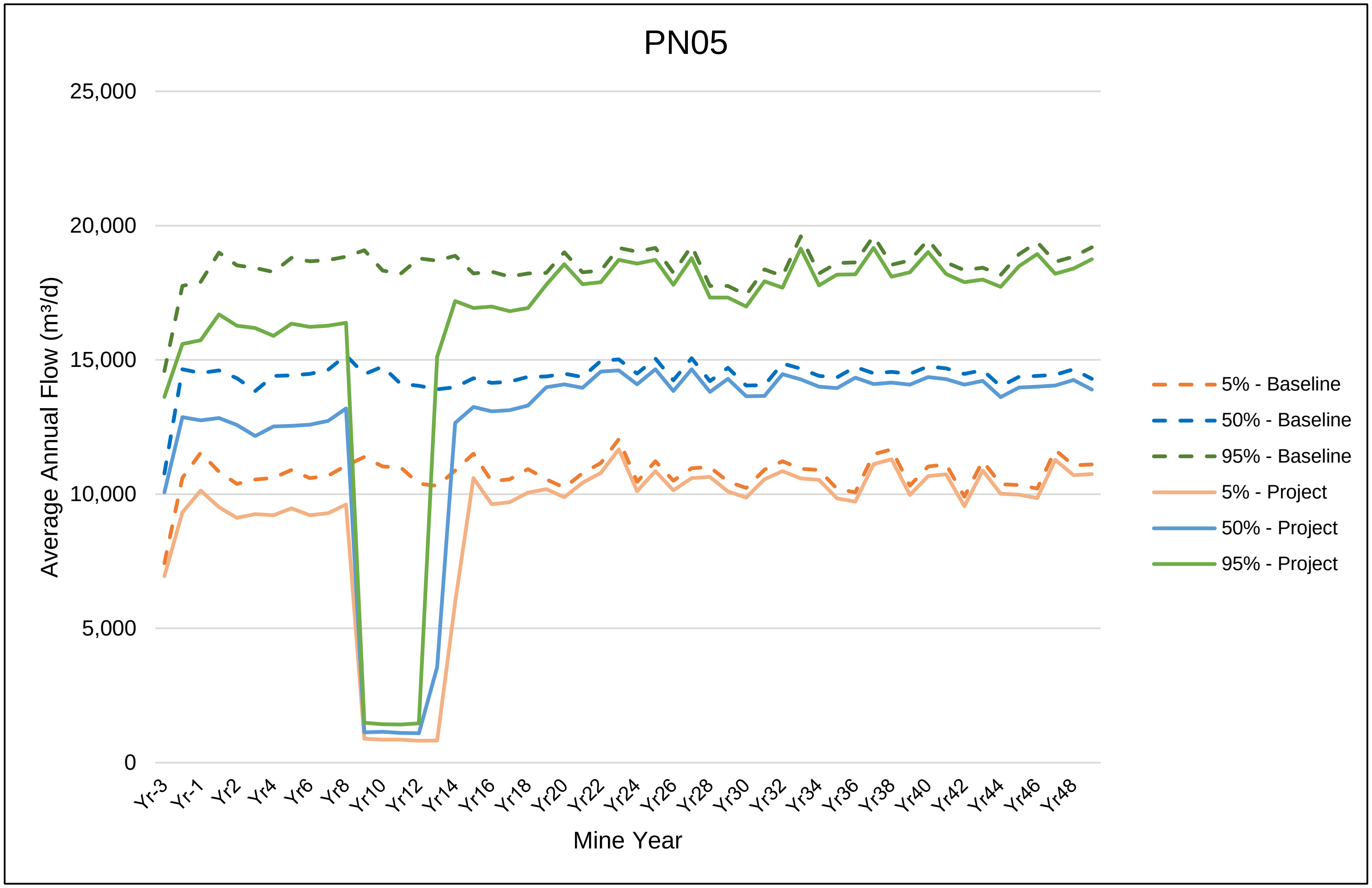
Job No: 1CS020.018 Filename: Figures_WLB_Report.pptx	Back River Project	Water and Load Balance Report **Project and Baseline Average Annual Flow at PN02** Date: June 2020 Approved: TRS Figure: **6-8**



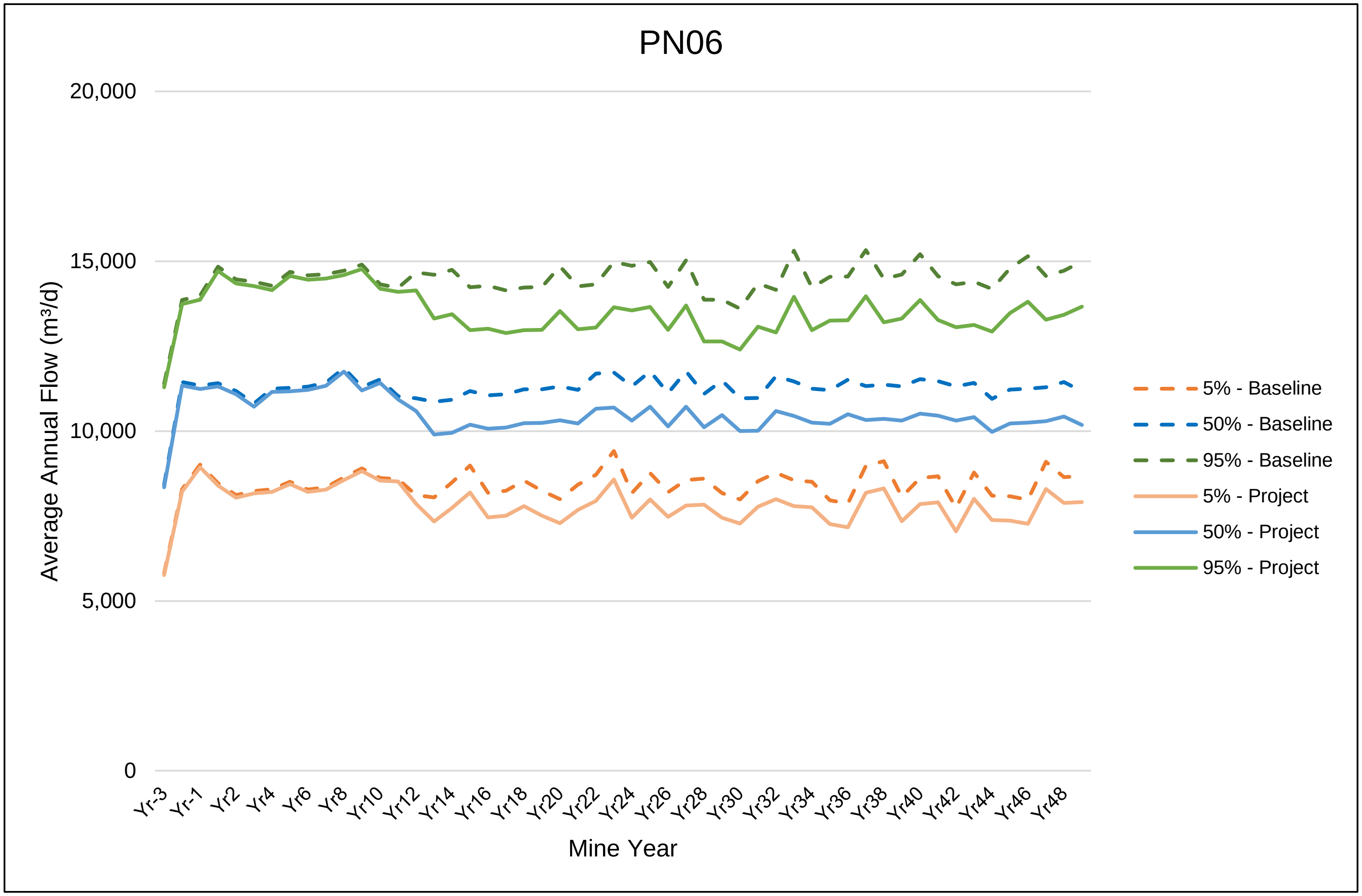
srk consulting	Sabina GOLD & SILVER CORP.	Water and Load Balance Report **Project and Baseline Average Annual Flow at PN03**
Job No: 1CS020.018 Filename: Figures_WLB_Report.pptx	Back River Project	Date: June 2020 · Approved: TRS · Figure: **6-9**



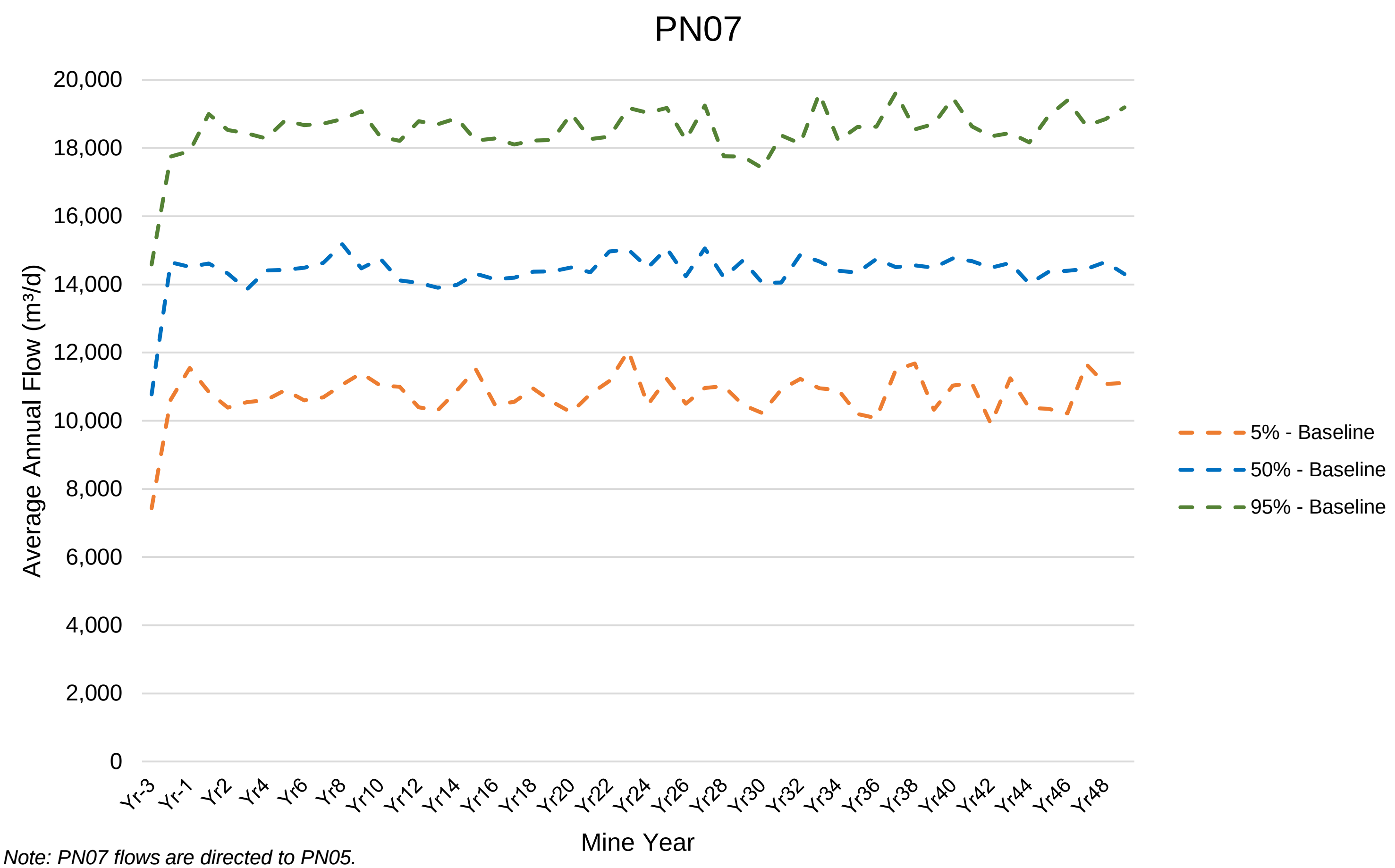
srk consulting	Sabina GOLD & SILVER CORP.	Water and Load Balance Report **Project and Baseline Average Annual Flow at PN04**
Job No: 1CS020.018 Filename: Figures_WLB_Report.pptx	Back River Project	Date: June 2020 | Approved: TRS | Figure: **6-10**



srk consulting	Sabina GOLD & SILVER CORP.	Water and Load Balance Report
		Project and Baseline Average Annual Flow at PN05
Job No: 1CS020.018 Filename: Figures_WLB_Report.pptx	Back River Project	Date: June 2020 · Approved: TRS · Figure: **6-11**

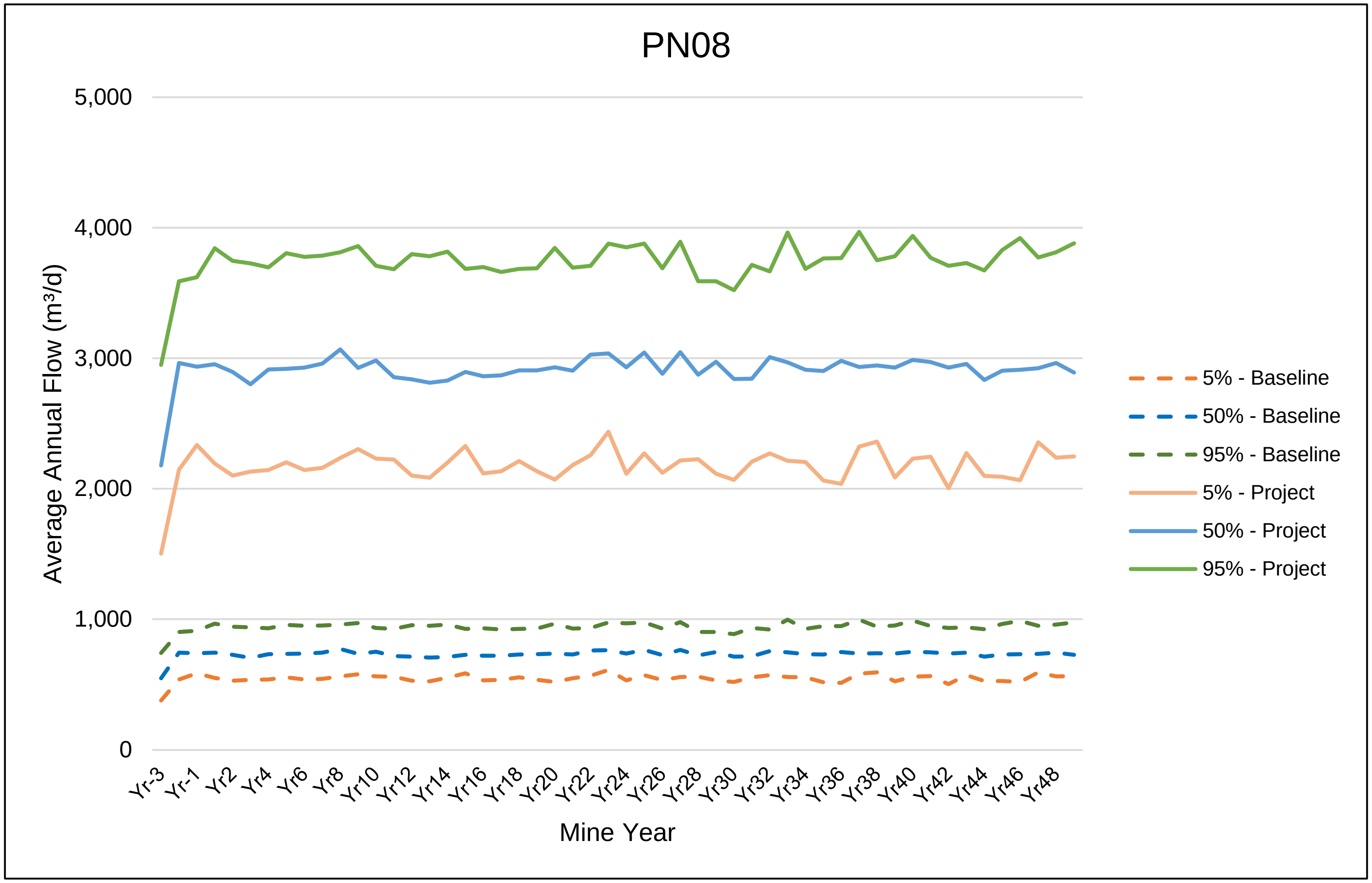


srk consulting	Sabina GOLD & SILVER CORP.	Water and Load Balance Report
		Project and Baseline Average Annual Flow at PN06
Job No: 1CS020.018 Filename: Figures_WLB_Report.pptx	Back River Project	Date: June 2020 · Approved: TRS · Figure: **6-12**

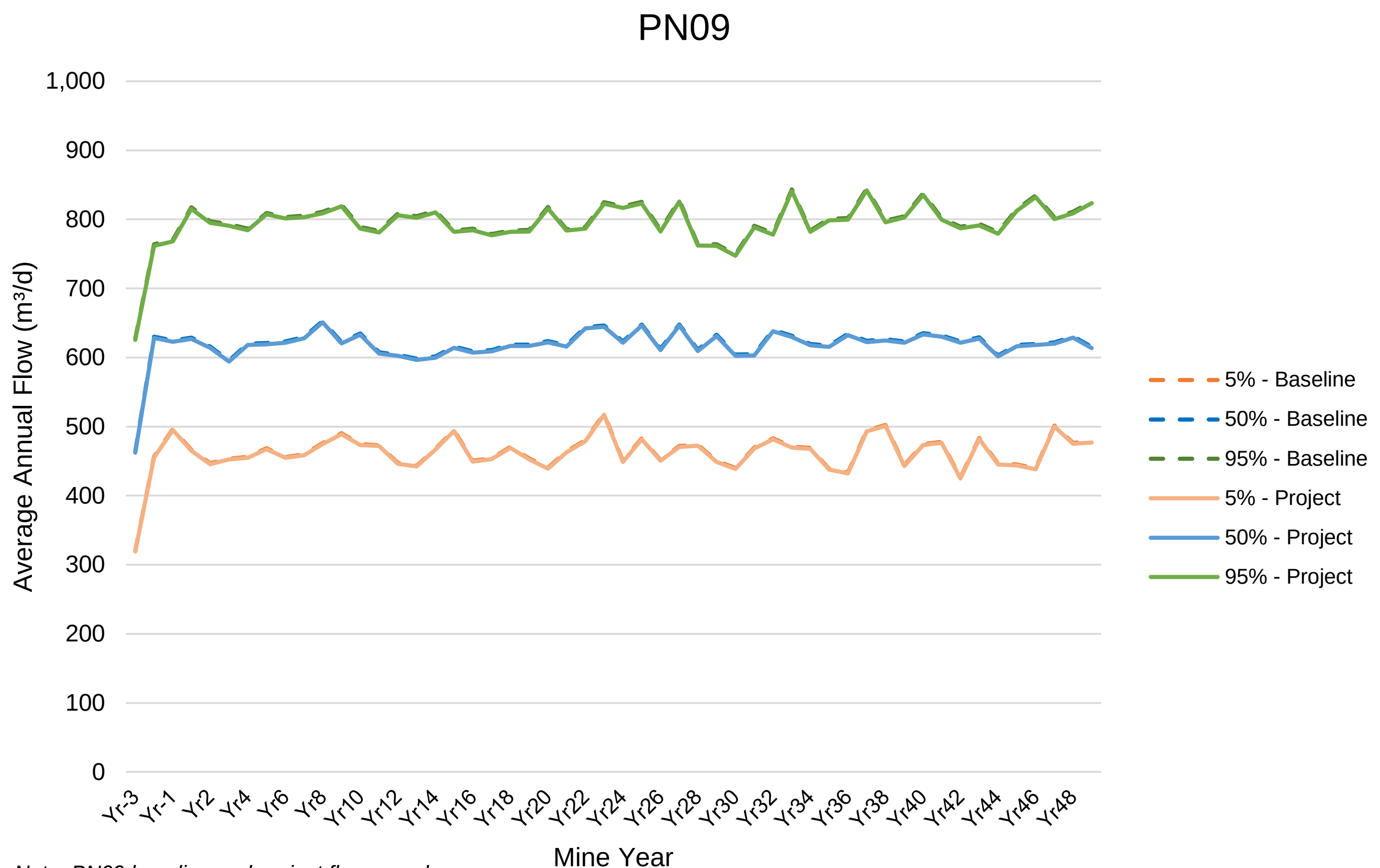


Note: PN07 flows are directed to PN05.

srk consulting	Sabina GOLD & SILVER CORP.	Water and Load Balance Report
		Project and Baseline Average Annual Flow at PN07
Job No: 1CS020.018 Filename: Figures_WLB_Report.pptx	Back River Project	Date: June 2020 / Approved: TRS / Figure: **6-13**

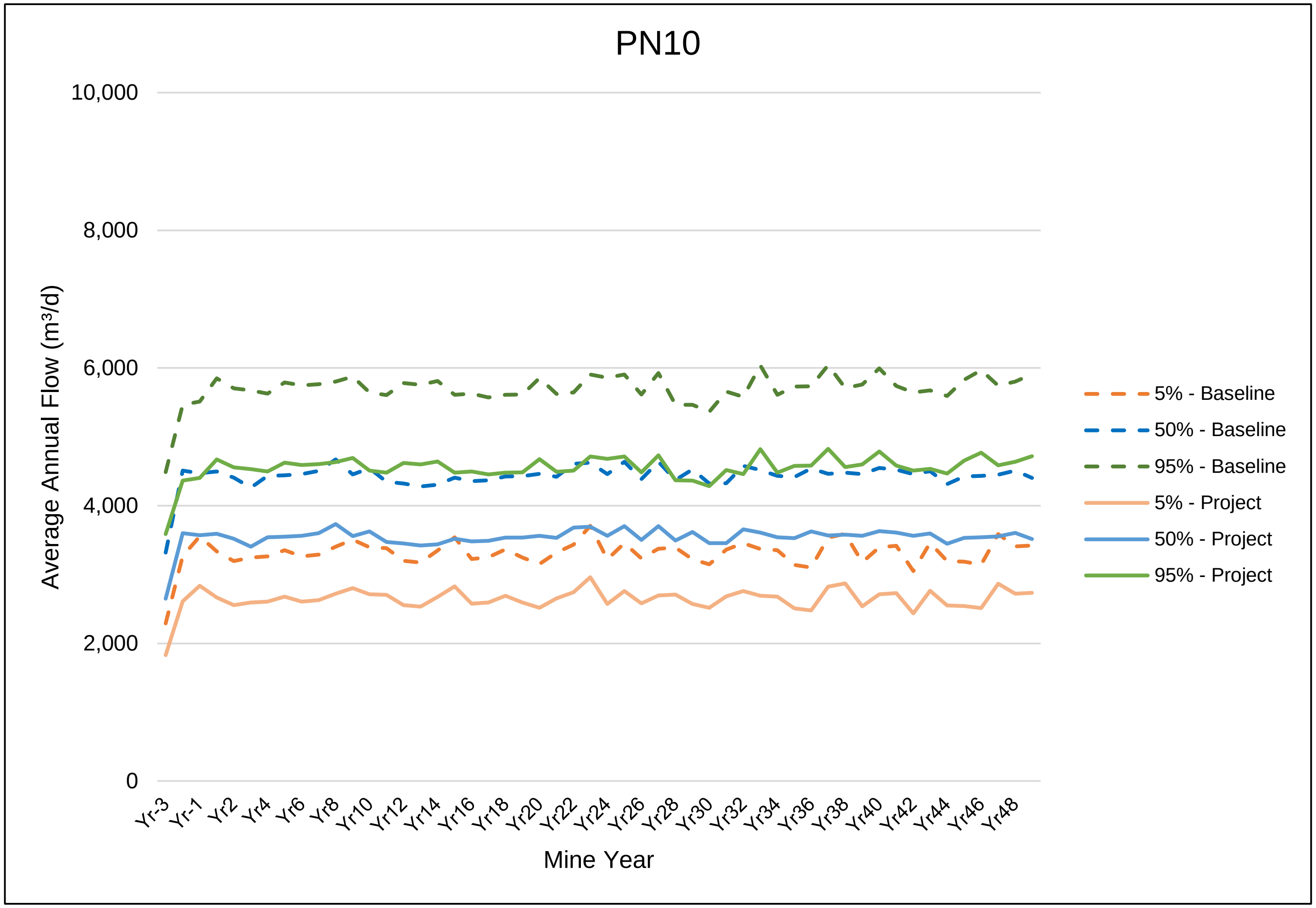


srk consulting	Sabina GOLD & SILVER CORP.	Water and Load Balance Report
		Project and Baseline Average Annual Flow at PN08
Job No: 1CS020.018 Filename: Figures_WLB_Report.pptx	Back River Project	Date: June 2020 / Approved: TRS / Figure: **6-14**



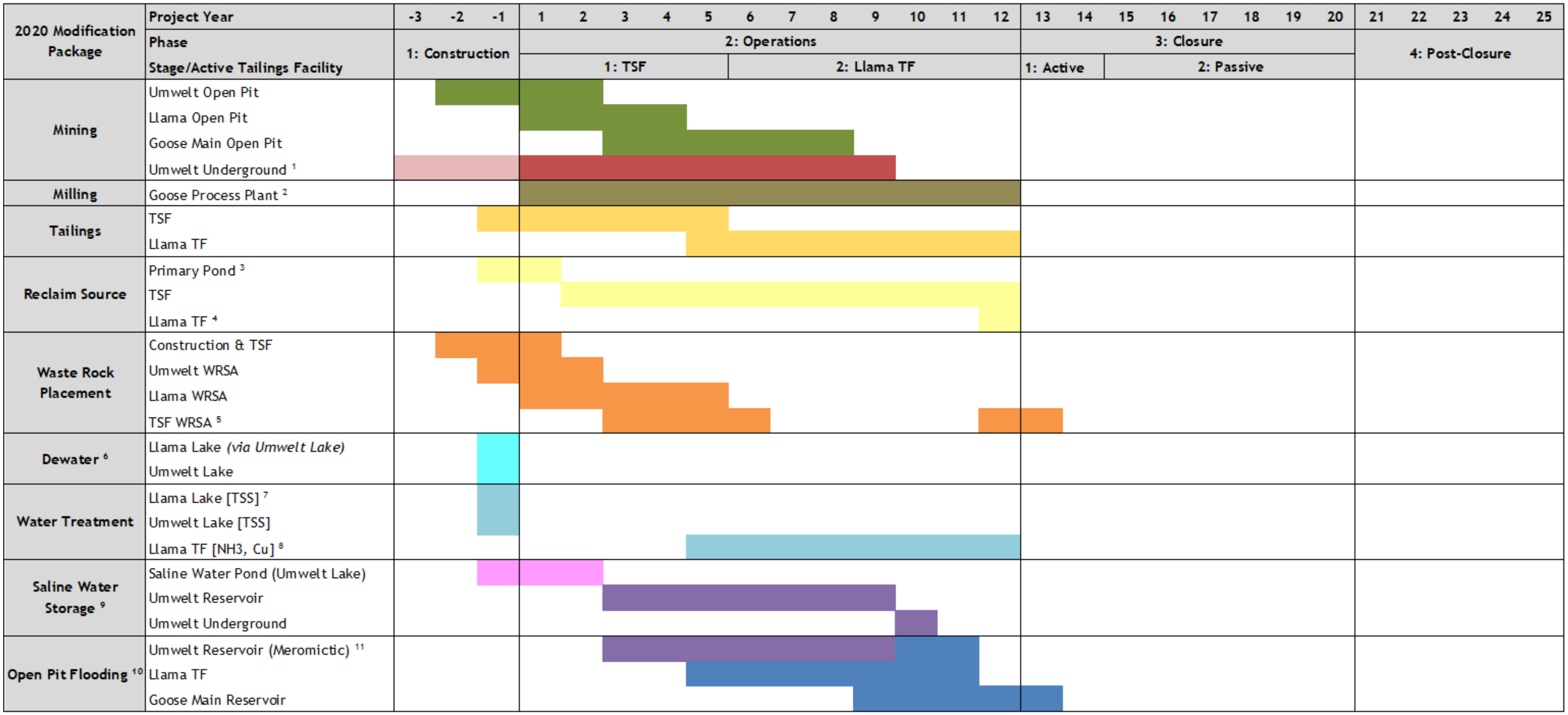
Note: PN09 baseline and project flows overlap.

srk consulting	Sabina GOLD & SILVER CORP.	Water and Load Balance Report
		Project and Baseline Average Annual Flow at PN09
Job No: 1CS020.018 Filename: Figures_WLB_Report.pptx	Back River Project	Date: June 2020 / Approved: TRS / Figure: **6-15**



srk consulting	Sabina GOLD & SILVER CORP.	Water and Load Balance Report
		Project and Baseline Average Annual Flow at PN10
Job No: 1CS020.018 Filename: Figures_WLB_Report.pptx	Back River Project	Date: June 2020 | Approved: TRS | Figure: **6-16**

Appendix A – Back River Project Timeline



1: Light red denotes Underground Development (decline) in advance of Production.
2: Milling, tailings deposition, and reclaim anticipated to start Year -1 Q4.
3: Reclaim from Primary Pond used for start-up and Year 1 until TSF supernatant pond is sufficiently established.
4: Reclaim from Llama TF will begin once TSF supernatant reclaim is no longer practical (i.e., in Year 12 Q2, based on average hydrological conditions).
5: Final portion of waste rock cover paused during Operations to allow TSF reclaim to finish. Once TSF supernatant reclaim is complete, then final portion of waste rock cover will be placed.
6: 50% direct discharge to Goose Lake; 50% treated for Total Suspended Solids (TSS) before discharge. Dewatering from both lakes assumed to be completed in one open water season.
7: TSS = Total Suspended Solids.
8: NH3 = ammonia, Cu = copper. Year-round treatment for ammonia and copper required; contingency allowance for treatment of Total Suspended Solids and arsenic (if required).
10: Saline Water Pond provides temporary storage until Umwelt Reservoir is available for permanent storage. Saline water will also be stored in mined-out underground as space is available.
11: Flooding timelines denote average hydrologic conditions.
12: Purple denotes saline water as part of flooding; dark blue denotes flooding with contact and fresh water runoff.

COLOUR LEGEND

- Mining - Pits
- Mining - Underground
- Milling
- Reclaim - For Mill
- Tailings Deposition
- Rock / Waste Rock Placement
- Lake Dewatering
- Water Treatment
- Saline Water (Temporary Storage)
- Saline Water (Permanent Storage)
- Contact and Fresh Water

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Water and Load Balance Report

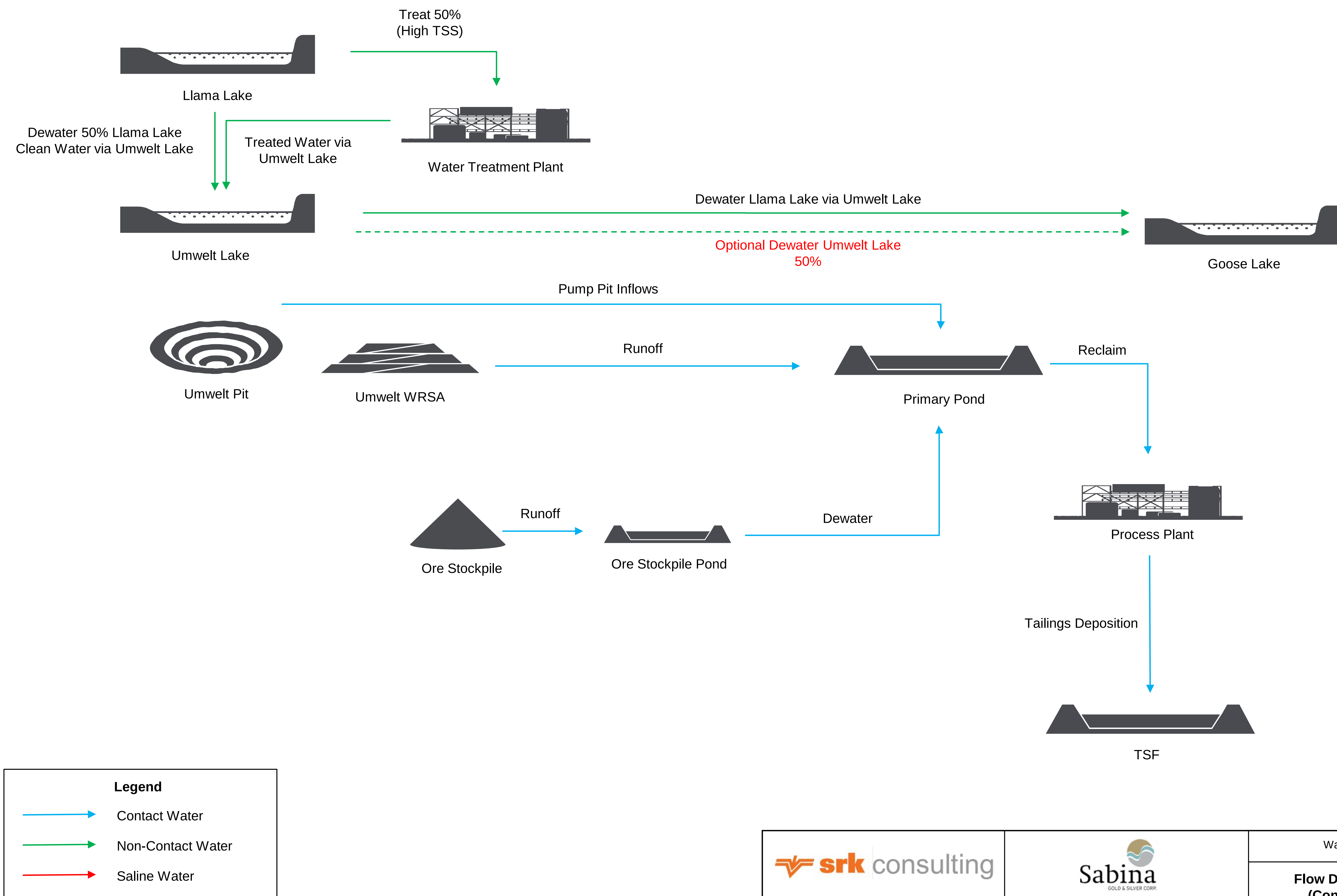
Project Timeline

Job No: 1CS020.18
Filename: AppendixA_Project_Timeline.pptx

Back River Project

Date: June 2020 | Approved: JBK | Figure: A-1

Appendix B – Water Balance Figures / Block Flow Diagrams



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Water Management

Flow Diagram: Phase 1 (Construction) Yr-1

Job No: 1CS020.016

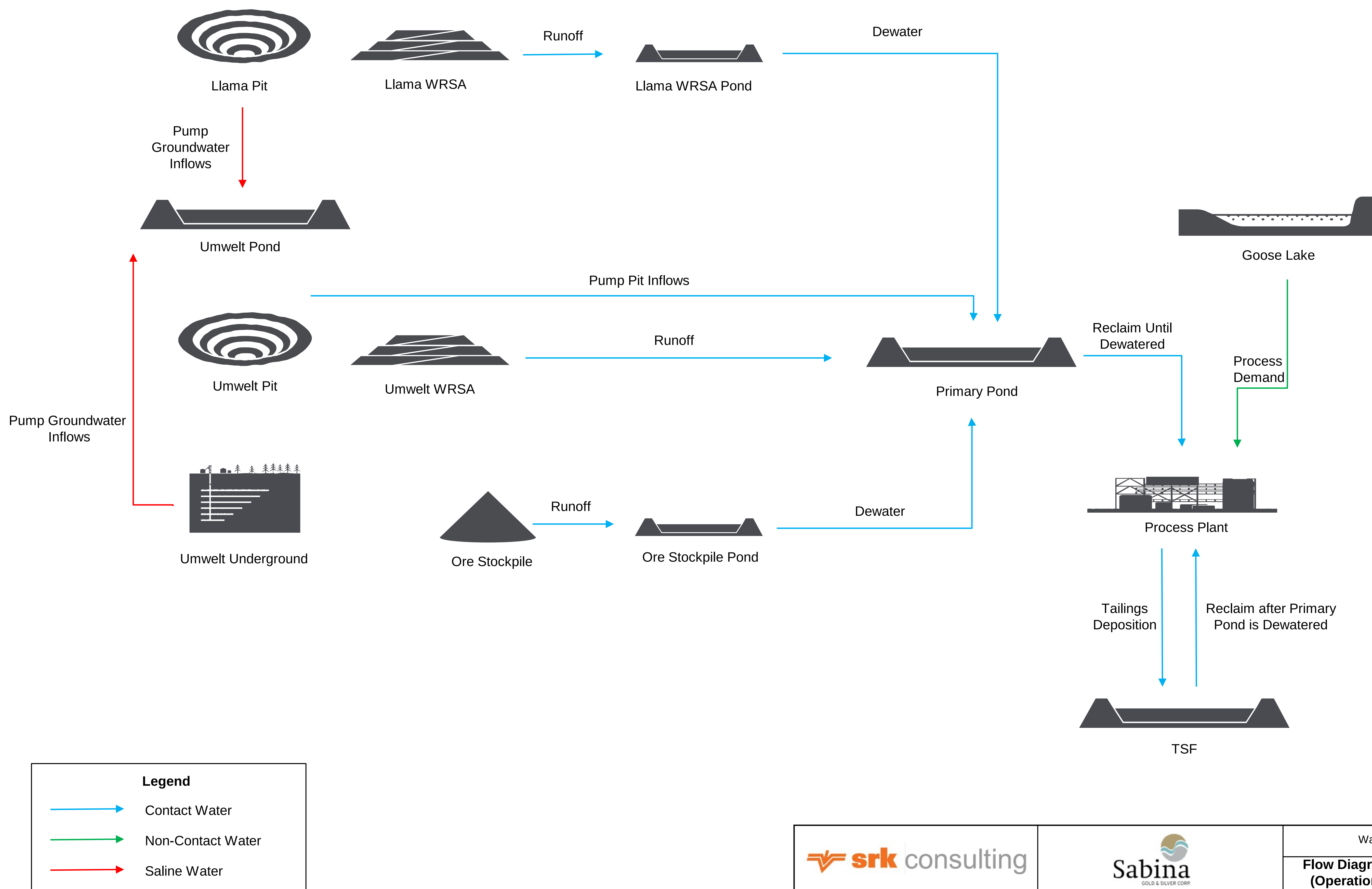
Filename: BackRiver_WaterMgmt_FlowDiagram.pptx

Back River

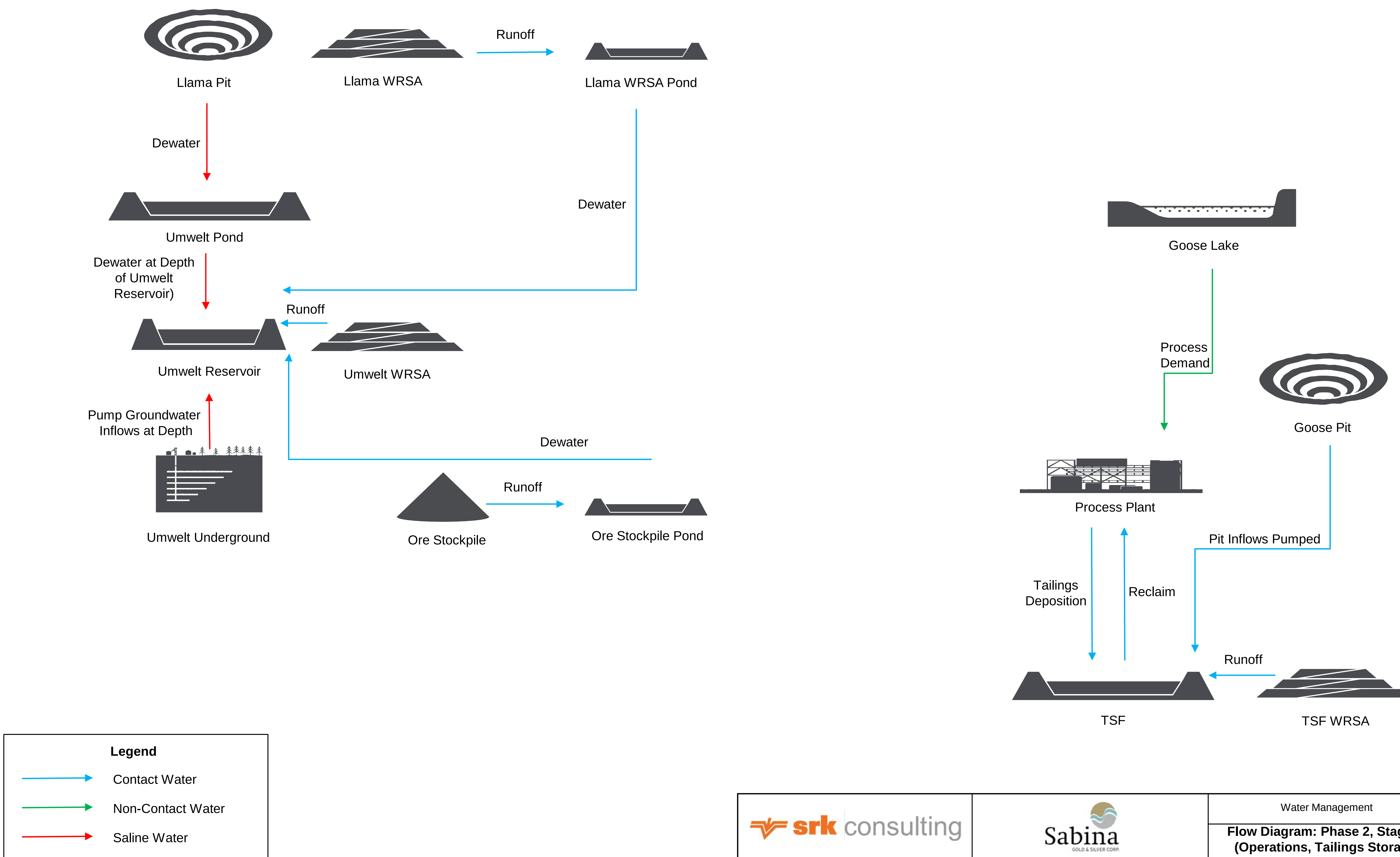
Date: 2019-05-03

Approved: MGS

Figure: **B-1**



srk consulting	Sabina GOLD & SILVER CORP.	Water Management **Flow Diagram: Phase 2, Stage 1 (Operations, Tailings Storage Facility) Yr1 to Yr2**
Job No: 1CS020.016 Filename: BackRiver_WaterMgmt_FlowDiagram.pptx	Back River	Date: 2019-05-03 / Approved: MGS / Figure: **B-2**



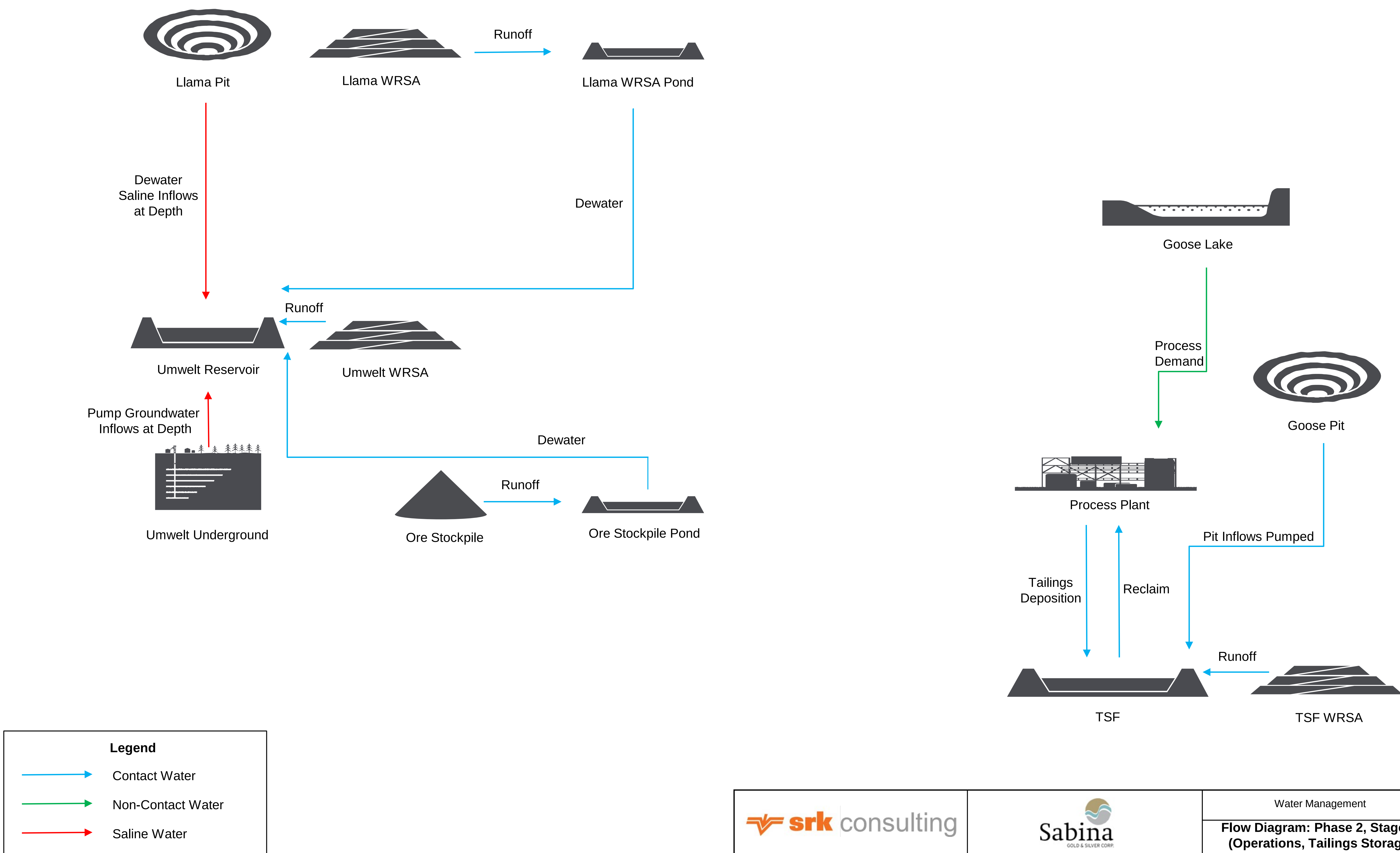
srk consulting | Sabina Gold & Silver Corp. | Water Management

Flow Diagram: Phase 2, Stage 1 (Operations, Tailings Storage Facility) Yr2 to Yr4

Job No: 1CS020.016
Filename: BackRiver_WaterMgmt_FlowDiagram.pptx

Back River

Date: 2019-05-03 | Approved: MGS | Figure: **B-3**



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Water Management

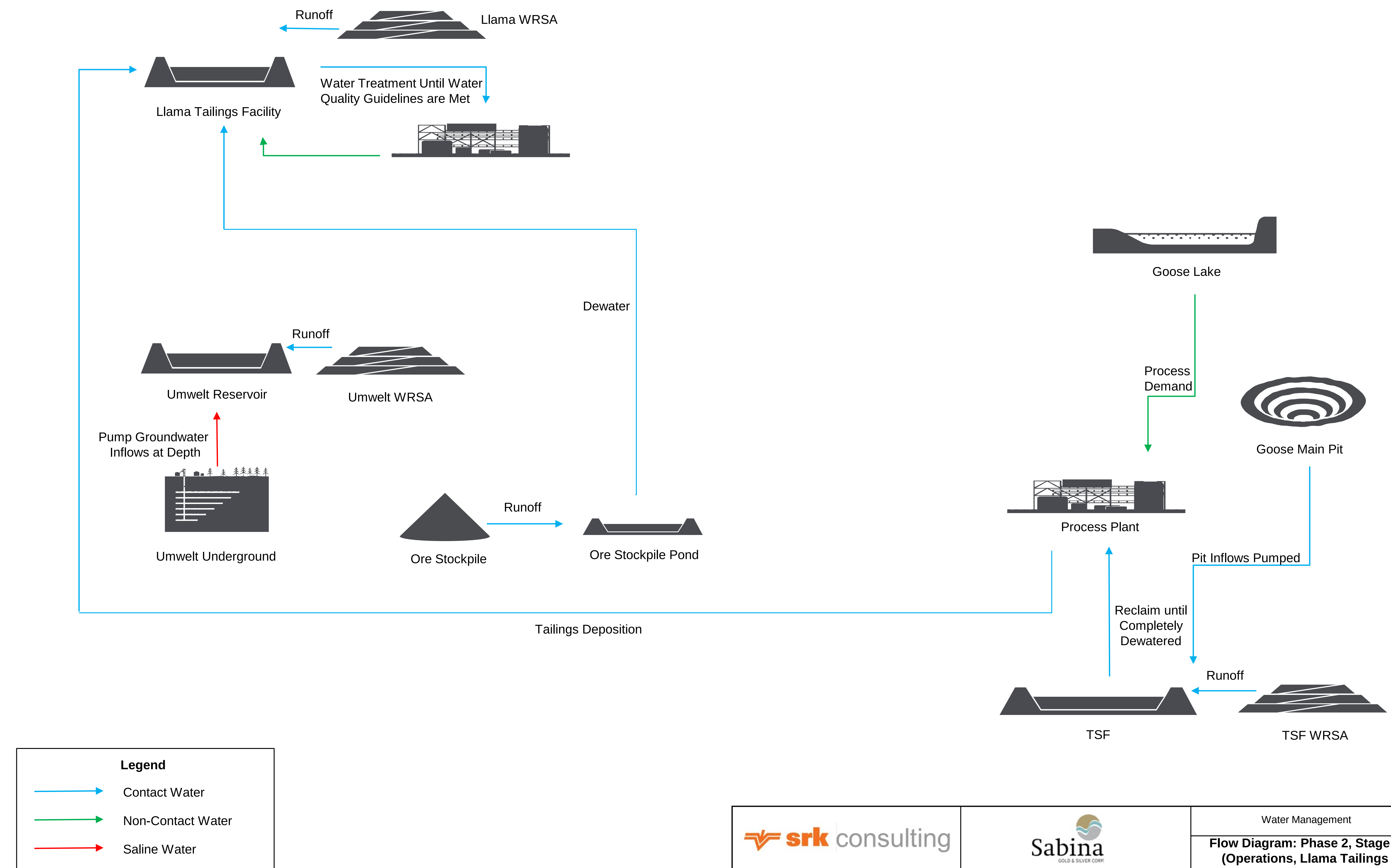
Flow Diagram: Phase 2, Stage 1 (Operations, Tailings Storage Facility) Yr4 to Yr 5

Job No: 1CS020.016

Filename: BackRiver_WaterMgmt_FlowDiagram.pptx

Back River

Date: 2019-05-03 | Approved: MGS | Figure: **B-4**



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Water Management

Flow Diagram: Phase 2, Stage 2 (Operations, Llama Tailings Facility) Yr 5 to Yr 8

Job No: 1CS020.016

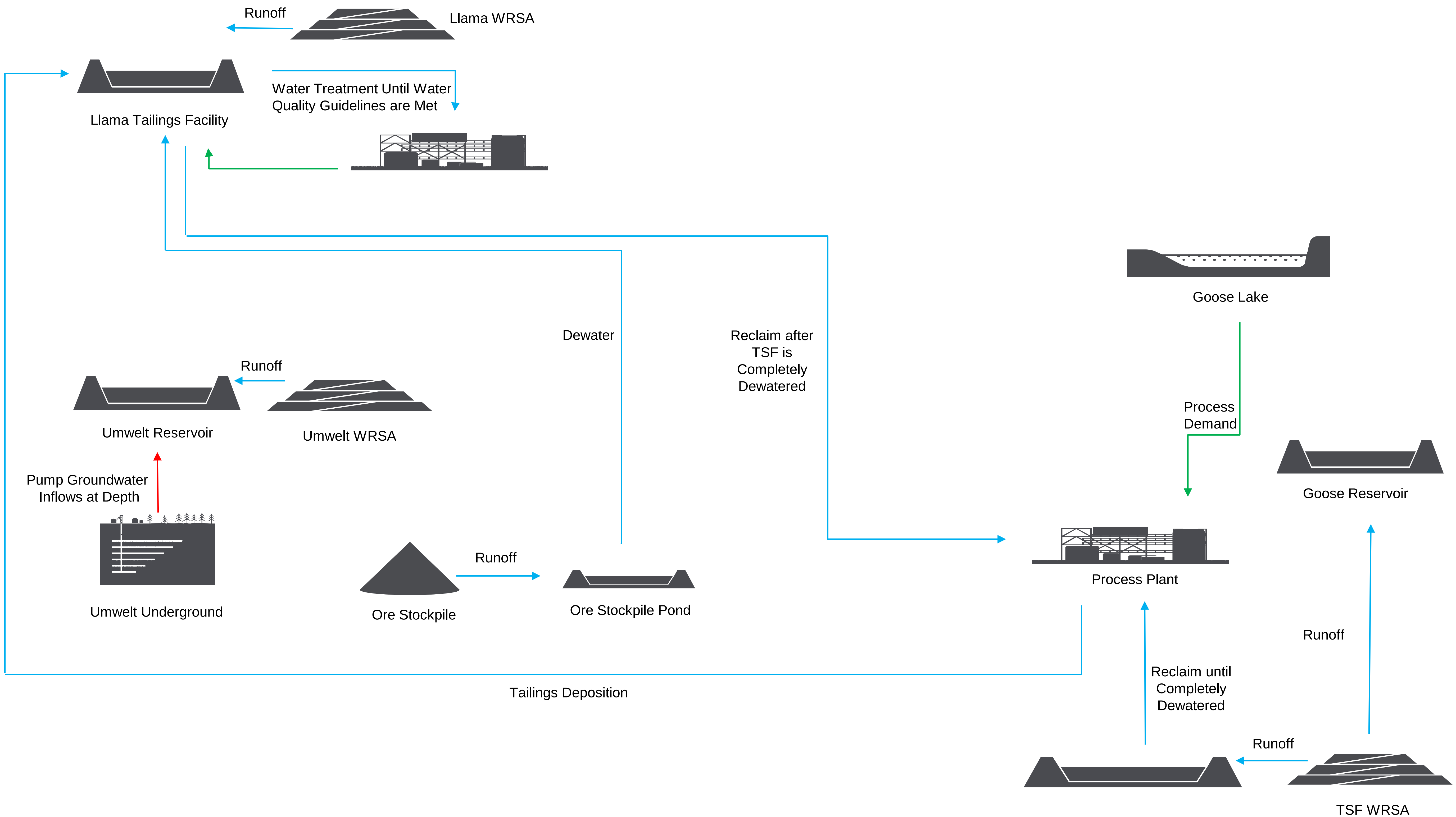
Filename: BackRiver_WaterMgmt_FlowDiagram.pptx

Back River

Date: 2019-05-03

Approved: MGS

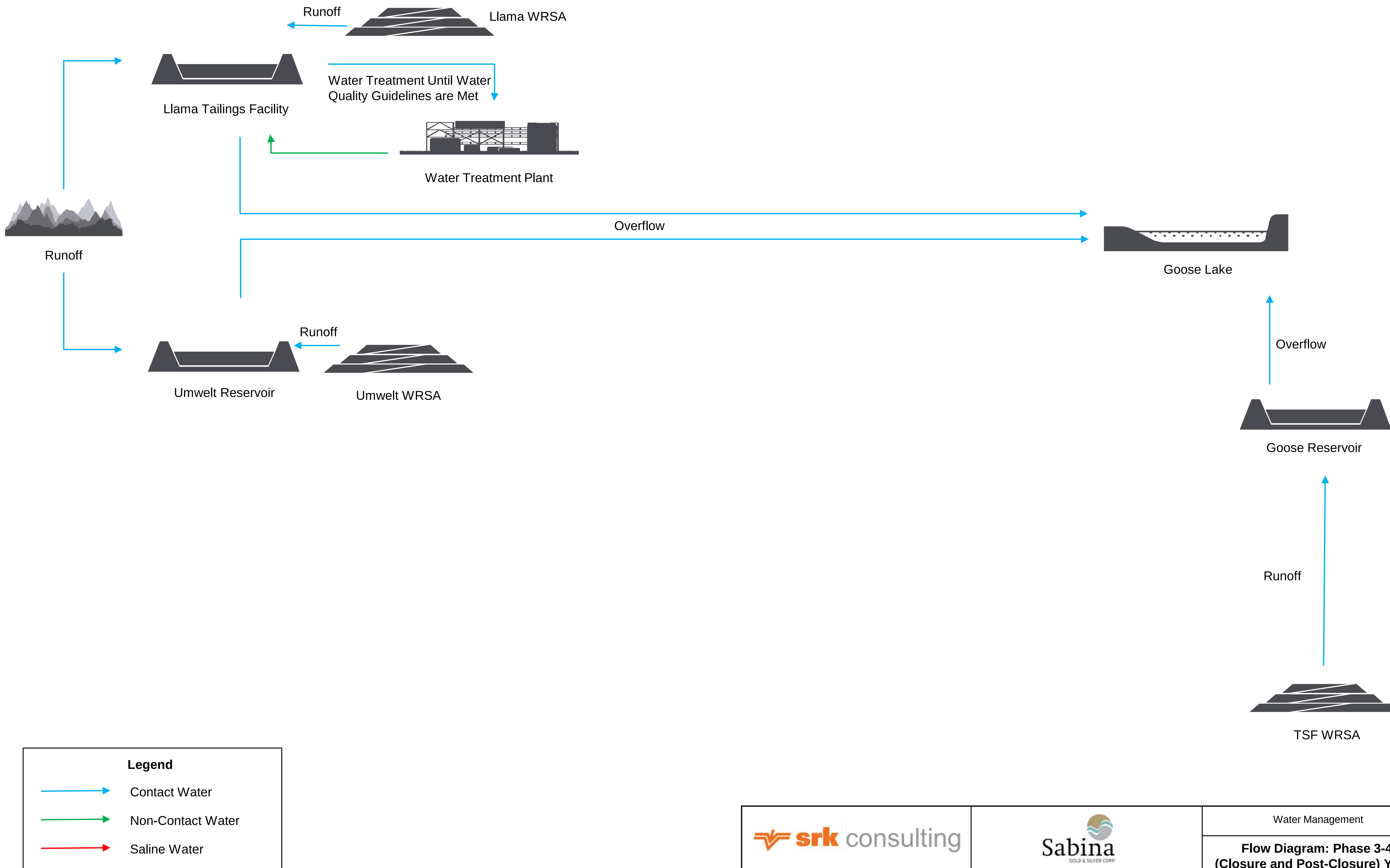
Figure: **B-5**



Legend

- Contact Water
- Non-Contact Water
- Saline Water

srk consulting	Sabina	Water Management
		Flow Diagram: Phase 2, Stage 2 (Operations, Llama Tailings Facility) Yr8 to Yr12
Job No: 1CS020.016 Filename: BackRiver_WaterMgmt_FlowDiagram.pptx	Back River	Date: 2019-05-03 · Approved: MGS · Figure: **B-7**



srk consulting

Sabina GOLD & SILVER CORP.

Water Management

Flow Diagram: Phase 3-4 (Closure and Post-Closure) Yr13+

Job No: 1CS020.016	Back River	Date: 2019-05-03	Approved: MGS	Figure:	B-8
Filename: BackRiver_WaterMgmt_FlowDiagram.pptx					

Appendix C – Water Chemistry Input Data

Type	Baseline	Process Water	Sewage	Pad	Stockpile-Pad	Stockpile-Ore_Pad	Stockpile_Frozen	Beach	WR-Umwelt_Ops	WR-Umwelt_Closure
Units	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
TDS	26	1900	1	87.49	770.58	2661.21	429.27	1326.65	2972.74	392.66
TSS	3	0	0	0	0	0	0	0	0	0
Free_CN	0	0	0	0	0	0	0	0	0	0
Total_CN_N	0.0023	0.59231	0	0	0	0	0	1.163019	0	0
WAD_CN	0	0.2	0	0	0	0	0	1.4	0	0
CNO_N	0	20	0	0	0	0	0	0	0	0
SCN_N	0	22.7	0	0	0	0	0	0	0	0
Sulphate	4.8	1055	0	36	492.147	1884.697	247.07	1055	2143.003	209.899
Chloride	2.7	92.4	0	0	32.179	0	16.155	5.061	0	16.014
Ammonia_N	0.005	51.1	10	0	0	0	0	0	0	0
Nitrate_N	0.005	0.13	1	0	2.66058	0	1.33568	0.17343	0	1.1556
Nitrite_N	0.001	0.142	30	0	0.66265	0	0.33267	0.03712	0	0.28699
Alkalinity	3.8	79	0	24.68	119.5	191.849	119.5	82	199.026	119.5
Ortho_P	0.001	0	1	0	0	0	0	0	0	0
Phosphate_P	0	0	1	0	0	0	0	0	0	0
TOC	3.5	0	0	0	0	0	0	0	0	0
Hardness	12	617	0	0	966.82	0	485.37	650.83	0	427.01
Aluminum	0.0085	1.34453	0.021	2.784491	1.72403	1.72453	1.72403	9.273099	2.969391	2.968891
Antimony	0.00005	0.0020093	0	0.001002	0.0025093	0.0025093	0.0025093	0.002002	0.002502	0.002502
Arsenic	0.00021	0.0736	0.0001	0.0437593	0.1446	0.2676	0.1446	0.081256	0.2198593	0.0968593
Barium	0.0053	0.0418	0	0.008936	0.107345	0.0015	0.054637	0.040281	0.008936	0.059835
Beryllium	0.0002	0.000025	0	0	0.00067	0	0.000336	0.000669	0	0.000347
Bismuth	0.0005	0.000273	0	0.000004	0.000523	0.000023	0.000523	0.000042	0.000004	0.000504
Boron	0.001	0.0743	0	0.0003	2.31904	0.0003	1.16436	0.37981	0.0003	1.33004
Cadmium	0.00001	0.0000262	0.0001	0.0000013	0.0001062	0.0001062	0.0001062	0.0002075	0.0001013	0.0001013
Calcium	2.6	178.53	0	16.404	73.88	645.056	73.88	205.711	621.394	73.624
Chromium	0.0001	0.003526	0.0001	0.003046	0.006634	0.001026	0.003842	0.008017	0.003046	0.006065
Cobalt	0.00013	0.0601628	0	0.0180129	0.0178628	0.0178628	0.0178628	0.0602988	0.0180129	0.0180129
Copper	0.0013	0.059787	0.0024	0.00362	0.011787	0.011787	0.011787	0.38254	0.01191	0.01191
Iron	0.055	3.68035	0.014	2.10923	4.07885	4.07935	4.07885	23.19236	2.10923	2.10873
Lead	0.00005	0.0029203	0.0001	0.0001195	0.0083315	0.0011003	0.0047305	0.000728	0.0001195	0.0030077
Lithium	0.00061	0.01	0	0	0.1160874	0	0.0582787	0.023851	0	0.0680824
Magnesium	1.4	47.359	0	4.385	11.209	131.346	11.209	47.291	207.751	11.145
Manganese	0.0043	0.160036	0	0.14956	0.483036	0.483036	0.42829	0.828815	0.48056	0.40773
Mercury	0.00000077	0.00346	0	0.757606309	0.0035	0.0035	0.0035	0.755057952	0.757649309	0.757649309
Molybdenum	0.00005	0.082607	0.0001	0.0008126	0.005182	0.000032	0.005182	0.0830221	0.0000226	0.0051726
Nickel	0.0026	0.002053	0.0004	0.059177	0.058833	0.030533	0.058833	0.053696	0.030877	0.059177
Phosphorus	0.0019	0.309225	1	0.010083	0.25411	0.009225	0.132163	0.032369	0.010083	0.130812
Potassium	0.37	77.976	0	0.3494	114.9047	0.076	57.7228	7.2583	0.3494	63.0362
Selenium	0.0001	0.003609	0	0.000334	0.002009	0.002009	0.002009	0.003604	0.002004	0.002004
Silicon	0.173	6.64171	0	5.4619	72.94811	4.74171	38.98298	15.77643	5.4619	39.14399
Silver	0.00001	0.0000688	0	0.0000147	0.0000458	0.0000458	0.0000458	0.0000647	0.0000417	0.0000417
Sodium	0.63	338.0306	0	0.2459	46.2557	0.0306	23.2367	6.3308	0.2459	18.9458
Strontium	0.015	0.7184	0	0.00028	0.68675	0.0004	0.34496	0.53685	0.00028	0.32406
Tellerium	0	0	0	0	0	0	0	0	0	0
Thallium	0.00005	0.0000195	0	0.000004	0.0003144	0.0000015	0.0001586	0.0000492	0.000004	0.0001657
Thorium	0	0	0	0	0	0	0	0	0	0
Tin	0.0001	0.001	0	0	0.01045	0	0.005246	0.001698	0	0.006073
Titanium	0.0001	0.026352	0	0.052022	0.049201	0.020852	0.035084	0.052108	0.052022	0.067852
Uranium	0.00001	0.0000102	0.0001	0.0000245	0.0465838	0.0000102	0.0233913	0.0007168	0.0000245	0.0267368
Vanadium	0.000057	0.007925	0	0.00088005	0.07587446	0.000525	0.03835226	0.00263646	0.00088005	0.02828623
Zinc	0.0008	0.00424	0.002	0.015027	0.01699	0.01704	0.01699	0.028313	0.016827	0.016777
Zirconium	0.00006	0.0009	0	0	0.0045895	0	0.002304	0.0007502	0	0.0026094

Type	WR-Llama Ops	WR-Llama Closure	WR-Goose Ops	WR-Goose Closure	WR-TSF_Ops	WR-TSF_Closure	PW-Umwelt	PW-Llama	PW-Goose
Units	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
TDS	2893.65	386.58	3007.93	429.44	836.33	389.36	91.5	96.36	72.31
TSS	0	0	0	0	0	0	0	0	0
Free_CN	0	0	0	0	0	0	0	0	0
Total_CN_N	0	0	0	0	0	0	0	0	0
WAD_CN	0	0	0	0	0	0	0	0	0
CNO_N	0	0	0	0	0	0	0	0	0
SCN_N	0	0	0	0	0	0	0	0	0
Sulphate	2079.699	206.408	2169.803	247.07	751	304	53.107	56.219	40.234
Chloride	0	15.998	0	16.155	0	0	6.072	5.948	3.427
Ammonia_N	0	0	0	0	0	0	0	0	0
Nitrate_N	0	1.16847	0	1.33568	0	0	0.10686	0.10188	0.09101
Nitrite_N	0	0.29041	0	0.33267	0	0	0.37734	0.48834	0.07359
Alkalinity	199.984	119.5	197.559	119.5	119.5	119.5	24.397	25.526	25.861
Ortho_P	0	0	0	0	0	0	0	0	0
Phosphate_P	0	0	0	0	0	0	0	0	0
TOC	0	0	0	0	0	0	0	0	0
Hardness	0	422.54	0	485.37	0	0	60.68	63.71	53.07
Aluminum	2.881629	2.968891	2.881629	2.968891	2.881129	2.968891	1.524762	2.684024	2.678313
Antimony	0.002502	0.002502	0.002502	0.002502	0.002502	0.002502	0.0025093	0.002502	0.002502
Arsenic	0.2197732	0.0968593	0.2197732	0.0968593	0.1362732	0.0968593	0.230804	0.1636487	0.1837612
Barium	0.00894	0.060493	0.00894	0.062073	0.00894	0.008936	0.00964	0.016926	0.015438
Beryllium	0	0.000335	0	0.000336	0	0	0.0002	0.0002	0.0002
Bismuth	0.000004	0.000504	0.000004	0.000504	0.000004	0.000004	0.002609	0.003388	0.000504
Boron	0.0003	1.26567	0.0003	1.16436	0.0003	0.0003	0.09421	0.09271	0.08885
Cadmium	0.0001011	0.0001013	0.0001011	0.0001013	0.0000011	0.0000013	0.0001062	0.0001011	0.0001011
Calcium	628.317	73.624	618.097	73.624	73.614	73.624	16.161	16.874	14.601
Chromium	0.002976	0.005921	0.002976	0.005861	0.002976	0.003046	0.001442	0.003446	0.003238
Cobalt	0.0179988	0.0180129	0.0179988	0.0180129	0.0179988	0.0180129	0.0178628	0.0179988	0.0140488
Copper	0.011824	0.01191	0.011824	0.01191	0.011824	0.01191	0.011787	0.011824	0.011824
Iron	2.2714	2.10873	2.2714	2.10873	2.2714	2.10923	4.07885	2.2709	2.2709
Lead	0.0001162	0.0030365	0.0001162	0.0037498	0.0001162	0.0001195	0.0015059	0.0005329	0.0003751
Lithium	0	0.0657618	0	0.0582787	0	0	0.049995	0.0630686	0.012425
Magnesium	185.059	11.145	219.46	11.145	11.141	11.145	5.607	5.682	4.474
Manganese	0.480326	0.382997	0.480326	0.425814	0.480326	0.48056	0.123044	0.125094	0.086125
Mercury	0.755031951	0.757649309	0.755031951	0.757649309	0.755031951	0.757649309	0.0035	0.755031951	0.755031951
Molybdenum	0.0000221	0.0051726	0.0000221	0.0051726	0.0051721	0.0051726	0.0018386	0.001856	0.0011092
Nickel	0.030845	0.059177	0.030845	0.059177	0.059145	0.059177	0.058833	0.059145	0.040253
Phosphorus	0.010129	0.131403	0.010129	0.133021	0.010129	0.010083	0.019332	0.020327	0.020221
Potassium	0.3469	59.6811	0.3469	57.9962	0.3469	0.3494	4.7045	4.7701	4.6575
Selenium	0.002004	0.002004	0.002004	0.002004	0.002004	0.002004	0.002009	0.002004	0.002004
Silicon	5.45353	39.32594	5.45353	39.70317	5.45353	5.4619	7.3616	7.97699	7.89178
Silver	0.0000417	0.0000417	0.0000417	0.0000417	0.0000417	0.0000417	0.0000458	0.0000417	0.0000417
Sodium	0.2268	19.7247	0.2268	23.452	0.2268	0.2459	5.8437	6.8664	4.915
Strontium	0.0003	0.31798	0.0003	0.34484	0.0003	0.00028	0.51473	0.66636	0.10899
Tellerium	0	0	0	0	0	0	0	0	0
Thallium	0.0000041	0.000161	0.0000041	0.0001611	0.0000041	0.000004	0.0000515	0.0000541	0.0000541
Thorium	0	0	0	0	0	0	0	0	0
Tin	0	0.005862	0	0.005246	0	0	0.000444	0.000452	0.000417
Titanium	0.048141	0.067615	0.048141	0.066254	0.048141	0.052022	0.030852	0.058141	0.058141
Uranium	0.0000245	0.0237464	0.0000245	0.0234056	0.0000245	0.0000245	0.0013683	0.0012242	0.0012856
Vanadium	0.00082472	0.03028751	0.00082472	0.03870731	0.00082472	0.00088005	0.00747734	0.0096823	0.00369855
Zinc	0.016785	0.016777	0.016785	0.016777	0.016785	0.016827	0.010958	0.010014	0.008022
Zirconium	0	0.0024786	0	0.002304	0	0	0.0004	0.0004	0.0004

Type	HW-Umwelt	HW-Llama	HW-Goose
Units	(mg/L)	(mg/L)	(mg/L)
TDS	33.91	10.5	10.63
TSS	0	0	0
Free_CN	0	0	0
Total_CN_N	0	0	0
WAD_CN	0	0	0
CNO_N	0	0	0
SCN_N	0	0	0
Sulphate	23.66	4.085	4.085
Chloride	1.086	1	1
Ammonia_N	0	0	0
Nitrate_N	0.01974	0.0065	0.0065
Nitrite_N	0.00451	0.001	0.001
Alkalinity	4.285	2	2
Ortho_P	0	0	0
Phosphate_P	0	0	0
TOC	0	0	0
Hardness	18.65	10.75	10.75
Aluminum	2.881129	2.499779	2.499779
Antimony	0.000167	0.0000593	0.000052
Arsenic	0.0540664	0.048795	0.0009682
Barium	0.018761	0.00662	0.01406
Beryllium	0.000304	0.0002	0.0002
Bismuth	0.000504	0.000523	0.000504
Boron	0.02794	0.0053	0.0053
Cadmium	0.0000625	0.0000162	0.0000111
Calcium	4.504	2.67	2.404
Chromium	0.003194	0.001176	0.003126
Cobalt	0.0102631	0.0002828	0.0004188
Copper	0.011824	0.002167	0.002204
Iron	2.2709	3.67535	1.8674
Lead	0.0007961	0.0011503	0.0001662
Lithium	0.0058548	0.005	0.005
Magnesium	2.224	1.639	1.571
Manganese	0.044529	0.012941	0.010231
Mercury	0.754994733	0.00346	0.754991951
Molybdenum	0.0001766	0.000082	0.0000721
Nickel	0.019564	0.003858	0.00417
Phosphorus	0.015351	0.013125	0.014029
Potassium	1.4804	0.413	0.6839
Selenium	0.000222	0.000109	0.000104
Silicon	6.87223	5.02021	5.73203
Silver	0.0000125	0.0000158	0.0000117
Sodium	0.9554	0.6916	0.8878
Strontium	0.01458	0.00984	0.00974
Tellerium	0	0	0
Thallium	0.0000541	0.0000515	0.0000541
Thorium	0	0	0
Tin	0.000179	0.0001	0.0001
Titanium	0.058141	0.030852	0.058141
Uranium	0.0007429	0.0000202	0.0000345
Vanadium	0.00128345	0.000578	0.00087772
Zinc	0.015174	0.00424	0.003985
Zirconium	0.0004	0.0004	0.0004

Appendix D – Water Quality Prediction Results

Water Quality Prediction without Treatment												
Parameter	**Goose Lake**		**Goose Pit**		**Llama TF**		**Primary Pond**		**TSF Reservoir**		**Umwelt Pond**	
(mg/L)	**Post-Clos**	**Max**	**Post-Clos**	**Max**	**Post-Clos**	**Max**	**Post-Clos**	**Max**	**Post-Clos**	**Max**	**Post-Clos**	**Max**
TDS	9.463	20.56	16.34	16.79	10.01	31.67	0	66.45	22.7	498.5	0	992.9
TSS	0.1824	0.3943	0.3429	2.15	0.1754	2.348	0	1.441	1.069	55.65	0	25.16
Free_CN	0.00786	3.961	0.004562	0.1994	7.48E-05	144.7	0	185.6	4.035	57.3	0	0.889
Total_CN_N	0.0001695	0.0005169	0.0003094	0.001348	0.0001753	0.006119	0	0.001156	0.001118	0.01221	0	0.2222
WAD_CN	0.005133	0.01872	0.01047	0.09796	0.005191	0.2145	0	0.09859	0.05038	0.4936	0	1.166
CNO_N	0.006849	0.02501	0.006603	0.01224	0.009058	6.755	0	0.03754	0.01746	0.2507	0	287.8
SCN_N	0.000187	0.0004221	0.0001768	0.0002401	0.0002028	0.001221	0	0.001163	8.07E-05	0.004264	0	0.06353
Sulphate	0.0004651	0.001088	0.0004424	0.0006014	0.0004907	0.04876	0	0.002909	0.0002056	0.001041	0	2.114
Chloride	0.01353	0.02918	0.001331	0.04858	0.06495	4.32	0	0.2368	0.04274	2.244	0	184.2
Ammonia_N	1.05E-05	2.56E-05	8.98E-06	5.68E-05	1.44E-05	0.0009867	0	5.83E-05	1.51E-05	0.001241	0	0.04289
Nitrate_N	6.707	71.42	10.34	10.62	6.848	17717	0	1570	105.3	1224	0	753961
Nitrite_N	3.077	36.43	2.564	3.474	3.657	3847	0	2768	48.67	217	0	1044000
Alkalinity	0.0003464	0.001065	0.0004782	0.002626	0.0004594	0.01115	0	0.002123	0.002022	0.04854	0	0.3224
Ortho_P	0.001142	0.3916	0.002456	0.002912	3.08E-06	35.5	0	6.71E-05	0	10.06	0	0.0001991
Phosphate_P	0.001454	0.008064	0.002378	0.007701	0.001409	0.1056	0	0.01126	0.0187	0.3623	0	0.5527
TOC	0.001921	0.009467	0.002525	0.006919	0.001976	0.1049	0	0.00872	0.02679	2.261	0	0.5152
Hardness	0	0	0	0	0	0	0	0	0	0	0	0
Aluminum	16.03	65.77	11.2	31.18	33.31	49830	0	116.3	19.99	3862	0	2121000
Antimony	0.1784	0.6375	0.2841	1.749	0.1686	6.791	0	1.929	1.914	137.7	0	201
Arsenic	8.48E-05	0.000438	5.72E-05	0.0002469	0.0002009	0.005534	0	0.001184	0.0007325	0.004414	0	0.2139
Barium	0.001366	0.01003	0.0006636	0.008002	0.004064	7.863	0	0.0211	0.004793	0.142	0	334.8
Beryllium	1.863	10.44	2.359	2.851	1.849	1107	0	54.01	14.02	282.6	0	47212
Bismuth	0.03048	0.06525	0.05911	0.06064	0.02831	3.213	0	0.1761	0.1242	4.954	0	137.9
Boron	0.04084	0.08911	0.08225	0.62	0.0388	0.3762	0	0.2683	0.1526	4.694	0	4.624
Cadmium	0.0003638	0.01267	0.000587	0.0006144	0.0003886	0.2268	0	0.001071	0.02912	0.4904	0	1.99
Calcium	0.007192	0.01525	0.01032	0.02297	0.007131	0.03351	0	0.03761	0.01139	0.3425	0	1.107
Chromium	0.09927	7.599	0.004651	0.3214	0.09072	46.7	0	300.9	16.19	28.9	0	55.11
Cobalt	0.06428	0.7464	0.0008958	0.04106	0.01776	3.196	0	15.05	1.113	1.995	0	8.284
Copper	0.00279	0.01507	0.000884	0.001025	0.0009479	0.06865	0	0.005816	0.006662	0.02017	0	2.974
Iron	0.001872	0.01308	0	0	1.99E-05	0.2436	0	0	0.006646	0.02004	0	10.36
Lead	0.005411	0.01804	0.002833	0.01477	0.008471	3.654	0	0.03316	0.009577	0.1973	0	155.7
Lithium	1.024	12.63	0.3828	2.665	3.432	265.8	0	12.19	24.12	65.02	0	11347
Magnesium	1.90E-29	0.3168	0	0	0	40.36	0	0	0	11.44	0	0
Manganese	0.0001876	0.0008252	0.0002988	0.001094	0.0001976	0.01089	0	0.0009453	0.00158	0.02154	0	0.4335
Mercury	0.8987	2.092	0.8578	5.849	2.264	20.1	0	10.44	3.907	95.31	0	92.03
Molybdenum	1.12E-05	2.87E-05	1.33E-05	2.56E-05	1.15E-05	0.000986	0	6.00E-05	2.44E-05	0.0004026	0	0.04268
Nickel	1.99	187.3	0.56	2.858	2.782	7530	0	6.171	372.2	1008	0	320385
Phosphorus	0.02025	0.3998	0.01388	0.06053	0.03356	365.4	0	0.1763	0.1862	3.194	0	15549
Potassium	19.97	396.6	35.81	38.84	16.98	6369	0	606.7	879.6	6246	0	2902
Selenium	46.99	131.9	68.09	69.88	48.28	6412	0	877.8	112	7907	0	1742000
Silicon	1.93E-05	4.17E-05	8.73E-08	0.001628	0.0001003	0.001306	0	0.0006576	6.14E-05	0.0009504	0	0.01091
Silver	4.77E-05	0.0001056	4.46E-05	6.13E-05	5.46E-05	0.004873	0	0.0002913	8.92E-06	0.0003708	0	0.2102
Sodium	6.73E-06	2.36E-05	1.04E-05	8.46E-05	1.23E-05	0.0003179	0	7.22E-05	6.13E-05	0.001309	0	0.000741
Strontium	0.0001482	0.0003267	8.84E-05	0.0002492	0.0003876	0.009861	0	0.001176	0.0002935	0.01018	0	0.4265
Tellerium	0.003152	0.00686	0.005801	0.0477	0.003627	0.1226	0	0.02863	0.01635	0.3241	0	5.576
Thallium	3.959	8.687	3.864	4.614	4.063	4.33	0	24.88	0.07064	6.944	0	226.2
Thorium	0.001183	0.001855	0.002507	0.002983	4.40E-05	1.059	0	0.002324	0	1.372	0	0.07411
Tin	2.756	6.332	2.652	3.076	2.787	2.986	0	17.45	0.04848	4.758	0	159.3
Titanium	0.0002426	0.0005251	1.15E-05	0.0006911	0.0012	0.001286	0	0.004654	0.0001042	0.004255	0	0.04749
Uranium	0	0	0	0	0	0	0	0	0	0	0	0
Vanadium	0.000384	0.0008343	0.0001418	0.002215	0.001569	0.03665	0	0.008829	0.0002736	0.01592	0	1.599
Zinc	5.35E-05	0.007689	0	0	5.00E-05	0.1859	0	0	0.06349	8.498	0	0
Zirconium	0.001995	0.004263	0.002881	0.005497	0.00198	0.3323	0	0.01021	0.0044	0.1737	0	14.27

Parameter	Umwelt Reservoir		PN01		PN02		PN03		PN04		PN05	
(mg/L)	Post-Clos	Max	Post-Clos	Max	Post-Clos	Max	Post-Clos	Max	Post-Clos	Max	Post-Clos	Max
TDS	42.17	5453	5.512	10.16	7.254	10.16	9.463	10.16	7.463	20.61	11.69	15.47
TSS	1.199	615.2	0.05999	0.1949	0.1142	0.1949	0.1824	0.1949	0.1797	0.5698	0.2457	0.3255
Free_CN	9.89E-06	3380	0.005088	2.301	0.006057	2.307	0.00786	3.961	0.002294	28.13	0.003484	0.2573
Total_CN_N	0.0009777	0.2214	8.31E-05	0.000254	0.0001212	0.000254	0.0001695	0.000254	0.0001493	0.0008628	0.0002209	0.0002914
WAD_CN	0.03975	9.674	0.001549	0.009199	0.003134	0.009199	0.005133	0.009199	0.005077	0.03996	0.007409	0.009775
CNO_N	0.02537	1.975	0.006073	0.01229	0.006409	0.01229	0.006849	0.01229	0.006457	0.03194	0.004973	0.006962
SCN_N	0.0001962	0.0002288	0.0001992	0.0002141	0.0001935	0.0002141	0.000187	0.0002138	0.0001475	0.0001961	0.0001353	0.0001995
Sulphate	0.0004169	0.001643	0.0004973	0.0005491	0.0004821	0.0005491	0.0004651	0.0005491	0.0003596	0.0005975	0.0003387	0.0004986
Chloride	0.3741	0.3875	0.00453	0.01441	0.008518	0.01441	0.01353	0.01441	0.04147	0.05717	0.001003	0.002329
Ammonia_N	3.68E-05	0.0002857	1.03E-05	1.30E-05	1.03E-05	1.30E-05	1.05E-05	1.31E-05	1.03E-05	1.81E-05	6.87E-06	1.08E-05
Nitrate_N	55.94	3624	3.836	35.09	5.102	35.09	6.707	35.09	6.645	155.2	7.416	9.814
Nitrite_N	19.82	90.84	2.89	17.9	2.969	17.9	3.077	17.9	3.278	80.96	1.957	2.992
Alkalinity	0.002297	0.6729	0.0001858	0.0005229	0.0002568	0.0005229	0.0003464	0.0005229	0.0003703	0.001575	0.0003475	0.0004645
Ortho_P	4.08E-07	2.564	0.0003055	0.1754	0.0006725	0.1799	0.001142	0.3891	8.74E-07	4.006	0.001707	0.002515
Phosphate_P	0.009383	3.98	0.0005825	0.003962	0.0009683	0.003962	0.001454	0.003962	0.001425	0.01517	0.001712	0.00229
TOC	0.006719	0.8001	0.001521	0.004648	0.001695	0.004648	0.001921	0.004648	0.001559	0.0153	0.001851	0.002454
Hardness	0	0	0	0	0	0	0	0	0	0	0	0
Aluminum	142.1	147.8	13.43	32.31	14.56	32.31	16.03	32.31	23.17	98.47	8.554	12.96
Antimony	0.9922	466.1	0.09121	0.3132	0.1297	0.3132	0.1784	0.3132	0.1823	1.047	0.2058	0.2722
Arsenic	0.001008	0.02645	6.01E-05	0.000215	7.09E-05	0.000215	8.48E-05	0.000215	0.0001481	0.0007735	4.31E-05	5.69E-05
Barium	0.0224	0.0288	0.0008597	0.004927	0.001083	0.004927	0.001366	0.004927	0.00274	0.0192	0.0005037	0.000887
Beryllium	9.25	968.8	1.527	5.271	1.673	5.28	1.863	5.516	1.702	23.92	1.737	2.286
Bismuth	0.1438	33.04	0.01282	0.03225	0.02063	0.03225	0.03048	0.03225	0.02235	0.0759	0.04196	0.05582
Boron	0.2942	167.4	0.01109	0.04405	0.02425	0.04405	0.04084	0.04405	0.0412	0.08843	0.05886	0.07765
Cadmium	0.005661	0.1796	0.0001355	0.006223	0.0002364	0.006223	0.0003638	0.006223	0.0004764	0.02772	0.0004144	0.0005468
Calcium	0.02469	13.08	0.004357	0.007535	0.00561	0.007535	0.007192	0.007535	0.005969	0.009163	0.007525	0.01009
Chromium	4.566	5520	0.03027	4.134	0.06078	4.143	0.09927	4.397	0.294	23.04	0.003547	0.4142
Cobalt	0.3416	276	0.01759	0.3211	0.03714	0.3211	0.06428	0.3211	0.02567	1.382	0.000685	0.02146
Copper	0.001469	0.005813	0.00148	0.004757	0.002021	0.004757	0.00279	0.005814	0.0007442	0.00696	0.0006767	0.0009973
Iron	0.001065	0.005812	0.0004889	0.00377	0.001064	0.00377	0.001872	0.004902	6.65E-05	0.006601	0	0
Lead	0.0415	2.228	0.002876	0.007341	0.003957	0.007341	0.005411	0.007613	0.00591	0.01526	0.002112	0.002792
Lithium	21.41	77.34	0.557	6.207	0.7632	6.207	1.024	6.207	2.42	26.45	0.2905	0.4359
Magnesium	0	1.692	3.10E-30	0.08278	9.53E-30	0.1444	1.90E-29	0.3137	0	3.433	0	0
Manganese	0.0008711	0.0738	0.0001251	0.0004054	0.0001526	0.0004054	0.0001876	0.0004054	0.0001546	0.001398	0.0002152	0.0002839
Mercury	12.29	1207	0.4054	1.028	0.6237	1.028	0.8987	1.028	1.59	3.196	0.6231	0.8334
Molybdenum	2.13E-05	0.003248	1.05E-05	1.41E-05	1.08E-05	1.41E-05	1.12E-05	1.41E-05	8.76E-06	2.59E-05	9.87E-06	1.30E-05
Nickel	66.83	333.1	0.9947	92	1.434	92	1.99	92	4.889	411.7	0.4281	0.6452
Phosphorus	0.2367	0.7589	0.01679	0.1964	0.01829	0.1964	0.02025	0.1964	0.0295	0.8186	0.0106	0.01625
Potassium	216.7	7955	8.884	194.9	13.78	194.9	19.97	194.9	20.26	832.8	25.35	35.05
Selenium	188.9	19333	33.28	80.49	39.3	80.59	46.99	83.31	37.78	273	49.39	65.57
Silicon	0.0005767	0.001429	5.22E-06	2.06E-05	1.14E-05	2.06E-05	1.93E-05	2.06E-05	6.41E-05	8.85E-05	6.24E-08	3.88E-05
Silver	7.20E-05	0.0008933	5.01E-05	5.39E-05	4.89E-05	5.39E-05	4.77E-05	5.38E-05	3.95E-05	5.25E-05	3.42E-05	4.99E-05
Sodium	8.58E-05	0.02117	1.83E-06	1.16E-05	3.99E-06	1.16E-05	6.73E-06	1.16E-05	1.04E-05	4.60E-05	7.44E-06	9.82E-06
Strontium	0.001779	0.001843	0.0001144	0.0001605	0.0001292	0.0001605	0.0001482	0.0001605	0.0002557	0.0003575	6.77E-05	0.0001014
Tellerium	0.02576	11.49	0.0009495	0.003391	0.001924	0.003391	0.003152	0.003391	0.003573	0.01057	0.004157	0.00549
Thallium	2.004	3.182	3.901	4.792	3.922	4.58	3.959	4.38	2.739	4.595	2.931	4.787
Thorium	5.84E-06	0.00565	0.002099	0.003084	0.001699	0.002618	0.001183	0.001694	0.001153	0.00592	0.001903	0.003091
Tin	1.373	1.989	2.974	3.146	2.872	3.146	2.756	3.139	2.044	2.872	2.03	2.992
Titanium	0.0071	0.007348	7.31E-05	0.0002594	0.0001482	0.0002594	0.0002426	0.0002594	0.0007803	0.001078	8.67E-06	2.33E-05
Uranium	0	0	0	0	0	0	0	0	0	0	0	0
Vanadium	0.00856	0.1946	0.0001452	0.0004117	0.0002509	0.0004117	0.000384	0.0004117	0.001049	0.001444	0.0001039	0.0001368
Zinc	0.002664	0.01454	1.43E-05	0.003778	3.17E-05	0.003778	5.35E-05	0.003778	0.0001662	0.01693	0	0
Zirconium	0.0072	3.32	0.001241	0.002104	0.001574	0.002104	0.001995	0.002104	0.001669	0.00351	0.002099	0.002805

Parameter	PN06		PN07		PN08		PN09		PN10	
(mg/L)	Post-Clos	Max	Post-Clos	Max	Post-Clos	Max	Post-Clos	Max	Post-Clos	Max
TDS	3.017	4.519	0	0	3.085	4.606	3.117	4.648	3.003	4.5
TSS	0.01308	0.03461	0	0	0.02209	0.04649	0.0264	0.05218	0.0111	0.032
Free_CN	0.003763	0.1764	0	0	0.003747	0.02517	0.003739	1.646	0.003767	0.08776
Total_CN_N	3.83E-05	5.09E-05	0	0	4.14E-05	5.50E-05	4.29E-05	5.70E-05	3.77E-05	5.00E-05
WAD_CN	0.0001892	0.0002512	0	0	0.0003309	0.0004393	0.0003987	0.0005293	0.0001582	0.00021
CNO_N	0.004315	0.006902	0	0	0.004325	0.006911	0.004331	0.006915	0.004313	0.0069
SCN_N	0.0001505	0.0001998	0	0	0.0001498	0.0001989	0.0001495	0.0001985	0.0001507	2.00E-04
Sulphate	0.0003763	0.0004996	0	0	0.0003747	0.0004974	0.0003739	0.0004964	0.0003767	5.00E-04
Chloride	0.0008928	0.001699	0	0	0.0008899	0.001693	0.0008885	0.00169	0.0008933	0.0017
Ammonia_N	7.53E-06	9.99E-06	0	0	7.50E-06	9.95E-06	7.49E-06	9.94E-06	7.53E-06	1.00E-05
Nitrate_N	2.068	3.113	0	0	2.113	3.17	2.134	3.198	2.059	3.1
Nitrite_N	2.092	2.997	0	0	2.083	2.984	2.079	2.978	2.094	3
Alkalinity	9.74E-05	0.0002027	0	0	0.0001069	0.000215	0.0001115	0.0002209	9.53E-05	2.00E-04
Ortho_P	0	0	0	0	0	0	0	0	0	0
Phosphate_P	0.0002146	0.0006664	0	0	0.0002723	0.0007414	0.0002999	0.0007773	0.0002019	0.00065
TOC	0.001021	0.001502	0	0	0.001028	0.001511	0.001032	0.001516	0.001019	0.0015
Hardness	0	0	0	0	0	0	0	0	0	0
Aluminum	9.232	12.99	0	0	9.192	12.93	9.171	12.9	9.24	13
Antimony	0.0451	0.06794	0	0	0.05177	0.07676	0.05496	0.08098	0.04363	0.066
Arsenic	3.77E-05	5.01E-05	0	0	3.79E-05	5.04E-05	3.81E-05	5.05E-05	3.77E-05	5.00E-05
Barium	0.000501	0.0008193	0	0	0.0004989	0.0008157	0.0004978	0.000814	0.0005015	0.00082
Beryllium	1.037	1.403	0	0	1.047	1.416	1.051	1.422	1.035	1.4
Bismuth	0.004882	0.01213	0	0	0.005347	0.01272	0.005571	0.01301	0.004779	0.012
Boron	0.0005412	0.0007189	0	0	0.003006	0.003991	0.004186	0.005557	7.06E-07	1.40E-06
Cadmium	3.82E-05	5.07E-05	0	0	4.07E-05	5.40E-05	4.19E-05	5.56E-05	3.77E-05	5.00E-05
Calcium	0.002539	0.005351	0	0	0.00272	0.005584	0.002807	0.005695	0.002499	0.0053
Chromium	0.003763	0.283	0	0	0.003747	0.4088	0.003739	2.667	0.003767	0.1392
Cobalt	0.0007526	0.0149	0	0	0.0007493	0.02119	0.0007478	0.1341	0.0007533	0.00771
Copper	0.0007526	0.0009991	0	0	0.0007493	0.0009947	0.0007478	0.0009927	0.0007533	0.001
Iron	0	0	0	0	0	0	0	0	0	0
Lead	0.001457	0.002008	0	0	0.001484	0.002043	0.001496	0.002059	0.001451	0.002
Lithium	0.2847	0.4	0	0	0.2846	0.3997	0.2846	0.3996	0.2847	0.4
Magnesium	0	0	0	0	0	0	0	0	0	0
Manganese	7.55E-05	0.0001002	0	0	7.62E-05	0.0001012	7.66E-05	0.0001017	7.53E-05	1.00E-04
Mercury	0.1719	0.3668	0	0	0.1889	0.3889	0.1971	0.3994	0.1681	0.362
Molybdenum	7.53E-06	1.00E-05	0	0	7.55E-06	1.00E-05	7.56E-06	1.00E-05	7.53E-06	1.00E-05
Nickel	0.4663	0.6297	0	0	0.4651	0.628	0.4645	0.6272	0.4666	0.63
Phosphorus	0.01149	0.01599	0	0	0.01144	0.01592	0.01142	0.01588	0.0115	0.016
Potassium	3.539	4.83	0	0	3.64	4.964	3.689	5.029	3.516	4.8
Selenium	21.03	33.05	0	0	21.22	33.29	21.32	33.4	20.99	33
Silicon	5.02E-10	6.66E-10	0	0	2.79E-09	3.70E-09	3.88E-09	5.15E-09	0	0
Silver	3.76E-05	5.00E-05	0	0	3.75E-05	4.98E-05	3.74E-05	4.97E-05	3.77E-05	5.00E-05
Sodium	6.84E-08	9.07E-08	0	0	3.80E-07	5.05E-07	5.29E-07	7.03E-07	0	0
Strontium	7.53E-05	9.99E-05	0	0	7.49E-05	9.95E-05	7.48E-05	9.93E-05	7.53E-05	1.00E-04
Tellerium	0.0001344	0.0002591	0	0	0.0003032	0.0004828	0.000384	0.0005899	9.73E-05	0.00021
Thallium	2.894	4.796	0	0	2.882	4.775	2.875	4.765	2.897	4.8
Thorium	0.001891	0.003097	0	0	0.001883	0.003084	0.001879	0.003077	0.001893	0.0031
Tin	2.258	2.997	0	0	2.248	2.984	2.243	2.978	2.26	3
Titanium	7.54E-06	1.00E-05	0	0	7.59E-06	1.01E-05	7.62E-06	1.01E-05	7.53E-06	1.00E-05
Uranium	0	0	0	0	0	0	0	0	0	0
Vanadium	4.21E-05	5.78E-05	0	0	4.48E-05	6.13E-05	4.61E-05	6.30E-05	4.15E-05	5.70E-05
Zinc	0	0	0	0	0	0	0	0	0	0
Zirconium	0.0007327	0.001413	0	0	0.0007785	0.001472	0.0008004	0.0015	0.0007227	0.0014

Water Quality Prediction with Treatment												
Parameter	Goose Lake		Goose Pit		Llama TF		Primary Pond		TSF Reservoir		Umwelt Pond	
(mg/L)	Post-Clos	Max	Post-Clos	Max	Post-Clos	Max	Post-Clos	Max	Post-Clos	Max	Post-Clos	Max
TDS	9.463	20.56	16.34	16.79	10.01	31.67	0	66.45	22.7	498.5	0	992.9
TSS	0.1824	0.3943	0.3429	2.15	0.1754	2.348	0	1.441	1.069	55.65	0	25.16
Free_CN	0.00786	2.014	0.004562	0.1996	7.48E-05	144.7	0	185.6	4.035	57.3	0	0.889
Total_CN_N	0.0001694	0.0005179	0.0003094	0.001348	0.0001753	0.006119	0	0.001156	0.001118	0.01221	0	0.2222
WAD_CN	0.005131	0.01875	0.01047	0.09796	0.005191	0.2145	0	0.09859	0.05038	0.4936	0	1.166
CNO_N	0.006847	0.02512	0.006603	0.01224	0.009059	6.755	0	0.03754	0.01746	0.2507	0	287.8
SCN_N	0.000187	0.0004221	0.0001768	0.0002401	0.0002028	0.001221	0	0.001163	8.07E-05	0.004264	0	0.06353
Sulphate	0.0004651	0.001088	0.0004424	0.0006014	0.0004907	0.04876	0	0.002909	0.0002056	0.001041	0	2.114
Chloride	0.01353	0.02917	0.001331	0.04858	0.06495	4.32	0	0.2368	0.04274	2.244	0	184.2
Ammonia_N	1.05E-05	2.56E-05	8.98E-06	5.68E-05	1.44E-05	0.0009867	0	5.83E-05	1.51E-05	0.001241	0	0.04289
Nitrate_N	6.702	71.74	10.34	10.62	6.848	17717	0	1570	105.3	1224	0	753961
Nitrite_N	3.075	36.49	2.564	3.474	3.657	3847	0	2768	48.67	217	0	1044000
Alkalinity	0.0003464	0.001066	0.0004782	0.002626	0.0004594	0.01115	0	0.002123	0.002022	0.04854	0	0.3224
Ortho_P	0.001142	0.3932	0.002456	0.002912	3.08E-06	35.5	0	6.71E-05	0	10.06	0	0.0001991
Phosphate_P	0.001453	0.00807	0.002378	0.007701	0.001409	0.1056	0	0.01126	0.0187	0.3623	0	0.5527
TOC	0.00192	0.009474	0.002525	0.006919	0.001968	0.1049	0	0.00872	0.02679	2.261	0	0.5152
Hardness	0	0	0	0	0	0	0	0	0	0	0	0
Aluminum	16.02	66.12	11.2	31.18	33.31	49830	0	116.3	19.99	3862	0	2121000
Antimony	0.1784	0.6379	0.2841	1.749	0.1686	6.791	0	1.929	1.914	137.7	0	201
Arsenic	8.47E-05	0.0004384	5.72E-05	0.0002469	0.0002009	0.005534	0	0.001184	0.0007325	0.004414	0	0.2139
Barium	0.001365	0.01013	0.0006636	0.008002	0.004064	7.863	0	0.0211	0.004793	0.142	0	334.8
Beryllium	1.863	10.45	2.359	2.851	1.849	1107	0	54.01	14.02	282.6	0	47212
Bismuth	0.03048	0.06525	0.05911	0.06064	0.02831	3.213	0	0.1761	0.1242	4.954	0	137.9
Boron	0.04084	0.08911	0.08225	0.62	0.0388	0.3762	0	0.2683	0.1526	4.694	0	4.624
Cadmium	0.0003622	0.01272	0.000587	0.0006144	0.0003886	0.2268	0	0.001071	0.02912	0.4904	0	1.99
Calcium	0.007192	0.01525	0.01032	0.02297	0.007131	0.03351	0	0.03761	0.01139	0.3425	0	1.107
Chromium	0.09924	7.606	0.004651	0.3217	0.0907	46.8	0	300.9	16.19	28.9	0	55.11
Cobalt	0.06426	0.7473	0.0008958	0.04106	0.01776	3.196	0	15.05	1.113	1.995	0	8.284
Copper	0.002789	0.01485	0.000884	0.001025	0.0009479	0.06865	0	0.005816	0.006662	0.02017	0	2.974
Iron	0.001872	0.01285	0	0	1.99E-05	0.2436	0	0	0.006646	0.02004	0	10.36
Lead	0.00541	0.01807	0.002833	0.01477	0.008471	3.654	0	0.03316	0.009577	0.1973	0	155.7
Lithium	1.022	12.68	0.3828	2.665	3.432	265.8	0	12.19	24.12	65.02	0	11347
Magnesium	1.92E-29	0.3186	0	0	0	40.36	0	0	0	11.44	0	0
Manganese	0.0001875	0.0008274	0.0002988	0.001094	0.0001976	0.01089	0	0.0009453	0.00158	0.02154	0	0.4335
Mercury	0.8985	2.095	0.8578	5.849	2.264	20.1	0	10.44	3.907	95.31	0	92.03
Molybdenum	1.12E-05	2.87E-05	1.33E-05	2.56E-05	1.15E-05	0.000986	0	6.00E-05	2.44E-05	0.0004026	0	0.04268
Nickel	1.967	188.1	0.56	2.858	2.781	7530	0	6.171	372.2	1008	0	320385
Phosphorus	0.02021	0.4024	0.01388	0.06053	0.03357	365.4	0	0.1763	0.1862	3.194	0	15549
Potassium	19.93	398	35.81	38.84	16.98	6369	0	606.7	879.6	6246	0	2902
Selenium	46.99	130.4	68.09	69.88	48.28	6412	0	877.8	112	7907	0	1742000
Silicon	1.93E-05	4.17E-05	8.73E-08	0.001628	0.0001003	0.001306	0	0.0006576	6.14E-05	0.0009504	0	0.01091
Silver	4.77E-05	0.0001056	4.46E-05	6.13E-05	5.46E-05	0.004873	0	0.0002913	8.92E-06	0.0003708	0	0.2102
Sodium	6.72E-06	2.36E-05	1.04E-05	8.46E-05	1.23E-05	0.0003179	0	7.22E-05	6.13E-05	0.001309	0	0.000741
Strontium	0.0001482	0.0003269	8.84E-05	0.0002492	0.0003876	0.009861	0	0.001176	0.0002935	0.01018	0	0.4265
Tellerium	0.003152	0.006859	0.005801	0.0477	0.003627	0.1226	0	0.02863	0.01635	0.3241	0	5.576
Thallium	3.959	8.687	3.864	4.614	4.063	4.33	0	24.88	0.07064	6.944	0	226.2
Thorium	0.001183	0.001855	0.002507	0.002983	4.40E-05	1.059	0	0.002324	0	1.372	0	0.07411
Tin	2.756	6.332	2.652	3.076	2.787	2.986	0	17.45	0.04848	4.758	0	159.3
Titanium	0.0002426	0.0005251	1.15E-05	0.0006911	0.0012	0.001286	0	0.004654	0.0001042	0.004255	0	0.04749
Uranium	0	0	0	0	0	0	0	0	0	0	0	0
Vanadium	0.000384	0.0008343	0.0001418	0.002215	0.001569	0.03665	0	0.008829	0.0002736	0.01592	0	1.599
Zinc	5.25E-05	0.007695	0	0	5.00E-05	0.1859	0	0	0.06349	8.498	0	0
Zirconium	0.001995	0.004263	0.002881	0.005497	0.00198	0.3323	0	0.01021	0.0044	0.1737	0	14.27

Parameter	Umwelt Reservoir		PN01		PN02		PN03		PN04		PN05	
(mg/L)	Post-Clos	Max	Post-Clos	Max	Post-Clos	Max	Post-Clos	Max	Post-Clos	Max	Post-Clos	Max
TDS	42.17	5453	5.512	10.16	7.254	10.16	9.463	10.16	7.463	20.6	11.69	15.47
TSS	1.199	615.2	0.05997	0.1949	0.1141	0.1949	0.1824	0.1949	0.1797	0.5684	0.2457	0.3255
Free_CN	9.89E-06	3380	0.005088	1.478	0.006057	1.482	0.00786	1.594	0.002294	14.87	0.003484	0.2573
Total_CN_N	0.000977	0.2214	8.31E-05	0.0002545	0.0001212	0.0002545	0.0001694	0.0002545	0.0001492	0.0008622	0.0002209	0.0002914
WAD_CN	0.03972	9.674	0.001549	0.009219	0.003134	0.009219	0.005132	0.009219	0.005075	0.03982	0.007409	0.009775
CNO_N	0.02535	1.975	0.006073	0.01232	0.006409	0.01232	0.006849	0.01232	0.006456	0.03199	0.004973	0.006962
SCN_N	0.0001962	0.0002288	0.0001992	0.0002142	0.0001934	0.0002142	0.000187	0.0002138	0.0001475	0.0001961	0.0001353	0.0001995
Sulphate	0.0004167	0.001643	0.0004973	0.0005491	0.0004821	0.0005491	0.0004651	0.0005491	0.0003596	0.0005979	0.0003387	0.0004986
Chloride	0.3741	0.3874	0.00453	0.01441	0.008517	0.01441	0.01353	0.01441	0.04146	0.05717	0.001003	0.002329
Ammonia_N	3.68E-05	0.0002857	1.03E-05	1.29E-05	1.03E-05	1.29E-05	1.05E-05	1.31E-05	1.03E-05	1.80E-05	6.87E-06	1.08E-05
Nitrate_N	55.86	3624	3.835	35.21	5.101	35.21	6.705	35.21	6.64	154.7	7.416	9.814
Nitrite_N	19.79	90.84	2.89	17.95	2.968	17.95	3.077	17.95	3.276	82.22	1.957	2.992
Alkalinity	0.002295	0.6729	0.0001858	0.0005237	0.0002568	0.0005237	0.0003464	0.0005237	0.0003703	0.001574	0.0003475	0.0004645
Ortho_P	4.08E-07	2.543	0.0003055	0.173	0.0006725	0.1798	0.001142	0.3887	8.74E-07	4.002	0.001707	0.002515
Phosphate_P	0.009369	3.98	0.0005824	0.003971	0.0009682	0.003971	0.001454	0.003971	0.001424	0.01516	0.001712	0.00229
TOC	0.006366	0.8001	0.001519	0.004088	0.001691	0.004088	0.001913	0.004088	0.001537	0.01272	0.001851	0.002454
Hardness	0	0	0	0	0	0	0	0	0	0	0	0
Aluminum	142.1	147.8	13.43	32.48	14.56	32.48	16.03	32.48	23.17	98.93	8.554	12.96
Antimony	0.9914	466.1	0.0912	0.3138	0.1297	0.3138	0.1784	0.3138	0.1822	1.046	0.2058	0.2722
Arsenic	0.001007	0.02645	6.01E-05	0.0002155	7.09E-05	0.0002155	8.48E-05	0.0002155	0.0001481	0.000773	4.31E-05	5.69E-05
Barium	0.02239	0.0288	0.0008597	0.004957	0.001083	0.004957	0.001366	0.004957	0.00274	0.01927	0.0005037	0.000887
Beryllium	9.241	968.8	1.527	5.25	1.673	5.259	1.863	5.494	1.701	23.87	1.737	2.286
Bismuth	0.1438	33.04	0.01282	0.03225	0.02063	0.03225	0.03048	0.03225	0.02235	0.07572	0.04196	0.05582
Boron	0.2942	167.4	0.01109	0.04405	0.02425	0.04405	0.04084	0.04405	0.0412	0.08857	0.05886	0.07765
Cadmium	0.005634	0.1796	0.0001354	0.006241	0.0002361	0.006241	0.0003633	0.006241	0.0004748	0.02769	0.0004144	0.0005468
Calcium	0.0247	13.08	0.004357	0.007535	0.00561	0.007535	0.007192	0.007535	0.005969	0.009163	0.007525	0.01009
Chromium	4.563	5520	0.03026	4.116	0.06076	4.125	0.09922	4.377	0.2938	23.02	0.003547	0.4142
Cobalt	0.3411	276	0.01759	0.3215	0.03713	0.3215	0.06427	0.3215	0.02564	1.397	0.000685	0.02146
Copper	0.001462	0.005777	0.00148	0.004757	0.002021	0.004757	0.002789	0.005814	0.0007439	0.006957	0.0006767	0.0009973
Iron	0.001058	0.005774	0.0004889	0.00377	0.001064	0.00377	0.001872	0.004902	6.61E-05	0.0066	0	0
Lead	0.04149	2.228	0.002876	0.007358	0.003957	0.007358	0.00541	0.007624	0.00591	0.01529	0.002112	0.002792
Lithium	21.38	77.34	0.557	6.224	0.763	6.224	1.023	6.224	2.419	26.43	0.2905	0.4359
Magnesium	0	1.695	3.10E-30	0.08295	9.52E-30	0.1444	1.90E-29	0.3136	0	3.558	0	0
Manganese	0.0008699	0.0738	0.0001251	0.0004063	0.0001526	0.0004063	0.0001876	0.0004063	0.0001545	0.001396	0.0002152	0.0002839
Mercury	12.28	1207	0.4054	1.029	0.6237	1.029	0.8986	1.029	1.59	3.194	0.6231	0.8334
Molybdenum	2.12E-05	0.003248	1.05E-05	1.41E-05	1.08E-05	1.41E-05	1.12E-05	1.41E-05	8.76E-06	2.59E-05	9.87E-06	1.30E-05
Nickel	66.44	330.9	0.9927	92.28	1.43	92.28	1.982	92.28	4.866	411.4	0.4281	0.6452
Phosphorus	0.2363	0.7567	0.01679	0.1978	0.01829	0.1978	0.02024	0.1978	0.02948	0.8219	0.0106	0.01625
Potassium	216	7955	8.879	195.4	13.77	195.4	19.96	195.4	20.21	832.1	25.35	35.05
Selenium	188.9	19333	33.28	80.33	39.3	80.43	46.99	83.14	37.78	272.9	49.39	65.57
Silicon	0.0005767	0.001429	5.22E-06	2.06E-05	1.14E-05	2.06E-05	1.93E-05	2.06E-05	6.41E-05	8.85E-05	6.24E-08	3.88E-05
Silver	7.20E-05	0.0008933	5.01E-05	5.39E-05	4.89E-05	5.39E-05	4.77E-05	5.38E-05	3.95E-05	5.25E-05	3.42E-05	4.99E-05
Sodium	8.58E-05	0.02117	1.83E-06	1.16E-05	3.99E-06	1.16E-05	6.73E-06	1.16E-05	1.04E-05	4.59E-05	7.44E-06	9.82E-06
Strontium	0.001778	0.001842	0.0001144	0.0001607	0.0001292	0.0001607	0.0001482	0.0001607	0.0002557	0.0003573	6.77E-05	0.0001014
Tellerium	0.02575	11.49	0.0009495	0.00339	0.001924	0.00339	0.003152	0.00339	0.003573	0.01054	0.004157	0.00549
Thallium	2.004	3.182	3.901	4.792	3.922	4.58	3.959	4.382	2.739	4.595	2.931	4.787
Thorium	5.84E-06	0.005635	0.002099	0.003084	0.001699	0.002618	0.001183	0.001694	0.001153	0.006764	0.001903	0.003091
Tin	1.373	1.989	2.974	3.148	2.872	3.147	2.756	3.139	2.044	2.872	2.03	2.992
Titanium	0.0071	0.007348	7.31E-05	0.0002594	0.0001482	0.0002594	0.0002426	0.0002594	0.0007803	0.001078	8.67E-06	2.33E-05
Uranium	0	0	0	0	0	0	0	0	0	0	0	0
Vanadium	0.00856	0.1946	0.0001452	0.0004117	0.0002509	0.0004117	0.000384	0.0004117	0.001049	0.001444	0.0001039	0.0001368
Zinc	0.002646	0.01444	1.42E-05	0.00379	3.15E-05	0.00379	5.32E-05	0.00379	0.0001652	0.01693	0	0
Zirconium	0.0072	3.32	0.001241	0.002104	0.001574	0.002104	0.001995	0.002104	0.001669	0.003505	0.002099	0.002805

Parameter	PN06		PN07		PN08		PN09		PN10	
(mg/L)	Post-Clos	Max	Post-Clos	Max	Post-Clos	Max	Post-Clos	Max	Post-Clos	Max
TDS	3.017	4.519	0	0	3.085	4.606	3.117	4.648	3.003	4.5
TSS	0.01308	0.03461	0	0	0.02209	0.04649	0.0264	0.05218	0.0111	0.032
Free_CN	0.003763	0.1764	0	0	0.003747	0.02517	0.003739	1.646	0.003767	0.08776
Total_CN_N	3.83E-05	5.09E-05	0	0	4.14E-05	5.50E-05	4.29E-05	5.70E-05	3.77E-05	5.00E-05
WAD_CN	0.0001892	0.0002512	0	0	0.0003309	0.0004393	0.0003987	0.0005293	0.0001582	0.00021
CNO_N	0.004315	0.006902	0	0	0.004325	0.006911	0.004331	0.006915	0.004313	0.0069
SCN_N	0.0001505	0.0001998	0	0	0.0001498	0.0001989	0.0001495	0.0001985	0.0001507	2.00E-04
Sulphate	0.0003763	0.0004996	0	0	0.0003747	0.0004974	0.0003739	0.0004964	0.0003767	5.00E-04
Chloride	0.0008928	0.001699	0	0	0.0008899	0.001693	0.0008885	0.00169	0.0008933	0.0017
Ammonia_N	7.53E-06	9.99E-06	0	0	7.50E-06	9.95E-06	7.49E-06	9.94E-06	7.53E-06	1.00E-05
Nitrate_N	2.068	3.113	0	0	2.113	3.17	2.134	3.198	2.059	3.1
Nitrite_N	2.092	2.997	0	0	2.083	2.984	2.079	2.978	2.094	3
Alkalinity	9.74E-05	0.0002027	0	0	0.0001069	0.000215	0.0001115	0.0002209	9.53E-05	2.00E-04
Ortho_P	0	0	0	0	0	0	0	0	0	0
Phosphate_P	0.0002146	0.0006664	0	0	0.0002723	0.0007414	0.0002999	0.0007773	0.0002019	0.00065
TOC	0.001021	0.001502	0	0	0.001028	0.001511	0.001032	0.001516	0.001019	0.0015
Hardness	0	0	0	0	0	0	0	0	0	0
Aluminum	9.232	12.99	0	0	9.192	12.93	9.171	12.9	9.24	13
Antimony	0.0451	0.06794	0	0	0.05177	0.07676	0.05496	0.08098	0.04363	0.066
Arsenic	3.77E-05	5.01E-05	0	0	3.79E-05	5.04E-05	3.81E-05	5.05E-05	3.77E-05	5.00E-05
Barium	0.000501	0.0008193	0	0	0.0004989	0.0008157	0.0004978	0.000814	0.0005015	0.00082
Beryllium	1.037	1.403	0	0	1.047	1.416	1.051	1.422	1.035	1.4
Bismuth	0.004882	0.01213	0	0	0.005347	0.01272	0.005571	0.01301	0.004779	0.012
Boron	0.0005412	0.0007189	0	0	0.003006	0.003991	0.004186	0.005557	7.06E-07	1.40E-06
Cadmium	3.82E-05	5.07E-05	0	0	4.07E-05	5.40E-05	4.19E-05	5.56E-05	3.77E-05	5.00E-05
Calcium	0.002539	0.005351	0	0	0.00272	0.005584	0.002807	0.005695	0.002499	0.0053
Chromium	0.003763	0.283	0	0	0.003747	0.4088	0.003739	2.667	0.003767	0.1392
Cobalt	0.0007526	0.0149	0	0	0.0007493	0.02119	0.0007478	0.1341	0.0007533	0.00771
Copper	0.0007526	0.0009991	0	0	0.0007493	0.0009947	0.0007478	0.0009927	0.0007533	0.001
Iron	0	0	0	0	0	0	0	0	0	0
Lead	0.001457	0.002008	0	0	0.001484	0.002043	0.001496	0.002059	0.001451	0.002
Lithium	0.2847	0.4	0	0	0.2846	0.3997	0.2846	0.3996	0.2847	0.4
Magnesium	0	0	0	0	0	0	0	0	0	0
Manganese	7.55E-05	0.0001002	0	0	7.62E-05	0.0001012	7.66E-05	0.0001017	7.53E-05	1.00E-04
Mercury	0.1719	0.3668	0	0	0.1889	0.3889	0.1971	0.3994	0.1681	0.362
Molybdenum	7.53E-06	1.00E-05	0	0	7.55E-06	1.00E-05	7.56E-06	1.00E-05	7.53E-06	1.00E-05
Nickel	0.4663	0.6297	0	0	0.4651	0.628	0.4645	0.6272	0.4666	0.63
Phosphorus	0.01149	0.01599	0	0	0.01144	0.01592	0.01142	0.01588	0.0115	0.016
Potassium	3.539	4.83	0	0	3.64	4.964	3.689	5.029	3.516	4.8
Selenium	21.03	33.05	0	0	21.22	33.29	21.32	33.4	20.99	33
Silicon	5.02E-10	6.66E-10	0	0	2.79E-09	3.70E-09	3.88E-09	5.15E-09	0	0
Silver	3.76E-05	5.00E-05	0	0	3.75E-05	4.98E-05	3.74E-05	4.97E-05	3.77E-05	5.00E-05
Sodium	6.84E-08	9.07E-08	0	0	3.80E-07	5.05E-07	5.29E-07	7.03E-07	0	0
Strontium	7.53E-05	9.99E-05	0	0	7.49E-05	9.95E-05	7.48E-05	9.93E-05	7.53E-05	1.00E-04
Tellerium	0.0001344	0.0002591	0	0	0.0003032	0.0004828	0.000384	0.0005899	9.73E-05	0.00021
Thallium	2.894	4.796	0	0	2.882	4.775	2.875	4.765	2.897	4.8
Thorium	0.001891	0.003097	0	0	0.001883	0.003084	0.001879	0.003077	0.001893	0.0031
Tin	2.258	2.997	0	0	2.248	2.984	2.243	2.978	2.26	3
Titanium	7.54E-06	1.00E-05	0	0	7.59E-06	1.01E-05	7.62E-06	1.01E-05	7.53E-06	1.00E-05
Uranium	0	0	0	0	0	0	0	0	0	0
Vanadium	4.21E-05	5.78E-05	0	0	4.48E-05	6.13E-05	4.61E-05	6.30E-05	4.15E-05	5.70E-05
Zinc	0	0	0	0	0	0	0	0	0	0
Zirconium	0.0007327	0.001413	0	0	0.0007785	0.001472	0.0008004	0.0015	0.0007227	0.0014

Appendix E – Waste Rock Runoff Coefficient Review

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Memo

To:	Project File	**Client:**	Sabina Gold & Silver Corp.
From:	Sarah Portelance, MEng, PEng.	**Project No:**	1CS020.008
Reviewed By:	Maritz Rykaart, PhD, PEng	**Date:**	October 23, 2015
Subject:	Back River Project: Waste Rock Runoff Coefficient Review - Final		

1 Introduction

This memo provides a summary and description of the rationale behind the adoption of the waste rock runoff coefficients used for the Back River Project (the Project).

Runoff coefficients are typically used in water and load balance models to describe precipitation losses on a catchment due to soil type and various other characteristics (Chow *et al.* 1988). It is however recognized that the use of runoff coefficients is a simplification of the complexity of hydrological processes to define runoff.

Waste rock pile hydrology is of great importance for the Project water and load balance as it affects the total volume and quality of water collected at the toe of the waste rock pile (called waste rock storage areas (WRSAs) for this Project). Water that comes into contact with the waste rock can mobilize constituents that may result in exceedances of downstream water quality criteria. Waste rock piles at the Project will be constructed on deep and cold continuous permafrost and therefore, deep seepage through the waste rock pile entering the groundwater system is not of concern. However, toe seepage that could enter the surface water environment, or direct waste rock pile runoff is of concern.

Over time, permafrost is expected aggregate into the waste rock piles because of extreme climatic conditions. As a result, over time, the waste rock piles will mimic the current landscape with a defined active layer overlying permafrost which will include much of the waste rock pile. This memo describes the simplified assumptions adopted for describing the hydrologic behaviour of waste rock piles in a permafrost environment, and provides a summary of the benchmark data from other mining projects in cold regions to justify the selection of runoff coefficients used for the Project.

2 Simplified Waste Rock Water Balance

Waste rock pile hydrology in temperate climates is a complex process and is extremely difficult to accurately measure and/or predict. Key factors causing these challenges include highly non-linear unsaturated flow, energy imbalances caused by the surface flux boundary, material property heterogeneity, preferential flow paths, and complex geometry. In addition to these challenges, the reality of determining the freezing temperatures further complicates the understanding of waste rock hydrology in cold climate regions. Although much research has been carried out in this area, and still continues, good practical and verified answers are still not available, which necessitates the need for simplifying assumptions. Typically, when analyzing the site wide water and load balance of a project, it is common to use a simplified waste rock pile water balance based on tracking inflows, outflows, and change in storage. This relationship can be defined as:

$$Water\ Storage = Water\ Input - Water\ Output$$

Water input is defined as precipitation (of which some infiltrates, some evaporates, and some reports at the toe of the pile as runoff), and the source of storage in a waste rock pile can be attributed to void spaces. Water output includes surface runoff, evaporation, and seepage at the toe. Deep groundwater seepage can be assumed to be zero as a result of the permafrost foundation. Since evaporation is lost to the environment, the total water output that can contribute to the water and load balance and geochemical load to the receiving environment is the sum of the surface runoff and toe seepage. This total flow is often referred to as the total net runoff.

The freeze back of the waste rock pile causes a change in the hydrology of the waste rock pile, and therefore a different conceptual hydrologic model applies to freezing and frozen periods of the pile. Figure 1 illustrates these differences. The key difference is the amount of unfrozen (and unsaturated) materials present. As freeze back occurs (i.e. the freezing period), this volume of unfrozen material continuously decreases until the steady state active layer has redeveloped in the waste rock pile. As a result, the amount of available void space in the waste rock that defines the available storage space in the waste rock pile continuously decreases until the steady state active layer develops at which time it remains essentially constant.

Therefore the simplified water balance assumes that during the freezing period much of the water that infiltrates the waste rock pile is locked up in storage as ice with the resultant effect of reducing toe seepage. However, as the pile freezes and the void space reduces, the amount of toe seepage increases because the infiltration remains constant but water is no longer lost due to void space lockup.

As a result, based on the definition of total net runoff described above, the total net runoff during freezing is less than when the waste rock pile is frozen, at which time the total net runoff is at its peak.

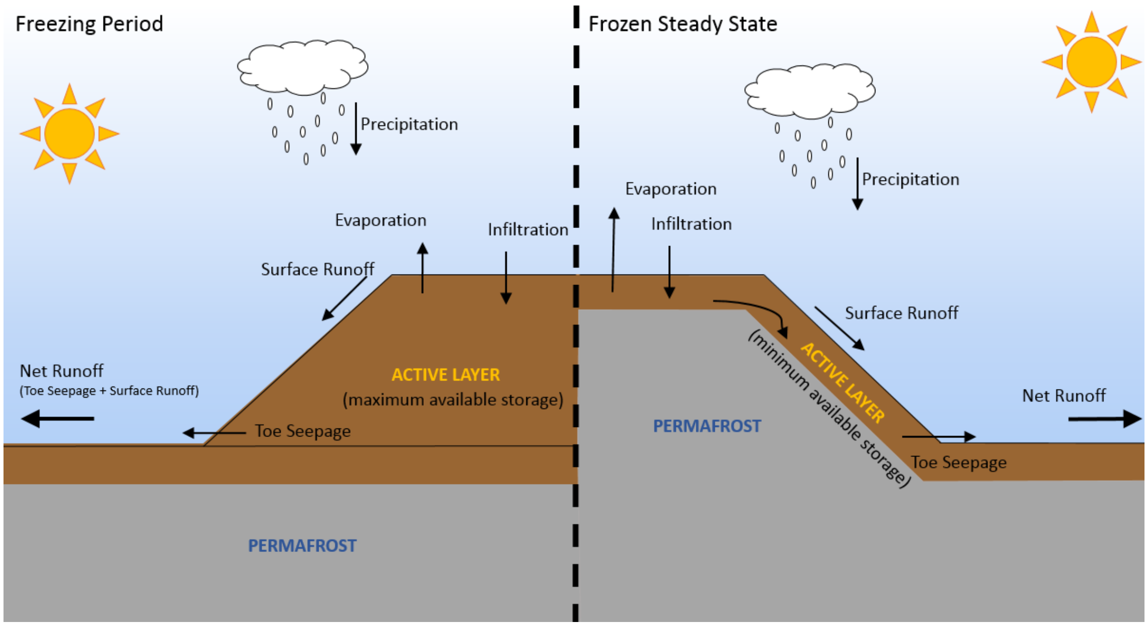

Figure 1: Simplified Waste Rock Pile Water Balance

For a simplified waste rock water balance, total net runoff is estimated using a runoff coefficient which takes into account all of the water balance components described above. The expression for the total surface runoff at the toe of the waste rock pile can be described as follows:

$$Surface\ Runoff = Area\ \times Precipitation\ \times Runoff\ Coefficient$$

3 Benchmarking Study

3.1 Database

Runoff coefficients often used in conjunction with the rational method typically in urban and agricultural settings to evaluate runoff from undeveloped and developed areas during storm events (Chow *et al.* 1988). Runoff coefficients for waste rock piles are however not well defined, especially in cold regions. As a result, a benchmarking study was undertaken to determine what runoff coefficient values for waste rock piles are being used in the context of northern Canadian mines for site wide water balance studies.

Figure 2 is extracted from a publication by Mining North, an official publication of the Northwest Territory (NWT) and Nunavut (NU) Chamber of Mines (Mining North 2014), and lists all the current natural resource projects in these regions as of November 2014. The public registry of the Nunavut Water Board and Mackenzie Valley Water Board was reviewed and any information pertaining to the adoption or use of waste rock pile runoff coefficients for these projects was compiled. The results are summarized in Tables 1 and 2.

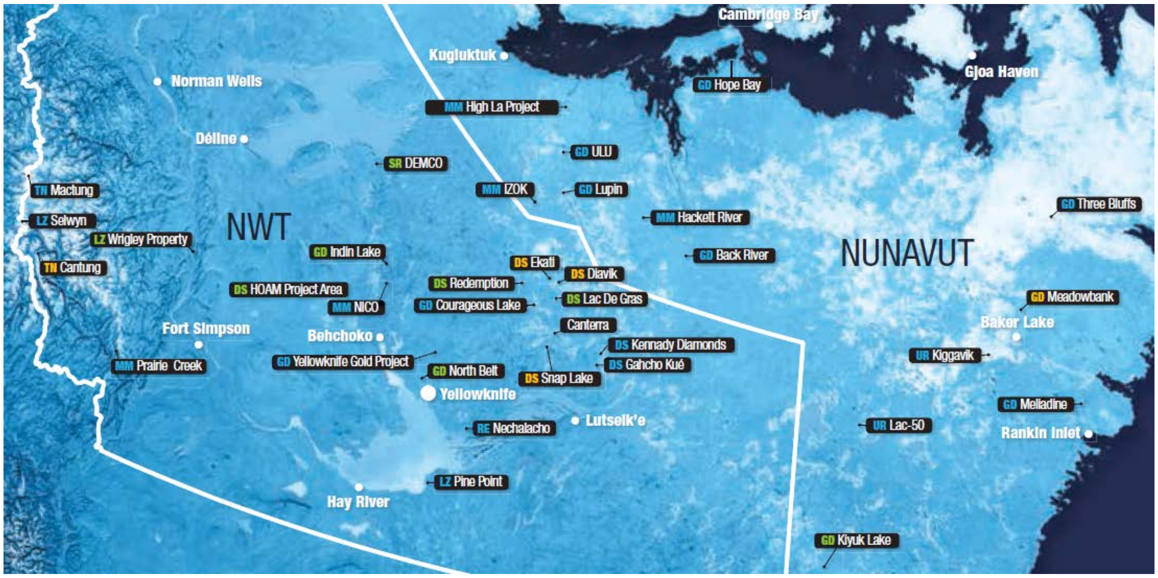

Figure 2: List of Mining and Exploration Project in NU and NWT (Mining North 2014)

Table 1: Projects/Mines with no Runoff Coefficient Information

Project/Mine	Project Status
High Lake Project (NU)	Exploration
Kennady Lake Project (NWT)	Exploration
Lupin Mine (NU)	Underground Mine in Care and Maintenance
Hacket River Project (NU)	Exploration
Committee Bay - Three Bluffs Gold (NU)	Exploration
Kiggavik (NU)	Exploration
Lac de Gras (NWT)	Exploration
Redemption (NWT)	Exploration
Courageous Lake (NWT)	Exploration
Hilltop – Canterra (NWT)	Exploration
King – Canterra (NWT)	Exploration
Gwen – Canterra (NWT)	Exploration
Marlin – Canterra (NWT)	Exploration

Table 2: Projects/Mines with Runoff Coefficient Information

Project/Mine	Runoff Factor	Material Type	Justification	Source
Meliadine Gold Project (NU)	0.70 (waste rock and tailings); 0.90 (pits); 0.80 (plant site)	ROM waste rock (open pit)	None provided	Golder (2014b)
ULU Exploration Project (NU)	0.75 (waste rock, camp and ore pads); 0.65 (natural watershed)	ROM waste rock (undefined)	Natural watershed estimated empirically. Waste rock surfaces assumed to have higher runoff coefficient due to increased infiltration and reduced sublimation and evaporation	BGC (2005)
Back River Project - PFS Stage (NU)	0.30	ROM waste rock (mixed underground and open pit)	None provided	Rescan (2013a)
Meadowbank Project (NU)	0.41	ROM waste rock (open pit)	Uncalibrated water balance	SNC Lavalin. (2013)
Hope Bay Project (NU)	0.20 (summer); 0.6 (winter)	ROM waste rock (underground; diabase and basalt)	Calibrated water balance (recorded flows)	SRK (2014)
Ekati Project (NWT)	0.05 to 0.30 (used 0.2)	ROM waste rock (underground)	Calibrated against observed runoff rates from Misery WRSA (BHP 2011)	Rescan (2013b)
Diavik Project (NWT)	0.24 to 0.74	ROM waste rock (open pit: granite and pegmatite)	Based on Test Pile III (assumes rainfall only – see Table 3 below)	Fretz (2013)
Snap Lake Project (NWT)	0.60 to 0.80 (freshet)	ROM waste rock (mixed underground and open pit; granite)	None provided	De Beers (2013)
Jay Project (at Ekati Mine) (NWT)	0.70 (waste rock); 0.90 (pits)	ROM waste rock (not specified)	None provided	Golder (2014c)
Mary River Project (NWT)	0.27 (operations and closure) and 0.34 (operations)	ROM waste rock (open pit; granite and sedimentary).	None provided	Hatch (2013)
Gahcho Kue Mine (NWT)	0.32 (operations); 0.64 (closure)	ROM waste rock (unspecified; host rock and kimberlite)	None provided	Golder (2014a); De Beers (2015)

Source:\\VAN-SVR0\Projects\06_REFERENCE_MATERIALS\Water Management\pdf\Papers\Waste Rock Runoff\Literature_Review_Waste Rock Runoff_r1.xlsx

3.2 Diavik Waste Rock Pile Research Project

The Diavik Waste Rock Pile Research Project was initiated in 2006 at the Diavik diamond mine with funding from government and international organizations, and partnerships with universities. The program consists of three 15 m high waste rock test piles that were instrumented during construction to monitor the hydrology, geochemistry, microbiology, gas transport, and heat transport mechanisms that influence acid rock drainage (Fretz *et al*. 2011).

A large number of papers and theses from university graduates have been published relating to flow mechanisms, water balances and hydrological parameters of waste rock observed at the Diavik Project. Runoff coefficients for the waste rock piles have however not been explicitly developed. Using the available data (Fretz 2013), SRK has back calculated runoff coefficients.

The mean annual precipitation at Diavik was determined to be 351 mm water equivalent with 164 mm (47%) as rain and 187 mm (53%) as snow (Golder 2008). Table 3 provides a summary of rainfall and total annual volumes of runoff collected (and measured) at the toe of the Diavik Type III test pile.

Runoff coefficients listed in Table 3 should be calculated by dividing the measured flow depth (i.e. total net runoff) by the total precipitation estimate. Snow depth and total precipitation data during the winter months are however a data gap in the water balance of the test piles at Diavik. It was therefore assumed that the total precipitation is roughly two times the rainfall estimate, based on the regional study described above (Golder 2008). Using the corrected total precipitation estimate, the runoff coefficients for the Type III test pile were found to be range from 0.14 to 0.34. This is almost 50% of the calculated runoff coefficient when compared to that for rainfall only which range from 0.24 to 0.73.

Table 3: Back Calculated Diavik Runoff Coefficients

Year	Measured Rainfall (mm)	Corrected Precipitation (mm)	Measured Flow Volume (m^3)	Calculated Flow Depth[1] (mm)	Calculated Runoff Coefficient	
					Rainfall Based	Precipitation Based
2007	152.7	258.1	110	37	0.24	0.14
2008	154.4	330.5	150	50	0.32	0.15
2009	74.0	158.4	117	39	0.53	0.25
2010	97.5	208.7	213	71	0.73	0.34
2011	145.5	311.4	176	59	0.40	0.19
Average					0.44	0.21
Mean					0.41	0.20

Source:\\VAN-SVR0\Projects\06_REFERENCE_MATERIALS\Water Management\pdf\Papers\Waste Rock Runoff\Literature_Review_Waste Rock Runoff_r1.xlsx

Note: [1] Total area of Type III pile is 3000 m^2 (50 m x 60 m)

Figure 3 presents a scatter plot of runoff against precipitation data for the Diaivik Type III test pile documented in Table 3. It is evident that there is no correlation based on the available annualized data. As a result, the back calculated Diavik data can at best be representative of a fairly wide range which is consistent with the greater data set described in Table 2.

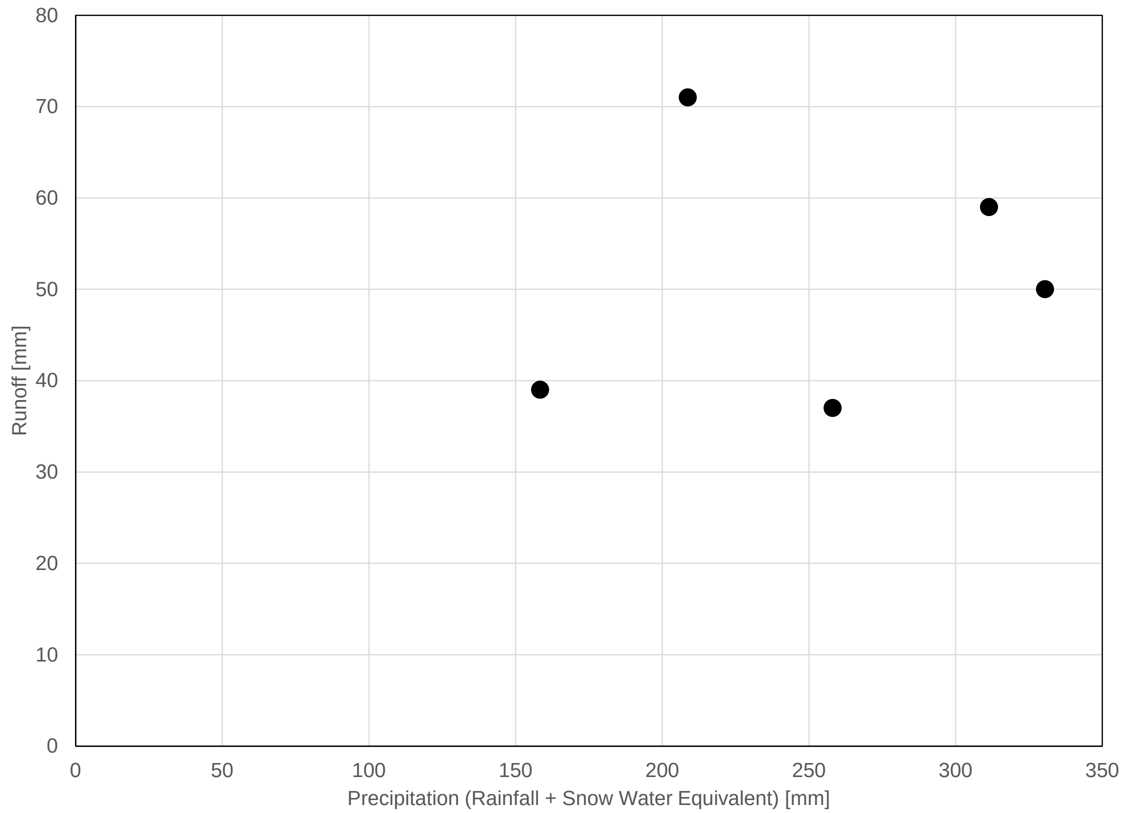

Figure 3: Scatter plot of Diavik Type III Test Pile Runoff vs. Precipitation

3.3 Benchmarking Conclusions

Figure 4 summarize the information gleaned from the benchmarking study of runoff coefficients at other NU and NWT projects and mines. Only three of the 13 projects for which data is available are using runoff coefficients that are based on actual calibrated data (highlighted in green). For the remaining 10 sites (highlighted in blue), there are no justification provided for the selection of runoff coefficients, other than statements such as “assumed”, “prior experience” or “engineering judgement”. In addition, in many cases the runoff coefficients were not explicitly defined but had to be back calculated based on average precipitation and total runoff volumes that were modelled for a waste rock pile.

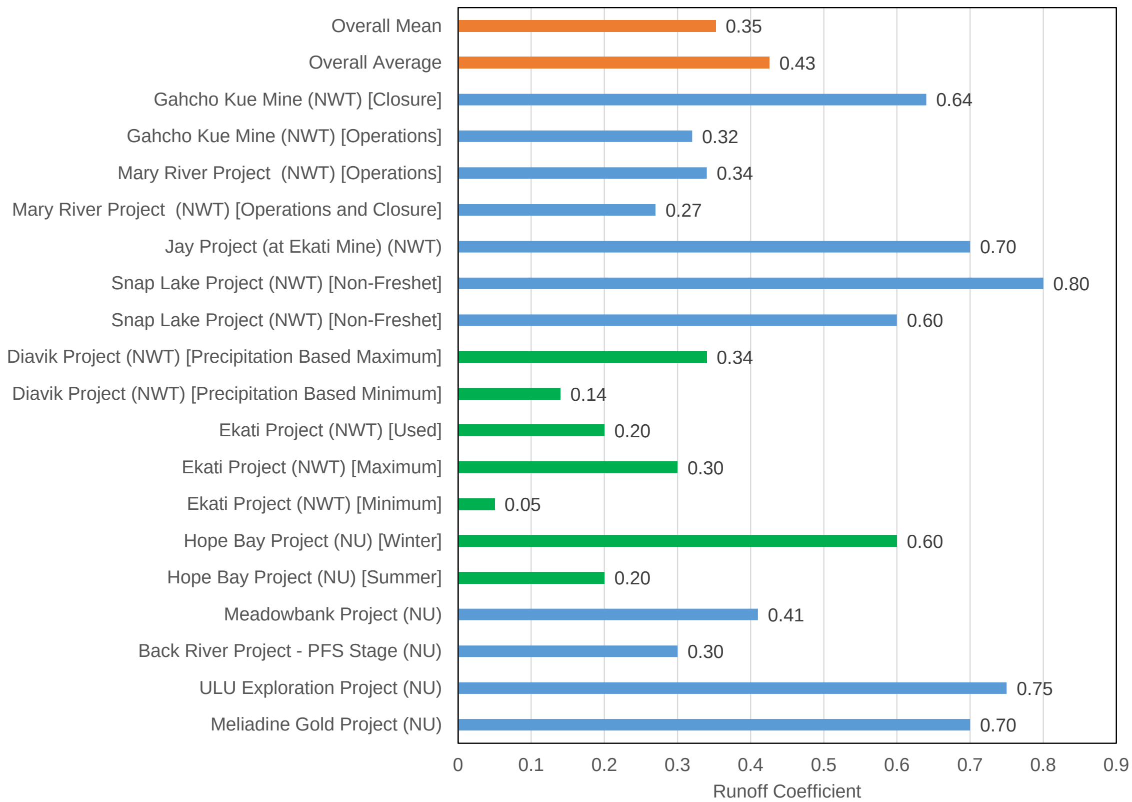

Figure 4: Runoff Coefficients used at Other NU and NWT Projects/Mines

It is clear from this benchmarking study that the range of runoff coefficients used for waste rock piles in water balances is significant (0.05 to 0.80), which is alarming considering the significant effect this parameter has on the water balance. Even more disconcerting is the fact that in over 75% of the projects, the numbers adopted have no scientific basis. Some loosely defined “rules of thumb” are quoted such as “waste rock pile runoff factors should be greater than that the natural watershed”, which have no scientific basis.

It can therefore be concluded that the general poor understanding of waste rock pile hydrology in permafrost environments, coupled with the use of simplified water balance assumptions such as the use of a runoff coefficient approach, has considerable inherent uncertainty. As a result, any water balance calculations should take a cautious and conservative approach. However, it should be recognized that water balances have many other uncertainties and therefore a broad based sensitivity analysis is not necessarily the most appropriate approach, but rather the focus should be on ongoing monitoring and verifying the water balance throughout the life of the Project.

4 Back River Project Waste Rock Runoff Coefficient

Based on the information described in this memo, SRK believes that the use of the runoff coefficient approach for the site wide water balance remains appropriate. It is however reasonable to assume that the total net runoff will change as permafrost migrates into the waste rock pile.

To account for the change in total runoff during the freezing period and frozen state, two different runoff coefficients were applied. Considering the lack of good scientific basis for making a selection, SRK adopted a runoff coefficient of 0.30 for the freezing stage. This value is based on the rounded up value for the 0.27 average runoff coefficient of the three sites that have calibrated data of some kind.

Due to limited data regarding the frozen period, SRK adopted a similar approach as what was applied at Gahcho Kue (De Beers 2013), where the frozen period runoff coefficient is double that of the freezing period. So for the Back River Project the runoff coefficient for waste rock during the frozen period is 0.6.

Appendix F – Assessment of Stratification for Llama Reservoir

Assessment of Stratification in the Proposed Back River Project Llama Pit Lake

Prepared by:

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28 October 2015

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EXECUTIVE SUMMARY

Closure plans for the Back River Project include filling the Llama mine open pit with water to form a lake. The bottom of the pit will be filled with a combination of intercepted talik groundwater and excess contact water to form a lower layer of high chloride concentration, capped by an upper layer of fresher water. We have been asked to assess the likelihood of meromixis, and to assess the range of likely surface layer chloride concentrations given the initial two layer stratification.

Temperate lakes typically experience stratification in summer during which a surface layer of warm, less-dense water isolates the deep water from the atmosphere. Temperate lakes typically undergo complete mixing during spring and fall turnover.

Under certain conditions lakes can be meromictic, that is they can be permanently stratified and never mix completely. Meromixis occurs when salinity stratification successfully resists turnover. Pit lakes are predisposed to meromixis because they are deep, have a relatively small surface area, and can contain relatively saline water.

In the proposed Llama pit lake, the lower layer will consist of groundwater diluted by other sources such as direct precipitation; the resulting salinity of the lower layer will remain high, 31,400 mg/L. This is significantly higher than the lower layer salinity in three examples of existing pit lakes in Northern Canada whose salinity ranges from 750 to 2,000 mg/L, and all three of which tend toward meromixis. The salinity in Llama pit lake is close to that of seawater, 35,000 mg/L. Because of the large contrast in salinity between the fresh water cap and the lower layer, the salinity stability – the energy needed to mix the salinity stratification – is very high, 120,000 J/m^2, and based on this meromixis is predicted.

A compartment model of the salinity stratification was used to assess the long term evolution of the stratification, and of the chloride concentration in the surface layer. Four scenarios were considered, each with two values of mixing during fall cooling. In the first scenario, with an initial surface layer salinity of 280 mg/L, the surface salinity and chloride concentration declined as the surface layer was flushed by inflow. For low fall mixing, the chloride concentration declined from 105 mg/L at ice-on in the first year to 5 mg/L in the long term. For high fall mixing, the chloride concentration declined from 155 mg/L in the first year to 100 mg/L in the long term for high fall mixing. The discharge criterion for chloride concentration of 500 mg/L was met throughout the model runs for both levels of fall mixing.

The other three scenarios considered increasing degrees of mixing with the lower saline layer during placement of the fresh water cap. Scenario 2 considered a case in which there had been some entrainment of the saline lower layer into the fresh water cap, such that the initial salinity in the fresh water cap was at the discharge criterion for chloride concentration. Due to ice melt, this scenario met the discharge criterion in the first year, and, due to flushing of the surface layer by inflow, it met the discharge criteria by a factor of 5 in the long term.

Scenario 3 considered a linear decrease in salinity from the bottom to a surface value of 280 mg/L such that the mean salinity was the same as that in Scenario 1; this scenario did not meet the discharge criterion in the early years. Scenario 4 considered complete mixing of the water cap and lower layer of Scenario 1, and far exceeded the discharge criterion in the early years, but came close to the discharge criterion in the long term. Scenarios 2 to 4 highlight the natural processes of ice melt and flushing of the surface layer by inflow that enhances meromixis. Scenarios 3 and 4 highlight the importance of managing the degree of mixing with the saline lower layer during water cap placement.

INTRODUCTION

In this report we assess the likelihood of meromixis in the proposed Llama pit lake which is part of the Back River Project. While temperate lakes are generally temperature stratified in summer, they usually turnover in both spring and fall. However, pit lakes are often deep, have a relatively small surface area, and are more saline than surrounding natural waters. Consequently, these lakes are predisposed to permanent stratification, otherwise known as meromixis.

A schematic of the layers in a meromictic lake is shown in Figure 1. The surface layer or epilimnion mixes down through the summer, until the entire mixolimnion is included in the surface layer in the fall. Further deepening of the surface layer is resisted by the chemocline, leaving the monimolimnion relatively isolated throughout the year.

In a meromictic lake, dissolved and suspended substances make the deep water denser than the surface water. This stratification makes it less likely that the natural sources of mixing (typically wind, surface cooling and inflows) can provide enough energy to break down the density stratification and mix the entire lake. In temperate climates, the exclusion of salt from ice-cover and freshet inflow can provide a cap of fresh water sufficient to resist spring turnover (Pieters and Lawrence 2009a). During summer, warming of the surface means that the pit lake stability is augmented by temperature. However, it is in late fall, once the surface layer has deepened and cooled to ~ 4ºC, that the pit lake is most vulnerable to turnover. It is during this time that salinity alone maintains the stratification.

Here we estimate the magnitude of those factors that enhance the stability of the lake (e.g. the salinity of the water column, and the introduction of buoyant water at the surface by ice-melt and inflow) and compare to estimates of the work done against the salinity stratification by mixing processes during fall (wind, penetrative convection, and inflows).

Study site

The proposed Llama pit lake (62° 32.5’ N and 106° 30’ W) is located adjacent to Goose Lake in Nunavut, 160 km south of Bathurst Inlet. The Back River Project is in the Barren Grounds of the Canadian Arctic, a large expanse of uninhabited tundra in a region of continuous permafrost.

The physical characteristics of the proposed Llama pit lake are summarized in Table 1. Data from three other pit lakes are also presented for comparison. Of these, the Llama pit lake is similar in surface area, volume and depth to Zone 2 pit lake, larger than Waterline pit lake, and smaller than Faro pit lake.

Table 1. Characteristics of the proposed Llama pit lake and comparison to three existing pit lakes

PIT	LLAMA	WATERLINE[1]	Z2P[2]	FARO[3]
Surface elevation (m ASL)	294.4	1265	332	1066
Depth (m)	130	40	110	90
Area (m^2)	$1.12x10^5$	$2.6x10^4$	$1.5x10^5$	$5.1x10^5$
Volume (m^3)	$5.57x10^6$	$4.8x10^5$	$7.1x10^6$	$3x10^7$
Relative depth	0.34	0.18	0.25	0.11
Annual Inflow (m)	7.5	7.6*	0.2	-
Surface outflow (m)	7.5	7.6*	filling	filling
Bulk retention time (yrs)	6.6	2.4	50	-
Ice thickness (m)	2	~0.7	~0.8	~0.5
Deep salinity (mg/L)	31,400	1,400 to 2,000	750	1,200
Mictic status	meromictic	weakly meromictic	weakly meromictic	meromictic

[1] Equity Silver mine site, 30 km southeast of Houston B.C. (54.189 N, 126.263 W)
[2] Colomac Zone 2 Pit, 250 km north of Yellowknife, NWT (64.397 N, 115.089 W)
[3] Faro mine site, 200 km north of Whitehorse, Yukon (62.353 N, 133.364 W)
* Estimated as 15L/s during 5 months open water.

Pit lakes generally have a small surface area relative to their depth and Llama is no exception. The relative depth, h_r, is the maximum depth of the pit lake divided by the equivalent diameter of the surface area,

$$h_r = \frac{h_{\max}}{2\sqrt{A/\pi}},$$

where h_{max} (m) is the maximum depth, and A (m^2) is the surface area. The relative depth of Llama, $h_r = 0.34$, is high (Table 1). A high relative depth indicates a small surface area which reduces the ability of wind stress and surface cooling to effect mixing. For comparison most natural lakes have a small relative depth of < 0.02, while natural lakes that are considered deep have with a relative depth of > 0.04 (Wetzel 2001).

Characteristics of the Llama pit lake are described in a memo and subsequent emails, here referred to as SRK (2015). The water balance model predicts Llama pit will fill in 2035 (SRK 2015, Figure 2). We examine the potential for stratification once the pit is filled (2035 and following). Here we have assumed that it is possible to dissipate the energy of the water used to form the fresh water cap as it enters the pit lake, and limit mixing so that the initial stratification consists of two layers, an upper layer of fresh water (0 - 55 m), and a lower layer of talik and contact water (55 – 130 m).

Ice cover and fresh water inflow

Ice-cover can have an important effect on stratification as ice-melt can provide a cap of fresh water with enough stability to sustain meromixis. Ice thickness on Goose Lake adjacent to the proposed pit lake was measured at 2 m (SRK 2015). Additional ice data is available from Contwoyto Lake, 200 km west of the Back River site, where a long record of data (1968-1981) showed the ice thickness varying from 1.2 to 1.95 m and averaging 1.7 m. We use 1.7 m as a conservative estimate of total ice thickness for Llama pit lake.

Almost all dissolved salt is excluded from the ice as it forms, and the effective ice thickness gives the equivalent thickness of pure ice. No information is available about the salt content of the ice at Goose Lake. Ice characteristics from several other sites are listed in Appendix 4, and based on these data the effective ice thickness for Llama pit lake was estimated to be 1.1 m.

Fresh water inflow can also contribute to the salinity stratification and can play an important role in flushing the surface layer, resulting in a decrease in salinity of the mixolimnion, an increase in salinity stability and improved water quality. Once the diversion berms are breached at closure of Llama pit lake, the lake will receive a relatively large inflow of 839,700 m^3/year, corresponding to a depth of 7.5 m of water over the surface area of the pit lake. The inflow has a typical temperate hydrograph with a large peak during freshet in June (Appendix 2).

Salinity

The initial chloride concentration and the corresponding salinity for the two layers in the pit lake are listed in Table 2 (for details see Appendix 3). Also included are values for the inflow to the pit lake, which are assumed to have the same water quality as Goose Lake (SRK 2015). There is a large contrast in salinity between the upper and lower layers.

Note the surface layer has a salinity of 280 mg/L, which is higher than the salinity of the background runoff of 23 mg/L. The surface layer includes some groundwater that entered the pit during the time taken to add the freshwater cap. Once the pit lake is full, no further groundwater inflow is expected (SRK 2015).

Table 2 Estimated salinity and chloride concentration in the proposed Llama pit lake[1,2,3].

	[Cl] (mg/L)	Salinity (mg/L)
Lower layer, pit lake	**20,000**	31,400
Upper layer, pit lake	**164**	280
Background runoff (Goose Lake)	**1**	**23**
Surface layer [Cl] discharge criteria[4]	**500**	805

[1] Salinity and total dissolved solids (TDS) are considered to be the same for this report.
[2] The following approximation is used to convert between chloride concentration, [Cl], and salinity, $S \approx [Cl]*1.57 + 23$ where S and [Cl] are in units of mg/L, see Appendix 3.
[3] Values in bold were given in SRK (2015).
[4] Based on dilution to the CCME long term guideline of [Cl] = 120 mg/L in the receiving water (SRK 2015).

CONCEPTUAL MODEL FOR ASSESSING MEROMIXIS

To investigate the possibility of meromixis in the proposed Llama pit lake we wish to estimate the salinity stability at the time of maximum heat content, St_S*, and compare this to the decrease in salinity stability during fall, ΔSt_S, observed in the three examples of existing pit lakes.

Annual cycle

We divide the annual cycle of a northern pit lake into three periods: ice cover (mid-October to May), warming (June to August) and cooling (September to mid-October). We illustrate the behaviour of a meromictic pit lake with ice-cover by looking at the warming and cooling periods of the Waterline pit lake in 2001.

For the warming period, temperature and conductivity[1] profiles from the Waterline pit lake are plotted in Figure 2a,b. During the warming period there is little change in either temperature or salinity below the surface layer (4 m). The surface layer itself warms from 10 to 15 ºC (Figure 2a), and the salinity decreases slightly due to inflows (Figure 2b). Because of the slight freshening of the surface layer, the salinity stability increases slightly from 194 J/m^2 on 29 Jun 2001 to 200 J/m^2 on 17 Aug 2001.

During the cooling period, the surface layer not only cools but deepens. From 17 Aug to 2 Oct 2001, the surface layer cools from 15 to 5 ºC and mixes down from 4 to 9 m depth (Figure 2c). During this time the salinity of the surface layer increases as more saline water is mixed from below into the surface layer (Figure 2d). During the cooling period the salinity stability decreased from 200 J/m^2 on 17 Aug 2001 to 187 J/m^2 on 3 Oct 2001.

After 3 Oct 2001 the surface layer does not deepen further, rather it cools below the temperature of maximum density, 4 ºC. Water below 4 °C is buoyant and this layer of cold, buoyant water is referred to as reverse stratification; once the surface reaches 0 ºC, ice begins to form.

Salinity stability and meromictic ratio

Mixing a stratified water body raises the center of mass of the water body and the work against gravity needed to lift the center of mass is the stability, given in J/m^2. Both warmer surface temperatures and lower salinities contribute to the buoyancy of the surface layer. To examine the possibility of meromixis we would like to remove the effect of temperature. To do this we define the salinity stability as the energy needed to mix the water body with a given salinity stratification while at a constant temperature.

Of particular interest is the salinity stratification at the end of the warming period (late August) defined as St_S*. It varies from year to year, but for Waterline it is approximately 200 J/m^2. We compare St_S* with the reduction in salinity stability during the cooling period ΔSt_S. For the Waterline pit lake in fall 2001, ΔSt_S was approximately 13 J/m^2.

[1] Conductivity, C25, is a measure of salinity, for Waterline S[mg/L] ~ 0.9 C25 [μS/cm].

The meromictic ratio $M = St_S^*/\Delta St_S$ (15 for Waterline) is an indicator of the likelihood of meromixis. The higher M, the more likely the lake is to be meromictic.

In order to determine M for the Llama pit lake, we need both St_S^* and ΔSt_S. We have insufficient data to calculate ΔSt_S for the Llama pit lake, so based on the values from the Waterline, Z2P and Faro pit lakes shown in Table 3, we will use $\Delta St_S = 20$ J/m^2 as a point of comparison (Table 3). We will also apply a factor of safety of 10, and use $\Delta St_S = 200$ J/m^2 to account for potential differences between sites, such as higher wind speeds or reduced pit wall sheltering.

Table 3 Meromictic ratio for comparison sites

Site	Mictic Status	Year	St_S^* (J/m^2)	ΔSt_S (J/m^2)	$M = St_S^*/\Delta St_S$
Waterline	weakly meromictic	2001	200	13	15
Z2P	weakly meromictic	2004	140	25	6
		2005	145	≈19	8
Faro	meromictic	2004	700	≈20	≈35

COMPARTMENT MODEL AND MODEL SCENARIOS

A compartment model for salinity stratification is used to determine St_S* for the Llama pit lake, and to evaluate the salinity and chloride concentration of the surface layer. The salinity of the surface layer is then used to estimate the chloride concentration of the discharge. The compartment model is described in Pieters and Lawrence (2009b). The model accounts for surface layer deepening, salt exclusion from the ice, inflow and outflow.

The surface layer of the model evolves as follows:

- At ice off the surface layer deepens to twice the depth of the ice thickness. For example, in Tailings Lake, the surface layer was found to be 2-3 times the depth of the ice just after ice-off (Pieters and Lawrence 2009a).
- Throughout the open water season, inflow mixes with the surface layer, and outflow is taken from the surface layer.
- Through the warming period (June to August) the surface layer deepens gradually to a depth estimated from the empirical relationship of Gorham and Boyce (1989), giving the surface layer depth at the time of maximum heat content. The surface layer depth was estimated to be h_{GB} = 5.4 m using a surface temperature of 15 ºC and a wind speed for late summer storms of 6 m/s. The results of the model are not sensitive to this choice.
- In the fall, the model deepens the surface layer so that the salinity stability is reduced by ΔSt_S.
- After ice-on, salinity excluded from the ice is accumulated in the top layer, and if the salinity in the top layer exceeds that of the layer below, mixing occurs.

Scenarios

Four scenarios were run as shown in Table 4. Each scenario was run with two values of ΔSt_S, which represents the work done against the salinity stratification by mixing processes during the fall.

Table 4 Model scenarios

Sc.	Description		ΔSt_S (J/m^2)
1	two layer 0-55 m, 280 mg/L; 55-130 m, 31,400 mg/L	A	20
		B	200
2	two layer 0-55 m, 805 mg/L; 55-130 m, 31,400 mg/L	A	20
		B	200
3	linear stratification 280 mg/L to 29,600 mg/L*	A	20
		B	200
4	completely mixed 8,500 mg/L	A	20
		B	200

* Averaged over 4 m bins in the compartment model

Scenario 1 is the base scenario with a fresher water cap. The salinity of the surface layer is 280 mg/L, which is slightly more saline than the background water of the area (e.g. Goose Lake, 23 mg/L) due to the presence of a small amount of saline groundwater than entered the water cap during placement.

The other three scenarios considered increasing levels of mixing with the saline lower layer during placement of the freshwater cap. Scenario 2 considers a case in which there had been some entrainment of the saline lower layer as the fresh water cap was added such that the salinity of the fresh water cap was at the discharge criterion for chloride concentration, which in terms of salinity is 805 mg/L (Table 2).

Scenario 3 considers increased mixing between the saline lower layer and the fresh water cap such that the final stratification has salinity increasing linearly from the bottom to 280 mg/L at the surface. The mean salinity of the initial stratification was kept the same as that in Scenario 1.

The final scenario considers the fresh water cap and saline lower layer of Scenario 1 to be completely mixed; the mean salinity of the entire pit is 8,500 mg/L. At the start of the simulation, the surface layer exceeds the discharge criterion in terms of salinity, 805 mg/L (see Table 2).

RESULTS AND CONCLUSIONS

Likelihood of meromixis

In the proposed Llama pit lake, the salinity of the lower layer is high, 31,400 mg/L, significantly higher than the salinity in the three examples of existing pit lakes in Northern Canada where the salinity ranged from 750 to 2,000 mg/L. All three of the example pit lakes tended toward meromixis; for discussion of meromixis in these three examples, see Pieters and Lawrence (2014). The salinity in Llama pit lake is close to that of seawater, 35,000 mg/L.

Because of the large contrast in salinity between the fresh water cap and the lower layer, the salinity stability – the energy needed to mix the salinity stratification – is very high, $St_S* = 120,000\ J/m^2$. We can use this to estimate the meromictic ratio, M, for the Llama pit lake. As the initial salinity contrast is so large, it will be the dominant contribution to the salinity stability at maximum heat content, St_S*. The meromictic ratio compares the salinity stability at maximum heat content, St_S*, to the work done against the salinity stratification by fall mixing processes, ΔSt_S, $M = St_S*/\Delta St_S$.

We consider two values of ΔSt_S of 20 and 200 J/m^2 to account for differences between the sites such as changes in wind speed. For $\Delta St_S = 20\ J/m^2$, M = 6000, and for $\Delta St_S = 200\ J/m^2$, M = 600. Regardless of the choice of ΔSt_S, the meromictic ratio is one to three orders of magnitude larger than for the comparison sites, indicating that meromixis will occur.

Evolution of meromixis and the salinity of the surface layer

The results of the compartment model for Llama pit lake are shown in Figures 3 to 10. In each figure, the first panel (a) shows the predicted stability of the pit lake using two different scales: the salinity stability at the end of August (St_S*), and the meromictic ratio (M). The second panel (b) shows the predicted depth of the surface layer at the time of ice-on, when the depth is greatest. In most cases the depth of the surface layer at ice-on marks the depth of the chemocline.[2] The third panel (c) shows the predicted salinity of the surface layer at ice-on (red) and compares this to the initial salinity of the surface layer (dash line) and the mean salinity of all inflow (dotted line). The surface layer salinity just before ice-on is shown because, of the open water season, the surface layer salinity is highest at this time.

In Scenario 1A, Llama pit lake has a 55 m cap of relatively fresh water, and, as expected, the salinity stability is high, $St_S* \sim 120,000\ J/m^2$, and the meromictic ratio is large, M ~ 6000, indicating that meromixis will occur (Figure 3a). In the first year, fall cooling mixed to only 10 m depth due to the stability provided by the contrast between the ice melt and inflow and the surface layer itself (Figure 3b). However, the depth of fall cooling increased rapidly until it reached the chemocline at 55m around year 100 (Figure

[2] The exceptions are Figure 3b (year 0-100), Figure 5b (year 0-250) and Figure 6b (year 0-15) when a secondary chemocline is established above the main chemocline at 55 m.

3b). After this time the deepening was very slow; at year 250 the chemocline had deepened from 55 m to only 55.4 m depth (Figure 3b, year 100 onward). The salinity of the surface layer at ice-on declined from 188 mg/L in the first year to ~30 mg/L in the long term (Figure 3c). The long term chloride concentration represents a balance between the flux of saline water from below (as the chemocline deepens each year bringing chloride into the surface layer), and the flux of fresh inflow. The corresponding chloride concentrations were well within the discharge criterion (Figure 3c, Table 5).

Table 5 Surface layer salinity and chloride concentration just before ice-on

Sc.	Description		ΔSt_S (J/m^2)	1 yr S [Cl] (mg/L)	10 yr S [Cl] (mg/L)	100 yr S [Cl] (mg/L)
1	two layer, surf 280mg/L	A	20	188 105	81 37	31 5
		B	200	267 155	214 122	181 100
2	two layer, surf 805mg/L	A	20	342 203	129 68	48 16
		B	200	694 427	372 222	183 102
3	linear	A	20	383 229	171 94	80 36
		B	200	1230 770	600 430	296 174
4	mixed	A	20	990 620	317 188	132 69
		B	200	3230 2170	1220 770	380 227

* Grey shade marks chloride concentrations over the discharge criterion of 500 mg/L.

In Scenario 1B, a higher degree of fall mixing was considered. The salinity stability and meromictic ration remained high (Figure 4a). Because of the increased fall mixing the surface layer mixed down to the chemocline in the first year, and over the course of the simulation the surface layer deepened from 55 to 63.2 m (Figure 4b). This slightly higher rate of chemocline deepening increased the flux of saline water into the surface layer and the long term salinity of the surface layer rose a little from 31 mg/L in Scenario 1A to 181 mg/L in Scenario 1B (Figure 4c). The corresponding chloride concentrations remained within the discharge criterion (Table 5).

Three additional scenarios were considered to examine the effect of increased mixing during placement of the water cap. Scenario 2, considers a fresh water cap at the discharge criterion. The stability in Scenario 2 remained comparable to that in Scenario 1 (Figures 5a and 6a). With lower fall mixing the surface layer never reaches the chemocline (Figure 5b), while with higher fall mixing it reaches the chemocline after approximately 20 years (Figure 6b). The salinity reaches an equilibrium of 48 mg/L in Scenario 2A (Figure 5c, Table 5) and 183 mg/L in Scenario 2B (Figure 6c, Table 5); both values are a little higher than the corresponding values of Scenario 1, due to the presence of additional saline water in the initial surface cap. Chloride concentrations for Scenario 2 remain within the discharge criterion (Table 5); the highest concentration was 427 mg/L for Scenario 2B just before ice on during of the first year.

In Scenario 3, with linear stratification, the stability of the pit lake is 66,000 J/m^2 (Figures 7a and 8a) about half of the salinity stability in Scenarios 1 and 2, but still sufficient to ensure meromixis. The salinity stability is reduced because a fraction of the fresh water is below 55 m and a fraction of the saline water is above 55 m. In Scenario 3A the surface mixed layer deepens from 5 to 20 m over the course of the simulation (Figure 7b) and the surface salinity remains within the discharge criterion (Figure 7c). However, for increased fall mixing, Scenario 3B, the surface salinity is higher than the discharge criterion in the early years (Figure 8c and Table 5).

In Scenario 4, with a completely mixed pit, the stability in the end of the first year results only from ice melt and flushing with fresh water inflow, and is approximately 7,000 J/m^2 (Figures 9a and 10a). As the surface layer continues to be flushed by inflow the stability increases and the chloride concentration in the surface layer decreases, falling below the discharge criterion in the first few years for Scenario 4A (Figure 9c) and around year 20 for Scenario 4B (Figure 10c).

To conclude, we have focused on the deepening of the chemocline due to fall mixing. Note that other processes may also contribute to the flux of saline water from the lower layer into the mixolimnion including:

- mixing induced by inflow (dissipation of inflow energy can be engineered);
- injection of fluid at depth from groundwater inflow (groundwater inflow is predicted to end after Llama pit lake has filled); and
- earthquake inducing mixing (generally inefficient at mixing, see Appendix 5).

Based on both conceptual and compartment models for the salinity stratification, meromixis is predicted for Llama pit lake. Scenarios 1 and 2 of the compartment model meet the discharge criterion for chloride concentration, while Scenarios 3 and 4 do not meet the criterion in the short term, but do in the long term. All four scenarios highlight the natural processes of ice melt and flushing of the surface layer by fresh inflow that both enhances meromixis by increasing the salinity contrast, and improves water quality by reducing the chloride concentration of the surface layer. Scenarios 2, 3 and 4 also highlight the importance of managing energy dissipation and mixing with the saline lower layer during water cap placement.

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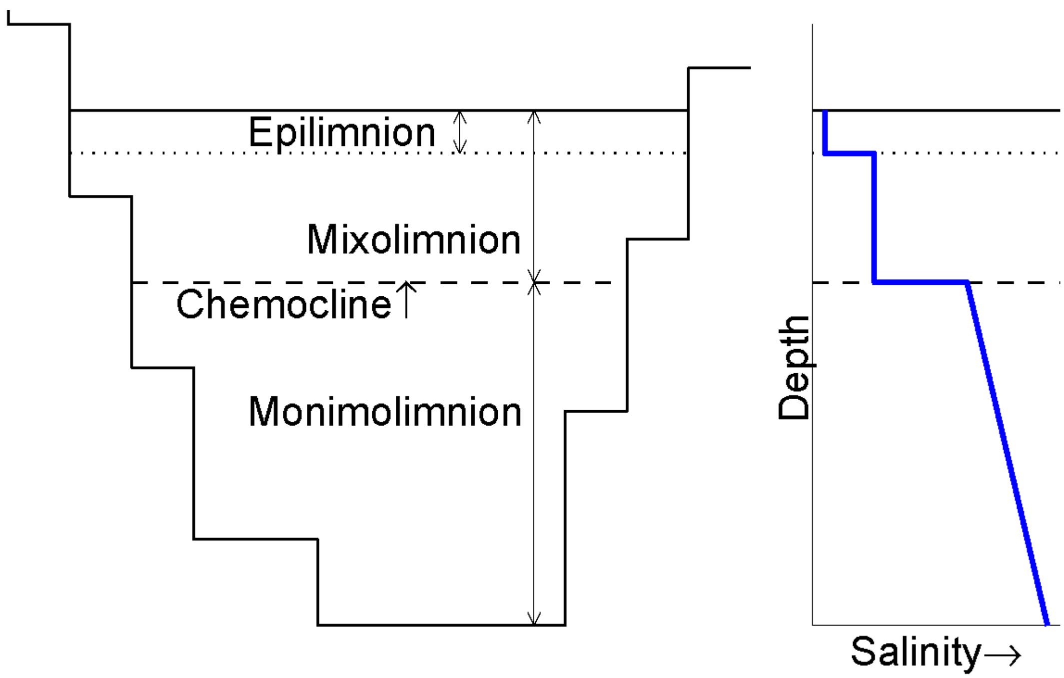

Figure 1. Schematic of a meromictic lake showing: the surface layer or **epilimnion** which is less saline as a result of ice-melt and freshet runoff; the **mixolimnion** which mixes seasonally; the **chemocline** where the largest step in salinity occurs and which resists further mixing; and the **monimolimnion** which is relatively isolated.

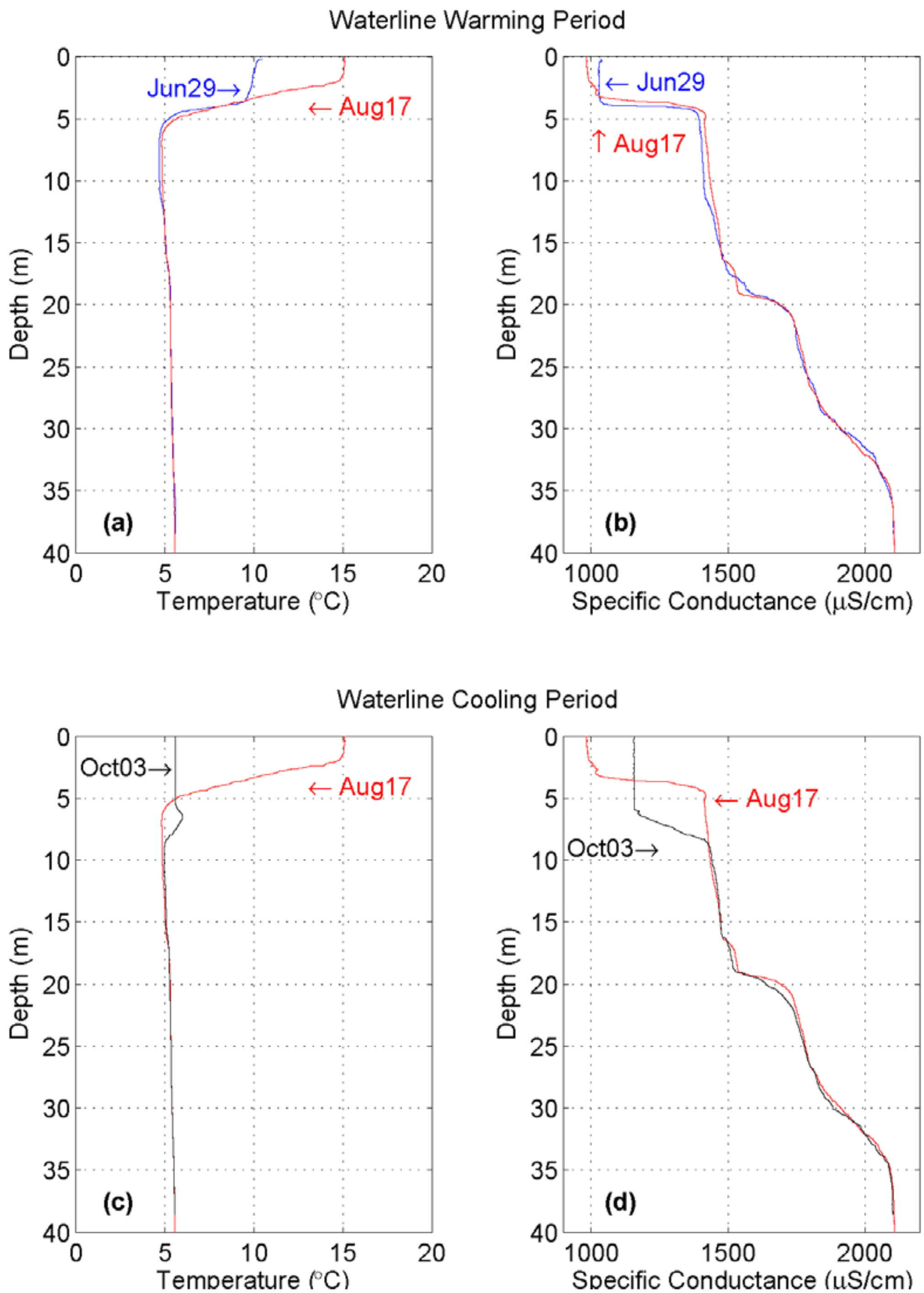

Figure 2. Waterline warming (Jun-Aug) and cooling (Aug-Oct) in 2001. The salinity stability was 194, 200 and 187 J/m^2 on Jun 29, Aug 17 and Oct 3, respectively.

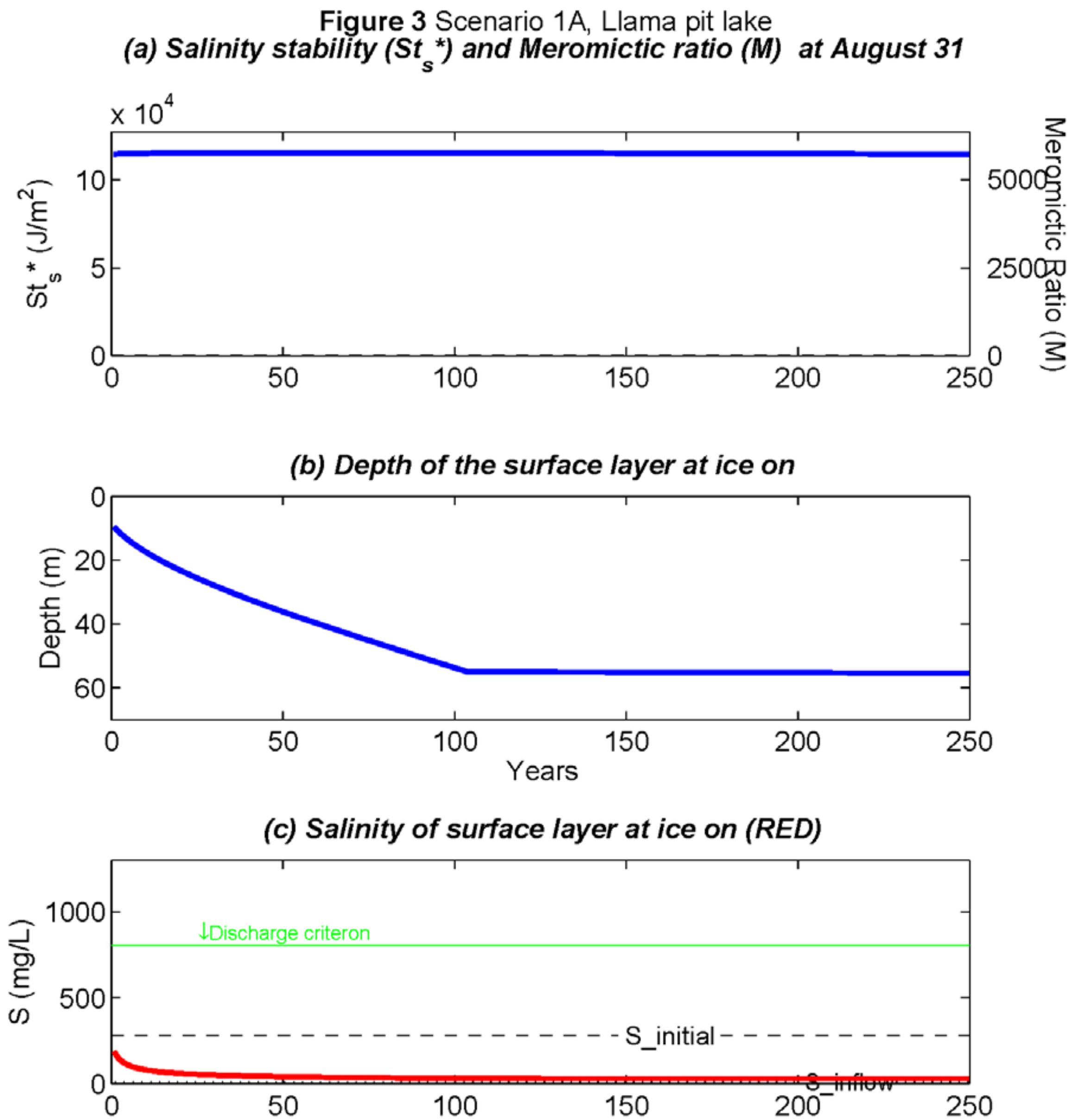

Figure 3 Scenario 1A Two layer stratification with $\Delta St_S = 20$ J/m^2. **(a)** Salinity stability shown on two different scales: the salinity stability at the end of August (St_S*), and the meromictic ratio (M). **(b)** Depth of the surface layer at the time of ice-on. **(c)** Salinity of the surface layer at ice-on (red), the initial salinity of the surface layer (dash line), the mean salinity of all inflow (dotted line), and the discharge criterion (green).

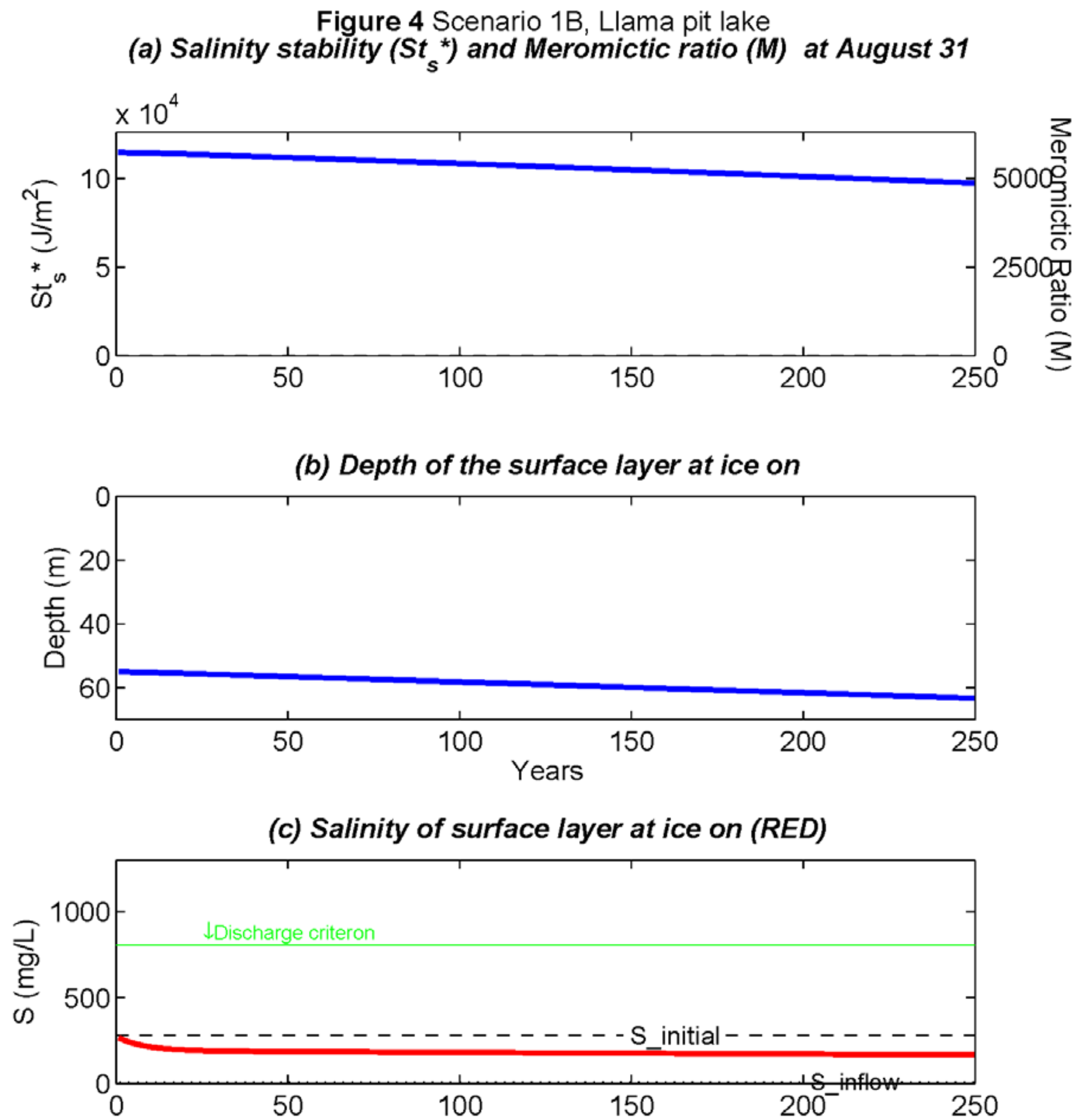

Figure 4 Scenario 1B Two layer stratification with ΔSt_S = 200 J/m^2. **(a)** Salinity stability shown on two different scales: the salinity stability at the end of August (St_S*), and the meromictic ratio (M). **(b)** Depth of the surface layer at the time of ice-on. **(c)** Salinity of the surface layer at ice-on (red), the initial salinity of the surface layer (dash line), the mean salinity of all inflow (dotted line), and the discharge criterion (green).