Attachment 2

Milne Port - Camp Pad Natural Stream Diversion – Hydrology & Hydraulic Calculations

H353004-2100-240-030-001, Rev. 0

Project Memo

H-353004

21 June 2017

To: Matt Weaver

cc: Tyler Bruce

From: A Grobbelaar

REGISTERED PROFESSIONAL ENGINEER
M. M. S. HASSAN
LICENSEE
21/JUNE/17
NT/NU

Baffinland Iron Mines LP
Mary River Project

Milne Port - Camp Pad Natural Stream Diversion- Hydrology & Hydraulic Calculations

1. Introduction

The accommodation camp pad intersects a minor seasonal stream. In order to maintain continuation of the stream, it has to be diverted around the camp pad. (See below camp pad location and streams identified)

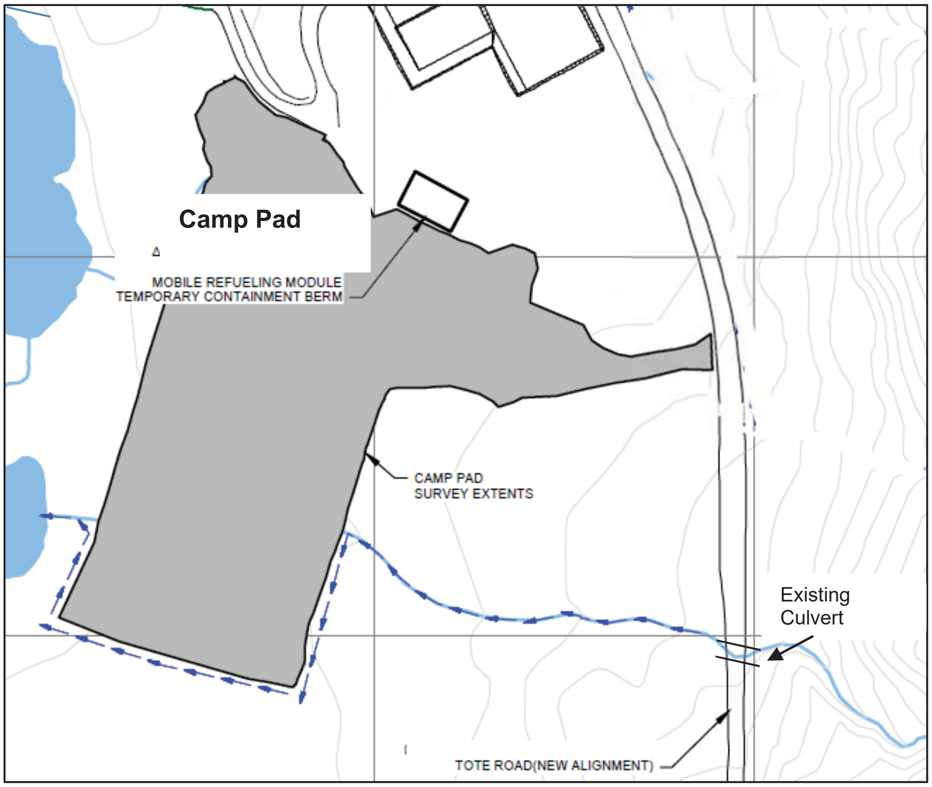


Figure 1: Accommodation Camp Pad Diversion

The catchment area for the seasonal stream is depicted below:

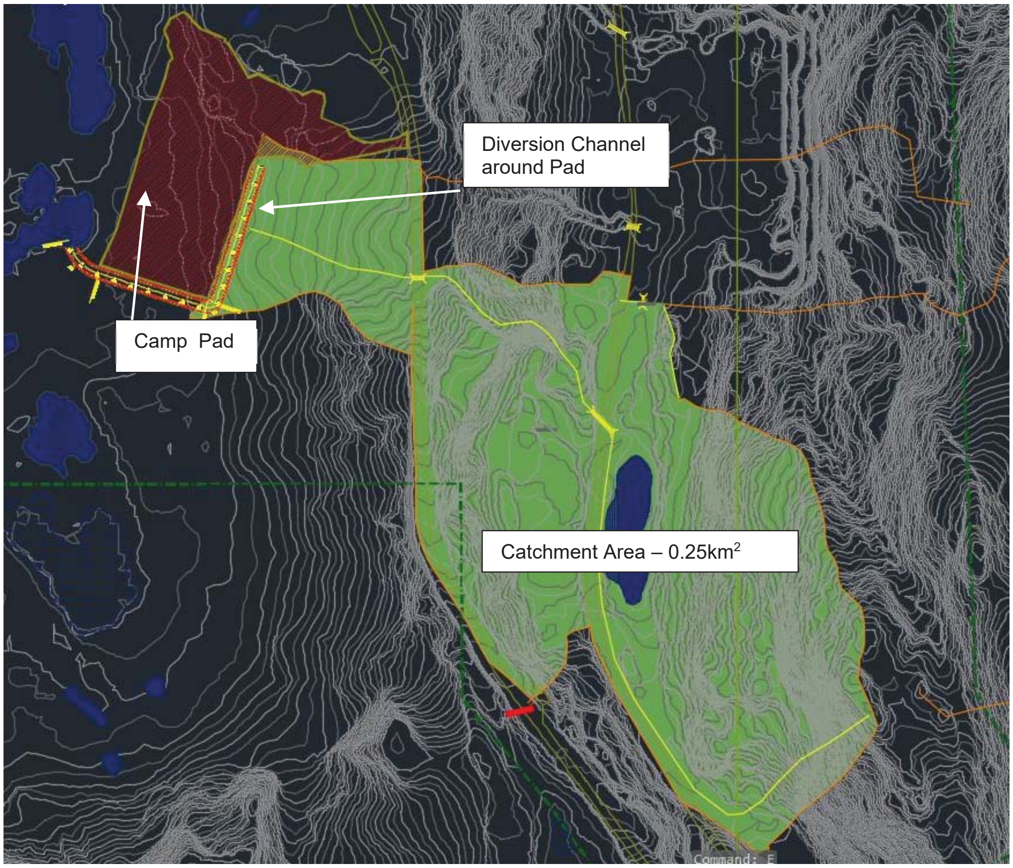


Figure 2: Seasonal Stream Catchment

A suitable sized culvert under the existing quarry access road will have to be installed in order to reduce the catchment size for the seasonal stream to 0.25km^2. Details, including elevations near the quarry access road, will need to be confirmed by onsite survey prior to finalizing culvert design and associated geotechnical engineering.

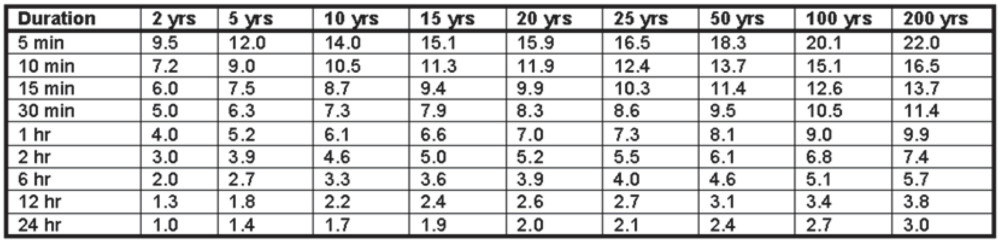
1.1 Design Calculations

1.1.1 Diversion Channel Catchment Runoff Calculation

In order to design the stream diversion, the expected storm water flow needs to be calculated (For the diversion design, Hatch used a 1:100 year return period storm in line with the previously approved design philosophy for external streams & stream diversions).

Rainfall intensities were obtained from a previous phase approved report by Hatch titled "Civil Design Criteria" – H-349000-1000-10-122-001 (Rev 1). In the report reference is made to the Knight Piesold calculated rainfall intensities for various return periods – See table 1-1 below:

Table 1-1: Rainfall Intensities for Various Return Periods



Duration	2 yrs	5 yrs	10 yrs	15 yrs	20 yrs	25 yrs	50 yrs	100 yrs	200 yrs
5 min	9.5	12.0	14.0	15.1	15.9	16.5	18.3	20.1	22.0
10 min	7.2	9.0	10.5	11.3	11.9	12.4	13.7	15.1	16.5
15 min	6.0	7.5	8.7	9.4	9.9	10.3	11.4	12.6	13.7
30 min	5.0	6.3	7.3	7.9	8.3	8.6	9.5	10.5	11.4
1 hr	4.0	5.2	6.1	6.6	7.0	7.3	8.1	9.0	9.9
2 hr	3.0	3.9	4.6	5.0	5.2	5.5	6.1	6.8	7.4
6 hr	2.0	2.7	3.3	3.6	3.9	4.0	4.6	5.1	5.7
12 hr	1.3	1.8	2.2	2.4	2.6	2.7	3.1	3.4	3.8
24 hr	1.0	1.4	1.7	1.9	2.0	2.1	2.4	2.7	3.0

The catchment area is 0.25km^2.

The Table 1-2 below indicates the calculation to determine the peak runoff from the 1:100 storm event:

Table 1-2: Peak Flow Calculation

Q = 0.28 C I A			**Tc = 0.06628(L$^{0.77}$/S$^{0.385}$)**		**Unit**	
Q=	**0.78**	m^3/s	Tc=	0.25	hr	15.1 min
C=	0.9		L=	1.177	km	
I=	12.6	mm/hr	S=	0.04317	m/m	
A=	0.25	km^2				

The diversion channel was sized based on a peak catchment flow of **0.78m^3/s** for the 1:100year return period storm.

1.1.2 *Diversion Channel Hydraulic Calculation*

Based on the previous phase approved report by Hatch titled **"Civil Design Criteria" – H-349000-1000-10-122-001 (Rev 1),** the channel properties were compiled. The side slopes of 2H:1V was used together with the rip rap and the Manning flow friction factor (n) value of 0.04 applied. Using the Flow Master software by Bentley Systems Inc, the flow depth was determined using the natural ground level slope along the accommodations camp pad. A minimum slope of 1:500 was applied where the natural ground was flatter.

Hatch Drawings No **H353004-4000-228-272-0001-0001 & H353004-4000-228-271-0001-0001** indicates the layout of the diversion channel and longitudinal profile respectively (see attached).

The seasonal minor stream is re-directed into the diversion channel through a long radius intercept channel, transitioning from the natural stream shape into the trapezoidal channel. This detail is apparent in the drawings referenced above. Some dimensional data will have to be determined on site and adjusted after consultation with the Engineer.

At the south east corner of the pad where the diversion channel turns through 90 degrees, the channel was sized and detailed to contain the specific energy calculated for the stream flow, thus ensuring that no spillage will occur during the storm event.

A general freeboard of 300 mm was applied throughout the channel design.

At the discharge end of the channel, a hydraulic flow dispersion structure is detailed to allow the energy of the 0.78^3/s flow to dissipate and not cause any erosion damage. The actual invert level of the natural water body that the diversion channel will drain into shall be confirmed on site and conveyed to the Engineer. This invert level cannot be above the diversion channel invert so as not to allow any capacity reduction of the channel. The Engineer must be consulted in the event that the invert of the natural water body is higher than the diversion channel to allow for adjustment in the details to be constructed.

In order to obtain the flow properties for the channel at various sections (change in gradient) the software by DEVOTECH was used. The EPA storm water management model - version 5.1 (build 5.1.006) calculates the flow properties at set sections and generates the long sections data as reflected on the drawing.

A Grobbelaar

AG:AG
Attachment(s)/Enclosure:

- Diversion Channel hydraulic calculation – Attachment 1
- Diversion Channel steady uniform flow calculation- Attachment 2
- H353004-4000-228-272-0001-0001- Attachment 3
- H353004-4000-228-271-0001-0001- Attachment 4

Attachment 1:
Diversion Channel Hydraulic Calculation

Project Description

Friction Method	Manning Formula
Solve For	Bottom Width

Input Data

Roughness Coefficient	0.040	
Channel Slope	0.20	%
Normal Depth	0.40	m
Left Side Slope	2.00	m/m (H:V)
Right Side Slope	2.00	m/m (H:V)
Discharge	0.78	m³/s

Results

Bottom Width	2.95	m
Flow Area	1.50	m²
Wetted Perimeter	4.74	m
Hydraulic Radius	0.32	m
Top Width	4.55	m
Critical Depth	0.18	m
Critical Slope	0.02947	m/m
Velocity	0.52	m/s
Velocity Head	0.01	m
Specific Energy	0.41	m
Froude Number	0.29	
Flow Type	Subcritical	

Attachment 2: Diversion Channel Steady Uniform Flow Calculation

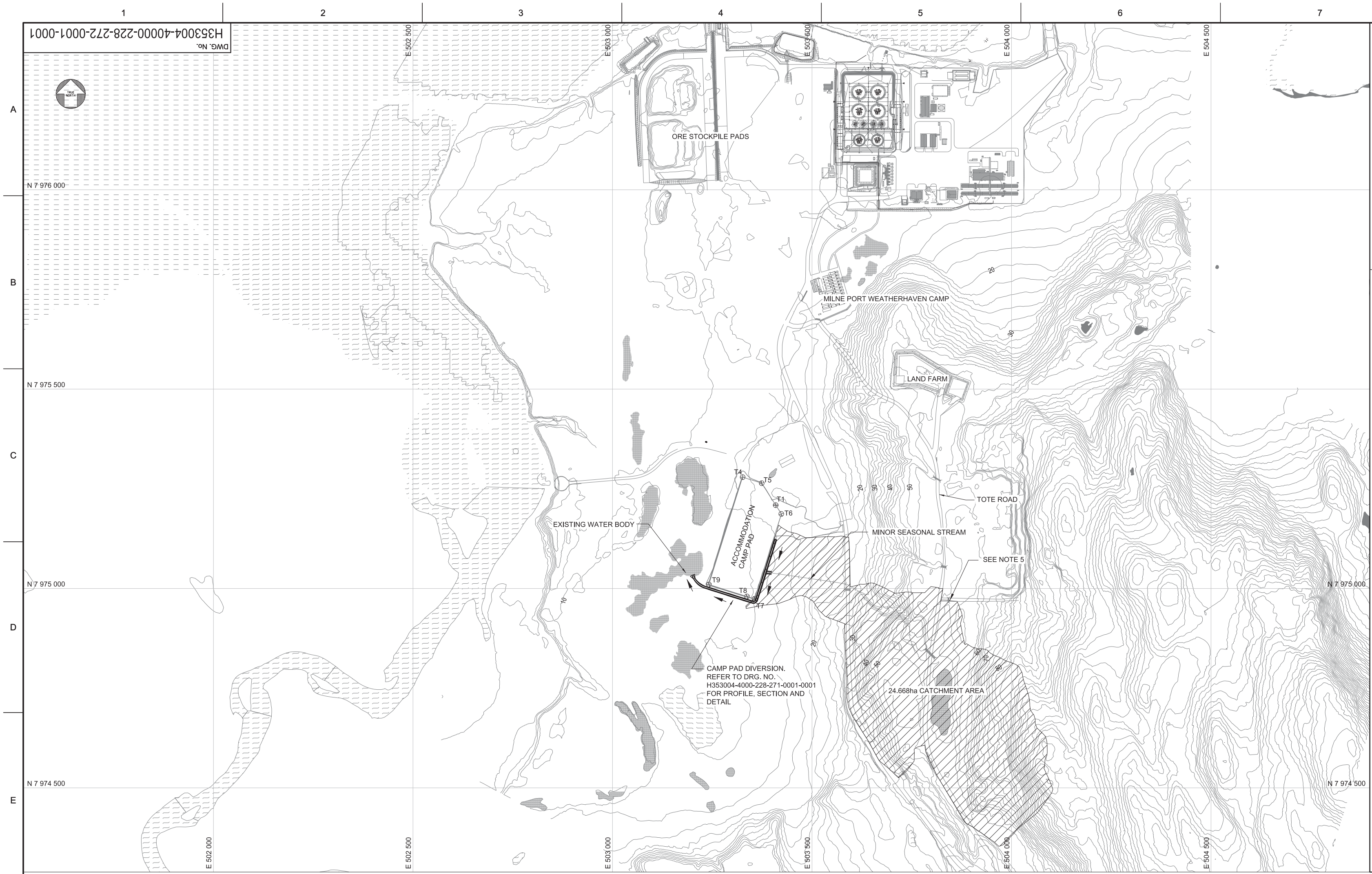
```
PA STORM WATER MANAGEMENT MODEL - VERSION 5.1 (Build 5.1.006)
  --------------------------------------------------------------

  About: File generated by iDAS (www.devotech.co.za)

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

  ****************
  Analysis Options
  ****************
  Flow Units ............... CMS
  Process Models:
    Rainfall/Runoff ........ NO
    RDII ................... NO
    Snowmelt ............... NO
    Groundwater ............ NO
    Flow Routing ........... YES
    Ponding Allowed ........ NO
    Water Quality .......... NO
  Flow Routing Method ...... STEADY
  Starting Date ............ JUN-08-2017 00:00:00
  Ending Date .............. JUN-09-2017 00:00:00
  Antecedent Dry Days ...... 0.0
  Report Time Step ......... 00:01:00
  Routing Time Step ........ 10.00 sec


  **************************        Volume         Volume
  Flow Routing Continuity        hectare-m      10^6 ltr
  **************************     ---------     ---------
  Dry Weather Inflow .......         0.000          0.000
  Wet Weather Inflow .......         0.000          0.000
  Groundwater Inflow .......         0.000          0.000
  RDII Inflow ..............         0.000          0.000
  External Inflow ..........         6.739         67.389
  External Outflow .........         6.739         67.389
  Internal Outflow .........         0.000          0.000
  Evaporation Loss .........         0.000          0.000
  Seepage Loss .............         0.000          0.000
  Initial Stored Volume ....         0.000          0.000
  Final Stored Volume ......         0.000          0.000
  Continuity Error (%) .....         0.000


  *******************************
  Highest Flow Instability Indexes
  *******************************
  All links are stable.


  *************************
  Routing Time Step Summary
  *************************
  Minimum Time Step           :    10.00 sec
  Average Time Step           :    10.00 sec
  Maximum Time Step           :    10.00 sec
  Percent in Steady State     :     0.00
  Average Iterations per Step :     1.00
  Percent Not Converging      :     0.00
```

```
******************
Node Depth Summary
******************


  ---------------------------------------------------------------------
                                 Average  Maximum  Maximum  Time of Max
                                   Depth    Depth      HGL   Occurrence
  Node                 Type       Meters   Meters   Meters  days hr:min
  ---------------------------------------------------------------------
  CN1                  JUNCTION     0.40     0.40    13.68     0  00:00
  CN4                  JUNCTION     0.40     0.40    13.62     0  00:00
  CN5                  JUNCTION     0.39     0.39    13.06     0  00:00
  CN6                  JUNCTION     0.39     0.39    12.91     0  00:00
  CN7                  JUNCTION     0.20     0.20    11.76     0  00:00
  CN8                  JUNCTION     0.19     0.19    11.43     0  00:00
  CN9                  JUNCTION     0.31     0.31    10.94     0  00:00
  CN10                 JUNCTION     0.40     0.40    10.85     0  00:00
  CN11                 JUNCTION     0.40     0.40    10.78     0  00:00
  CN12                 JUNCTION     0.52     0.52    10.82     0  00:00
  CN13                 JUNCTION     0.52     0.52    10.82     0  00:00
  CN14                 JUNCTION     0.40     0.40    10.64     0  00:00
  CN15                 JUNCTION     0.40     0.40    10.63     0  00:00
  MH70                 OUTFALL      0.39     0.39    10.62     0  00:00


*******************
Node Inflow Summary
*******************


  -------------------------------------------------------------------------------------------------
                                 Maximum  Maximum                  Lateral       Total        Flow
                                 Lateral    Total  Time of Max      Inflow      Inflow     Balance
                                  Inflow   Inflow   Occurrence      Volume      Volume       Error
  Node                 Type          CMS      CMS  days hr:min    10^6 ltr    10^6 ltr     Percent
  -------------------------------------------------------------------------------------------------
  CN1                  JUNCTION    0.780    0.780     0  00:00        67.4        67.4       0.000
  CN4                  JUNCTION    0.000    0.780     0  00:00           0        67.4       0.000
  CN5                  JUNCTION    0.000    0.780     0  00:00           0        67.4       0.000
  CN6                  JUNCTION    0.000    0.780     0  00:00           0        67.4       0.000
  CN7                  JUNCTION    0.000    0.780     0  00:00           0        67.4       0.000
  CN8                  JUNCTION    0.000    0.780     0  00:00           0        67.4       0.000
  CN9                  JUNCTION    0.000    0.780     0  00:00           0        67.4       0.000
  CN10                 JUNCTION    0.000    0.780     0  00:00           0        67.4       0.000
  CN11                 JUNCTION    0.000    0.780     0  00:00           0        67.4       0.000
  CN12                 JUNCTION    0.000    0.780     0  00:00           0        67.4       0.000
  CN13                 JUNCTION    0.000    0.780     0  00:00           0        67.4       0.000
  CN14                 JUNCTION    0.000    0.780     0  00:00           0        67.4       0.000
  CN15                 JUNCTION    0.000    0.780     0  00:00           0        67.4       0.000
  MH70                 OUTFALL     0.000    0.780     0  00:00           0        67.4       0.000


**********************
Node Surcharge Summary
**********************

No nodes were surcharged.


*********************
Node Flooding Summary
*********************

No nodes were flooded.


***********************
Outfall Loading Summary
***********************


  -----------------------------------------------------------
                         Flow       Avg       Max       Total
                         Freq      Flow      Flow      Volume
```

```
Outfall Node        Pcnt      CMS      CMS    10^6 ltr
-----------------------------------------------------------
MH70             100.00    0.780    0.780     67.389
-----------------------------------------------------------
System           100.00    0.780    0.780     67.389


********************
Link Flow Summary
********************

-----------------------------------------------------------------------------
                         Maximum  Time of Max   Maximum    Max/    Max/
                          |Flow|   Occurrence   |Veloc|    Full    Full
Link              Type          CMS  days hr:min     m/sec    Flow   Depth
-----------------------------------------------------------------------------
CH21              CONDUIT     0.780     0  00:00      0.37    0.57    0.74
CH24              CONDUIT     0.780     0  00:00      0.52    0.35    0.56
CH1               CONDUIT     0.780     0  00:00      0.51    0.36    0.57
CH17              CONDUIT     0.780     0  00:00      1.24    0.10    0.27
CH11              CONDUIT     0.780     0  00:00      1.20    0.10    0.27
CH8               CONDUIT     0.780     0  00:00      1.35    0.08    0.25
CH9               CONDUIT     0.780     0  00:00      0.52    0.35    0.56
CH10              CONDUIT     0.780     0  00:00      1.17    0.11    0.28
CH18              CONDUIT     0.780     0  00:00      0.68    0.24    0.45
CH19              CONDUIT     0.780     0  00:00      0.52    0.36    0.57
CH20              CONDUIT     0.780     0  00:00      0.52    0.36    0.57
CH22              CONDUIT     0.780     0  00:00      0.52    0.35    0.56
CH23              CONDUIT     0.780     0  00:00      0.51    0.36    0.57


*************************
Conduit Surcharge Summary
*************************

No conduits were surcharged.


Analysis begun on:  Tue Jun 20 16:00:38 2017
Analysis ended on:  Tue Jun 20 16:00:38 2017
Total elapsed time: < 1 sec
```

Attachment 3

DWG. No.
H353004-40000-228-272-0001-0001



LAYOUT

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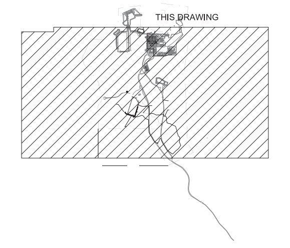

KEY PLAN

NTS

ACCOMMODATION CAMP PAD COORDINATES

POINT	EASTING	NORTHING
T1	503408,977	7975209,046
T4	503326,171	7975279,119
T5	503373,873	7975264,133
T6	503423,018	7975187,011
T7	503356,128	7974974,084
T8	503337,047	7974980,078
T9	503241,644	7975010,049

FOR CONSTRUCTION

NOTES:

1. LIDAR SURVEY PROVIDED BY PHOTSAT (2016)
2. COORDINATE GRID IS SHOWN IN UTM (NAD83) ZONE 17 AND IS IN METERS.
3. ALL DIMENSIONS ARE IN METERS.
4. CONTOURS ARE IN METERS, CONTOUR INTERVAL IS 2m.
5. MODIFY EXISTING CULVERT OR CONSTRUCT A NEW CULVERT AT THE QUARRY ROAD TO ENSURE POSITIVE DRAINAGE (FLOW FROM SOUTH TO NORTH) THROUGH CULVERT.

LEGEND:

┈	MINOR SEASONAL STREAMS
▨	WATER BODY
▨	CATCHMENT AREA
20	LIDAR GROUND CONTOUR
➤	FLOW DIRECTION

0 50 100 150 200 250
SCALE IN METERS

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REFERENCE DRAWINGS

DRAWING No.	DRAWING TITLE
H353004-40000-228-271-0001-0001	CAMP PAD NATURAL STREAM DIVERSION - PROFILE, SECTION AND DETAILS

REG. PROFESSIONAL

NAME
SIGNATURE
ENG REG NUMBER
REVISION DATE
ORIGINAL DATE

REVISIONS

No.	DESCRIPTION	BY	CHK'D	DATE
0	APPROVED FOR CONSTRUCTION	FH	SRH	20/06/2017

HATCH

ROLE	NAME	SIGNATURE	DATE
DRAFTSPERSON	F HUGO	NR	20/06/2017
DESIGNER	F HUGO	NR	20/06/2017
CHECKER	S HALL		20/06/2017
DESIGN COORD.	R GOOSEN		20/06/2017
RESP. ENG.	A GROBBELAAR		20/06/2017
LEAD DISC. ENG.	A GROBBELAAR		20/06/2017
AREA MANAGER	T BRUCE		20/06/2017
PROJ. MANAGER	S HEINER		20/06/2017
CLIENT			

DRAWING APPROVAL STATUS: Approved for Construction

Baffinland

BAFFINLAND IRON MINES LP
MARY RIVER PROJECT

MILNE PORT
CAMP PAD NATURAL STREAM DIVERSION
LAYOUT

SCALE	DWG. No.	REV
1:5,000 OR AS NOTED	H353004-40000-228-272-0001-0001	0

SHEET SIZE: D

jdc_pwservice
20-JUN-2017 19:24
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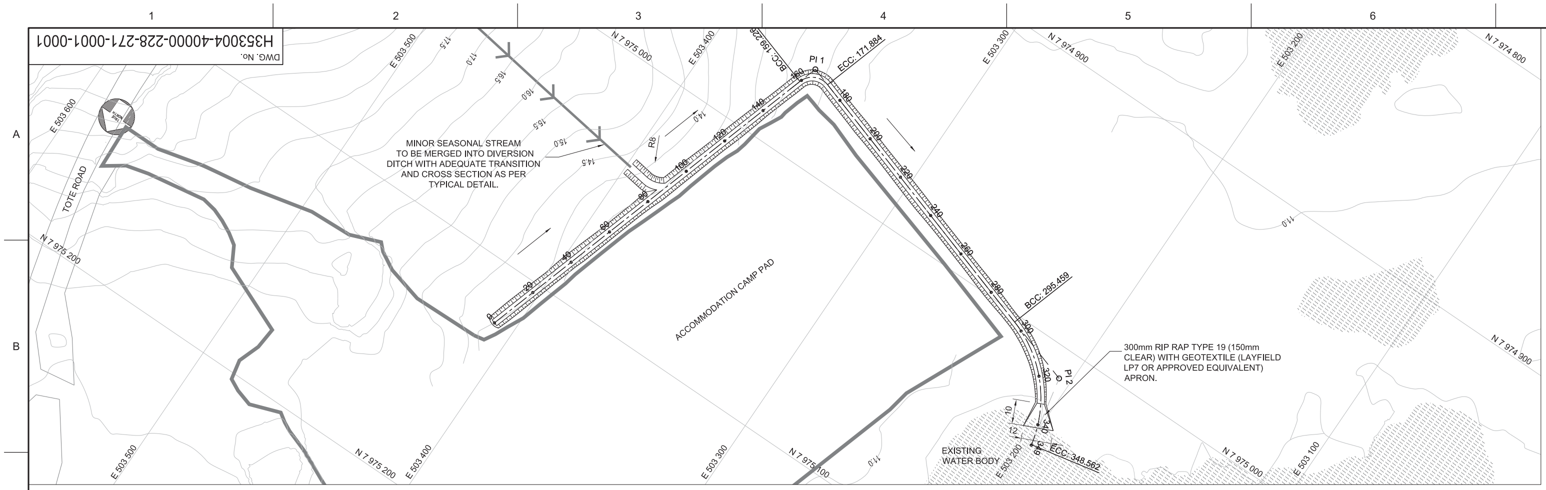
Attachment 4



LAYOUT

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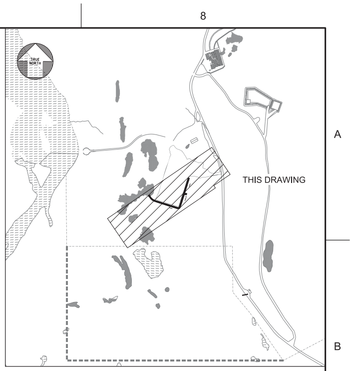


KEY PLAN

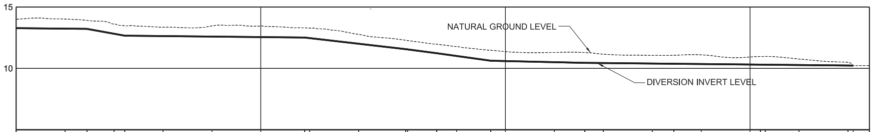
NTS

ACCOMODATION CAMP PAD DIVERSION SETTING OUT DATA

NAME	CH	E	N	DETAILS
START	0.000	503 408.443	7 975 122.942	L 159.226m
BCC1 PI1 ECC1	159.226 171.884	503 360.722 503 358.306 503 350.618	7 974 971.035 7 974 963.344 7 974 965.770	R 8.052m DA 90°04'10" TL 8.062m AL 12.658m
BCC2 PI2 ECC2	295.459 348.562	503 232.767 503 204.763 503 198.838	7 975 002.947 7 975 011.782 7 975 040.543	R 50.000m DA 60°51'10" TL 29.365m AL 53.103m
END	348.739	503 198.802	7 975 040.543	L 0.177m

SCALES:
Horizontal 1:1000
Vertical 1:200

DATUM 5.000



DEPTH TO INVERT	0.723	0.780	0.698	0.795	0.810	0.723	0.870	0.910	0.785	0.813	0.761	0.722	0.711	0.730	0.763
INVERT LEVELS	13.277	13.238	13.221	12.822	12.664	12.632	12.592	12.551	12.514	12.467	12.008	11.567	11.547	11.237	11.012
GROUND LEVELS ON CL	14.001	14.018	13.919	13.617	13.474	13.355	13.462	13.461	13.299	13.279	12.769	12.289	12.258	11.967	11.775
DISTANCE	0.000	20	28.900	40	44.399	60	80	100	117.923	120	140	159.226		171.883	180

DEPTH TO INVERT	0.857	0.771	0.794	0.843	0.726	0.666	0.692	0.745	0.615	0.662	0.673	0.485	0.258	0.000
INVERT LEVELS	10.623	10.596	10.506	10.450	10.435	10.395	10.378	10.355	10.315	10.307	10.303	10.275	10.234	10.230
GROUND LEVELS ON CL	11.480	11.367	11.300	11.294	11.161	11.061	11.070	11.100	10.930	10.968	10.975	10.759	10.492	10.230 10.230
DISTANCE	194.031	200	220	232.449	240	260	268.775	280	300	304.186	306.175	320	340	342.133 349

HORIZONTAL ALIGNMENT

DIRECTION 17°26'20"

CURVE 1 R=8.1m BCC1 159.226 171.884 ECC1 I=62°28'30"

DIRECTION 107°30'30"

BCC2 295.459 CURVE 2 R=50.0m I=137°56'00" 348.562 ECC2

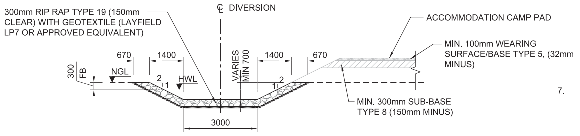
HYDRAULICS Q(m3/s)	HYDRAULICS V(m/s)	SLOPE / LENGTH
0.78	0.5	0.19% 1:513.2 28.90m
0.78	1.4	3.59% 1:27.8 15.50m
0.78	0.5	0.20% 1:490.1 73.52m
0.78	1.2	2.29% 1:43.6 41.30m
0.78	1.2	2.49% 1:40.2 13.28m
0.78	1.2	2.77% 1:36.1 22.15m
0.78	0.7	0.45% 1:222.3 38.42m
0.78	0.5	0.20% 1:499.7 36.33m
0.78	0.5	0.20% 1:498.2 35.38m
0.78	0.4	0.08% 1:1271.3 5.11m
0.78	0.5	0.21% 1:487.6 30.93m
0.78	0.5	0.20% 1:498.6 3.09m
0.78	0.5	0.20% 1:500.0 1.47m

DIVERSION LONGITUDINAL PROFILE

LEGEND:

→	MINOR SEASONAL STREAM
NGL	NATURAL GROUND LEVEL
CH	CHAINAGE
L	LENGTH
R	RADIUS
DA	DEFLECTION ANGLE
TL	TANGENT LENGTH
AL	ARC LENGTH
BCC	BEGINNING OF CURVE
ECC	END OF CURVE
PI	POINT OF INTERSECTION
HWL	HIGH WATER LEVEL
FB	FREE BOARD
▨	WATER BODY
←	FLOW DIRECTION
— · —	DIVERSION CENTER LINE

FOR CONSTRUCTION



TYPICAL DIVERSION CROSS SECTION

SCALE 1:100

NOTES:

1. LIDAR SURVEY PROVIDED BY PHOTSAT (2016)
2. COORDINATE GRID IS SHOWN IN UTM (NAD83) ZONE 17 AND IS IN METERS.
3. CONTOURS ARE IN METERS. CONTOUR INTERVAL IS 0.5m.
4. CROSS SECTION DIMENSIONS ARE IN MILLIMETERS. ALL OTHER DIMENSIONS ARE IN METERS.
5. THE STREAM BED ELEVATIONS ARE BASED ON LIDAR DATA. THERE COULD BE DIFFERENCES BETWEEN THE ACTUAL STREAM BED ELEVATIONS AND LIDAR DATA. NOTIFY THE COMPANY'S REPRESENTATIVE IF ANY DIFFERENCE IS FOUND AND FIELD ADJUST THE DITCH/BERM INVERT ELEVATIONS AS PER COMPANY'S REPRESENTATIVES DIRECTION, AS REQUIRED.
6. AS A GUIDELINE, THE DIVERSION INVERT ELEVATION AT THE UPSTREAM START SHALL BE AT LEAST MATCHING OR LOWER THAN THE CONNECTING STREAM BED ELEVATION AND THE DIVERSION INVERT ELEVATION AT THE DOWNSTREAM END SHALL BE AT LEAST MATCHING OR HIGHER THAN THE CONNECTING STREAM BED / WATER BODY ELEVATION TO ENSURE POSITIVE FLOWS AT THE DITCH START AND END.
7. PROVIDE 300mm RIP RAP TYPE 19 OVER GEOTEXTILE FOR THE ENTIRE LENGTH AND SECTION OF THE DIVERSION.

0 10 20 30 40 50
SCALE IN METERS

DRAWING No.	DRAWING TITLE
H343004-40000-228-271-0001-0001	CAMP PAD NATURAL STREAM DIVERSION - LAYOUT

REFERENCE DRAWINGS

NAME
SIGNATURE
ENG REG NUMBER
REVISION DATE
ORIGINAL DATE
REG. PROFESSIONAL

No.	DESCRIPTION	BY	CHK'D	DATE
0	APPROVED FOR CONSTRUCTION	FH	SRH	20/06/2017

REVISIONS

HATCH

ROLE	NAME	SIGNATURE	DATE
DRAFTSPERSON	F HUGO	NR	20/06/2017
DESIGNER	F HUGO	NR	20/06/2017
CHECKER	S HALL		20/06/2017
DESIGN COORD.	R GOOSEN		20/06/2017
RESP. ENG.	A GROBBELAAR		20/06/2017
LEAD DISC. ENG.	A GROBBELAAR		20/06/2017
AREA MANAGER	T BRUCE		20/06/2017
PROJ. MANAGER	S HEINER		20/06/2017
CLIENT			

DRAWING APPROVAL STATUS: Approved for Construction

Baffinland

BAFFINLAND IRON MINES LP
MARY RIVER PROJECT

MILNE PORT
CAMP PAD NATURAL STREAM DIVERSION
PROFILE, SECTION AND DETAILS

SCALE	DWG. No.	REV
1:1,000 OR AS NOTED	H353004-40000-228-271-0001-0001	0

SHEET SIZE: D

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