May 16, 2012

DESIGN BRIEF

West Island Fish Habitat Compensation Works

Submitted to:
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Attention:  Mr. David Wells

Project Number:  10-1328-0028/23000
Document Number:  1149 Ver. 0
PO Number:  D01713 line 1
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1.0 INTRODUCTION

In 2004, Dillon Consulting Ltd (Dillon) developed a design for fish habitat compensation works to be constructed in West Island Stream (ws1), which runs from West Island Lake (W1) to Lac de Gras in the Northwest Territories (Figure 1). These works were proposed as part of the Diavik Diamond Mines Inc. (DDMI) Fish Habitat Compensation Plan for the Diavik Mine. As described in Dillon (2004), ws1 currently provides limited fish access to W1 during spring and summer months, and the stream is not being used by fish for migration and/or spawning due to a series of cascades which form a barrier to passage near the outlet to Lac de Gras. The habitat compensation works proposed by Dillon included instream deflector berms, stream channelization, bank armouring, a step-pool sequence and the development of instream spawning habitats. The proposed works were intended to improve fish migration, spawning and nursery habitats.

Due to limited availability of timber and challenges of construction using large boulders, DDMI requested that Golder modify Dillon’s design to include, where practicable, the use of gabion baskets instead of timber cribbing and boulder structures. Although the original design prepared by Dillon proposed habitat enhancements for the lower portion of ws1 only, DDMI requested that Golder expand the fish habitat design to enhance the entire length of ws1 (Golder 2011 and 2012b). This design brief describes the proposed habitat compensation works at West Island, including the design modifications by Golder.

The scope of work described in this Design Brief is limited to the hydrotechnical engineering aspects only, and does not include any specific provisions for geotechnical engineering, the investigation, testing or assessment of the potential presence or impact of soil or groundwater contamination at the site, or fisheries services.

This design brief shall be read in conjunction with “Study Limitations” which is provided on page i of this brief. The reader’s attention is specifically drawn to this information as it is essential that it is followed for the proper use and interpretation of this design brief.
2.0 BACKGROUND INFORMATION

2.1 Project Location

Diavik Mine is located at approximately 64º31’ latitude north and 110º20’ longitude west, in the Canadian Northwest Territories. ws1 is located approximately 8 km west from Diavik Mine Site, on West Island, and connects W1 to Lac de Gras (Figure 1).

The Lac de Gras drainage basin is situated close to the southern boundary of Low Arctic, north of the tree line boundary, and at the transition from discontinuous to continuous permafrost where the ground is continuously below 0 ºC for two years or more (Golder, 2008).

2.2 Site Topography

In September 2011, Praetorian Construction Management performed a topographic survey of ws1 (Praetorian, 2011). Data collected during this survey (refer to Appendix II) has been used as a basis for the works proposed in this Design Brief. Note that the stations in Praetorian’s survey differ from those reported by Dillon (2004).

2.3 ws1 Hydrology

Based on the recent survey performed by Praetorian (refer to Appendix II), ws1 has a fairly well defined, low-gradient (0.15%) channel from W1 to about Sta.0+100 where it splits into at least two channels within an area of bog, before converging back into a single main channel at about Sta.0+250. Between Sta.0+250 and Sta.0+350 the single main channel is well defined with a moderate gradient (1.3% to 2.2%). Below Sta.0+350, the main channel splits into at least two channels, and includes a steep cascade reach (bed gradient of about 12.8%) between Sta.0+420 and Sta.0+440, before entering Lac de Gras at around Sta.0+465.

As described by Dillon (2004), flows entering ws1 originate mainly from W1, and to a minor extent from water entering the intervening area between W1 and Lac de Gras. Dillon (2004) estimated the drainage area at about 1.6 km², and the low and 1 in 5-year return period peak flows at approximately 0.08 m³/s and over 0.5 m³/s, respectively. Maximum flows in ws1 from the Dillon report are about 3 m³/s (Figure 4.1 in Dillon, 2004).

Students from the University of Alberta measured flows at three sections of ws1 channel during the summer months of 2009, 2010 and 2011. Based on un-published data collected in 2010 and 2011, daily average flows for the months of June and July at the downstream end of ws1 generally average between 0.04 m³/s and 0.07 m³/s, but have been observed to be as high 0.35 m³/s.
3.0 DESIGN CONSIDERATIONS AND APPROACH

3.1 Design Objectives

Golder understands that the fish habitat compensation works for ws1 are intended to meet two main objectives:

- Remove the cascade located near the outlet of ws1 to Lac de Gras and improve fish passage/migration opportunities along the lower and upper sections of the channel; and
- Increase fish habitat in the channel by better defining the highly braided channel sections and installing spawning habitat.

Golder understands that the target species of the proposed habitat compensation is Arctic grayling (Thymallus arcticus). Based on available literature, design considerations provided by Dillon (2004) and feedback obtained from fisheries specialists, it is estimated that sustained water velocities of up to 0.8 m/s and maximum jump heights of 0.2 m would be required to allow for migration of adult Arctic grayling. Furthermore, it is understood that Arctic grayling spawn in spring and that spawning habitats for this species require water velocities under 0.4 m/s and water depths of about 0.1 m to 0.6 m.

3.2 Design Flows

Since only limited historical flow data is available for ws1, Golder based the proposed design on the information described in Section 2.3, adopting the following design flows:

- Average low flow of 0.05 m³/s;
- Annual maximum flow of 0.4 m³/s; and
- Maximum flow of 3 m³/s.

3.3 Channel Modifications

As identified by Dillon (Dillon 2004), a steep cascade and ill-defined segments of the existing ws1 channel are acting as a barrier to migration. Based on a recent survey performed by Praetorian (2011) and cursory review of the site conditions, the ill-defined segments of the channel exist from Sta.0+100 to Sta.0+250, and Sta.0+350 to Sta.0+465. A steep cascade (bed slope of 12.8%) exists between Sta.0+420 and Sta.0+440.

These migration barriers are intended be removed by re-grading segments of ws1 to reduce the bed slope and excavating segments ws1 along its existing alignment to better define the channel geometry.

3.4 Instream Structures

Two types of instream structures, as described below, will be installed at different segments of ws1 to facilitate fish passage and enhance habitat.
**Step Pool Complexes**

Step pool complexes are intended to backup water in steeper segments (bed slope above 2%) of ws1, increasing water depths and reducing velocities. The design of step-pool structures is based on a jump height of 0.2 m in order to accommodate migration by Arctic grayling.

**Riffle Pool Complexes**

Riffle pool complexes are intended to enhance fish habitat in relatively flat (bed slope of 2%) segments of ws1 by incorporating resting pools and spawning material (specified as 2” minus crushed rock). Gabion basket deflectors will be placed upstream of the spawning material to shield these areas from direct flows. Gabion baskets will also be used to armour the toe of the opposite channel bank where flow deflectors are installed.

It is estimated that flows will be contained within the channel at the assumed annual maximum flow (0.4 m$^3$/s), resulting in flow depths between 0.2 m and 0.3 m, and velocities generally between 0.5 m/s and 1.2 m/s in the riffle pool segment of the channel. At the assumed average low flow, velocities in this segment of the channel are generally expected to remain below 0.3 m/s, and around 0.1 m/s immediately downstream of the deflector berms. Except for pool areas, water depths at the assumed average low flow would likely remain below 10 cm at the assumed average low flow.

The proposed structures have not been designed to withstand extreme flow events and natural hydraulic adjustment/sorting of the structures may occur. Monitoring of the structures will be required following large flow events to identify any potential maintenance needs and confirm they continue to meet design intent.
4.0 DESCRIPTION OF PROPOSED WORKS

Details on the proposed Habitat Compensation Works structures are provided in this section and in the set of Issued for Construction (IFC) Drawings prepared by Golder (2012). A half-size copy of the IFC drawings is provided in Appendix I, at the end of this document.

The IFC drawings are organized as follows:

- Drawing No. 16100-41D1-0000 – Title Sheet (Including Material and Installation Specifications)
- Drawing No. 16100-41D1-0001 – Overall Site Plan
- Drawing No. 16100-41D1-0002 – West Island Stream Channel
- Drawing No. 16100-41D1-0003 – Step Pool Complex Details
- Drawing No. 16100-41D1-0004 – Riffle Pool Complex Details

Based on Golder’s experience with this type of work, it is anticipated that field fitting of the design works will be required during construction. Specifically, the channel alignment and location of step pools may need to be adjusted according to field conditions, and shall be determined in the field by DDMI and Golder.

4.1 Channel Excavation

Segments of the ws1 channel will be excavated from Sta.0+100 downstream to Lac de Gras to create a new main channel (refer to Appendix I: Drawing No. 16100-41D1-0002). The inlets of existing side channels will be blocked with gabion baskets or boulders (where available), where required, to concentrate low flows into the main channel. The proposed channel will have a bottom width of 1 m, 2H:1V side slopes, and longitudinal bed slope between 1% to 4% (Table 1).

Table 1: Characteristics of Excavated Channel

<table>
<thead>
<tr>
<th>Option</th>
<th>Channel Section</th>
<th>Approx. Bed Slope (%)</th>
<th>Invert Elevation Upstream / Downstream (m)</th>
<th>Approx. Channel Depth (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sta.0+100 to Sta.0+135</td>
<td>1</td>
<td>423.4 / 423.1</td>
<td>0.1 – 0.5</td>
</tr>
<tr>
<td></td>
<td>Sta.0+135 to Sta.0+220</td>
<td>3</td>
<td>423.1 / 420.7</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sta.0+220 to Sta.0+238</td>
<td>2</td>
<td>420.7 / 420.3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sta.0+330 to Sta.0+400</td>
<td>2</td>
<td>418.6 / 417.2</td>
<td>0.4 – 1.3</td>
</tr>
<tr>
<td>A</td>
<td>Sta.0+400 to Sta.0+435</td>
<td>4</td>
<td>417.2 / 415.8</td>
<td>1.2 – 1.5</td>
</tr>
<tr>
<td></td>
<td>Sta.0+435 to Sta.0+465</td>
<td>1</td>
<td>415.8 / 415.4</td>
<td>0.2 – 1.2</td>
</tr>
</tbody>
</table>
Based on observations during site visits, the cascade area (Sta.0+400 to 0+435) has been identified as a potentially challenging section for excavation. For this reason, two options, A and B, have been provided for channel excavation in this area. If option A proves not to be feasible during construction, option B shall be constructed instead.

### 4.2 Step Pool Complexes (Sta. 0+100 to 0+240 and Sta. 0+400 to 0+440)

Step pool complexes shall be installed from Sta.0+100 to Sta.0+240 and from Sta.0+400 to Sta.0+440. The exact location of the complexes will be determined during construction to accommodate a maximum elevation difference of 0.2 m between complexes.

Each step pool complex shall consist of a geomembrane-lined v-shaped rock filled gabion basket weir and a 0.4 m (minimum) deep resting pool constructed immediately downstream. Each basket shall be 4.0 m long x 0.5 m wide (at the base and shaped to be narrower at the top) x 0.5 m high, and shall be embedded in the channel by at least 0.3 m. The gabion basket weirs shall be shaped to concentrate flows at the center of the channel (refer to Appendix I: Drawing No. 16100-41D1-0021).

2” minus crushed rock shall be placed upstream and downstream of each step as shown on the IFC drawings (Appendix I). Also, as recommended by Dillon (2004) and where available, boulders shall be randomly placed downstream of the weirs and within the pools to provide resting locations for migrating fish. These rocks shall have a diameter of at least 0.5 m and be embedded into the channel bed at least 0.2 m.

### 4.3 Riffle Pool Configuration (Sta. 0+330 to 0+400)

Fourteen riffle pool complexes at an approximate spacing of 5m shall be installed between Sta.0+330 and Sta.0+400 (refer to Appendix I: Drawing No. 16100-41D1-0004). Each riffle pool complex shall be constructed with a gabion basket deflector approximately 0.5 m high x 0.3 m wide and 1.0 m long, filled with 8” minus crushed rock. Deflectors shall be placed adjacent to the stream banks at an approximately 45° pointing downstream, embedded at least 0.3 m, and keyed into the channel banks about 0.5 m. A layer of 2” crushed rock approximately 1.0 m to 0.5 m wide, 2 m long and 0.2 m thick shall be placed downstream and around of each deflector. The 2” minus rock shall be filled up to the finished channel bed and placed as flat as possible (minimal longitudinal slope). For each complex, a pool shall be excavated adjacent to the 2” minus rock.
crushed rock, along the opposite bank. An approximately 2 m long section of the opposite bank toe shall be armoured along the length of the pool using a 0.5 m wide x 0.7 m tall x 2 m long gabion basket filled with 8” minus crushed rock, or alternatively, using 0.3 m diameter (minimum) boulders, if available.

Also, as recommended by Dillon (2004) and where available, boulders shall be randomly placed along this segment of the channel to provide resting locations, spawning isolation and additional cover habitat. These rocks shall have a diameter of at least 0.5 m and be embedded into the channel bed at least 0.2 m.
5.0 ESTIMATE OF QUANTITIES

Table 2 lists the estimated quantities of materials required for the fish habitat compensation works at ws1. These quantities have been estimated based on the structure dimensions and assumptions shown in the IFC drawings prepared by Golder (Appendix I).

Based on Golder’s experience with this type of work, it is anticipated that field-fitting of the design works will be required during construction to adapt to site conditions. Therefore, the quantities presented here should be considered approximate.

For the preparation of this estimate, it has been assumed that boulders required in this design will be readily available and sourced on site.

Table 2: Estimate of Materials Quantities

<table>
<thead>
<tr>
<th>Item Description</th>
<th>Dimensions</th>
<th>Quantity</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gabion baskets for toe armouring</td>
<td>0.5 m x 0.7 m x 2 m</td>
<td>14</td>
<td>un</td>
</tr>
<tr>
<td>Gabion baskets for deflectors</td>
<td>0.3 m x 0.5 m x 1 m</td>
<td>16</td>
<td>un</td>
</tr>
<tr>
<td>8” minus crushed rock (gabion baskets fill)</td>
<td>-</td>
<td>12</td>
<td>m³</td>
</tr>
<tr>
<td>2” minus crushed rock</td>
<td>-</td>
<td>4</td>
<td>m³</td>
</tr>
</tbody>
</table>

Table 3 summarizes the estimated net excavation volumes in ws1. These volumes do not include additional excavation required to create pools, install gabion basket weirs and layers of 2” minus crushed rock.

Table 3: Estimated Channel Excavation Volumes

<table>
<thead>
<tr>
<th>Section</th>
<th>Estimated Net Excavation (m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sta.0+100 to 0+240</td>
<td>175</td>
</tr>
<tr>
<td>Sta.0+330 to 0+465 - Option A</td>
<td>354</td>
</tr>
<tr>
<td>Sta.0+330 to 0+465 – Option B</td>
<td>245</td>
</tr>
</tbody>
</table>
6.0 MONITORING AND MAINTENANCE

- As recommended by Dillon (2004), it is recommended that a fisheries biologist is on site during construction to ensure constructed works meet the requirements to achieve fish passage.

- It is recommended that post construction monitoring is undertaken to assess the performance of installed instream structures during extended dry periods and shortly after extreme high flow events.

- The instream structures included in this design have not been designed to sustain peak flows of extreme events, and it is anticipated that periodic monitoring and maintenance will be required to keep them operational.
7.0 CLOSURE

We trust that this information is sufficient for your immediate requirements. Should you have any questions regarding the above, or if you require further information, please do not hesitate to contact our office.

GOLDER ASSOCIATES LTD.

ORIGINAL SIGNED

Jocelyn Ramsey, P.Eng. (BC)
Water Resources Engineer

ORIGINAL SIGNED AND SEALED

Dan R. Walker, Ph.D., P.Eng. (BC, NT/NU)
Associate, Hydrotechnical/Water Resources Engineer

JR/DRW/aw/dp
REFERENCES


Figure 1: West Island Fish Habitat Compensation Works, Northwest Territories, Canada

Key Plan

Location Inset

Key Features:
- West Island Lake (W1)
- West Island Stream (ws1)
- LAC DE GRAS
- West Island

Additional Information:
- Project: Diavik Diamond Mines Inc.
- Site: West Island Fish Habitat Compensation Works, Northwest Territories, Canada
- Scale: 1:50000
- Google

Scale In Metres (Scale 1:50000)
APPENDIX I
Design Drawings (Reduced to Half Size)

Design Drawing No. 16100-41D1-0000 – Title Sheet
Design Drawing No. 16100-41D1-0001 – Overall Site Plan
Design Drawing No. 16100-41D1-0002 – West Island Stream Channel
Design Drawing No. 16100-41D1-0003 – Step Pool Complex Details
Design Drawing No. 16100-41D1-0004 – Riffle Pool Complex Details
MATERIALS AND INSTALLATION SPECIFICATIONS

**DRAWING:**
- **STEP POOL COMPLEXES:** Shall consist of a gradient basin weir and an excavated settling pool.
- **REVIEW:** Shall consist of a gradient basin weir and an excavated settling pool with gabion baskets.

**REVIEW:** All grade, size and location of structures shown on the drawings shall be verified during excavation and construction.

**SHEET:** Where possible, set aside tundra mat from excavation and use to cover disturbed channel banks.

**DRAWN:**
- **DRAWING INDEX:**

<table>
<thead>
<tr>
<th>DWG No.</th>
<th>SHEET TITLE</th>
<th>REVISION</th>
<th>ISSUED FOR</th>
<th>DATE</th>
</tr>
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<td>TITLE SHEET</td>
<td>0</td>
<td>ISSUED FOR CONSTRUCTION</td>
<td>MAY 10, 2012</td>
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<tr>
<td>16100-41D1-0001</td>
<td>OVERALL SITE PLAN</td>
<td>0</td>
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<td>MAY 10, 2012</td>
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<td>16100-41D1-0002</td>
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<td>0</td>
<td>ISSUED FOR CONSTRUCTION</td>
<td>MAY 10, 2012</td>
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<td>16100-41D1-0003</td>
<td>STEP POOL COMPLEX DETAILS</td>
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<td>MAY 10, 2012</td>
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<tr>
<td>16100-41D1-0004</td>
<td>RIFFLE POOL COMPLEX DETAILS</td>
<td>0</td>
<td>ISSUED FOR CONSTRUCTION</td>
<td>MAY 10, 2012</td>
</tr>
</tbody>
</table>

**GABION BASKETS:**
- **BASKET:** Shall be made of galvanized or plastic-coated wire mesh.
- **DIMENSIONS:** Shall be designed to meet the requirements of the project.
- **MATERIALS:** Shall be made of galvanized or plastic-coated wire mesh.
- **INSTALLATION:** Shall be made in accordance with the approved plans and specifications.

**GEOMEMBRANE:**
- **INSTALLATION:** Shall be made in accordance with the approved plans and specifications.
- **MATERIALS:** Shall be made of bituminous or equivalent material.
- **INSTALLATION:** Shall be made in accordance with the approved plans and specifications.

**CRUSHED ROCK:**
- **QUALITY:** Shall be free of any organics, debris, or deleterious substances.
- **INSTALLATION:** Shall be made in accordance with the approved plans and specifications.
- **MATERIALS:** Shall be made of crushed rock.

**REFERENCES:**
- **DATE:**
  - FEBRUARY 25, 2012
  - MARCH 27, 2012
  - APRIL 27, 2012
  - MAY 18, 2012
  - JUNE 12, 2012

**NOTES:**
- **DATE:**
  - May 18, 2012
  - June 12, 2012

**DIMENSIONS:**
- **DATE:**
  - May 10, 2012
  - May 18, 2012
  - June 12, 2012

**SHEET SIZE:**
- **DATE:**
  - May 18, 2012
  - June 12, 2012

**CHECKS:**
- **DATE:**
  - May 10, 2012

**DRAWN BY:**
- **DATE:**
  - Thursday, May 17, 2012 1:19:25 PM

**CHECKED BY:**
- **DATE:**
  - Friday, May 18, 2012 9:56:24 AM

**LAYOUT:**
- **DATE:**
  - N:\Bur-Graphics\Projects\2010\1328\10-1328-0028\Drafting\CAD\Phase 23000 West Island FHC Design\Task 23400\10-1328-0028_23000_23400-00.dwg
EXCAVATED RESTING POOLS (MIN. 0.4m DEEP AND APPROXIMATELY 1.5m - 2m LONG)

GABION BASKET WEIR
2" MINUS CRUSHED ROCK
PLACED AT ANGLE OF REPOSE
KEYED INTO CHANNEL BANKS (MIN. 0.5m)

EXCAVATED CHANNEL POOLS (MIN. 0.4m DEEP AND APPROXIMATELY 1.5m - 2.0m LONG)

B - CHANNEL BED (~1m)
WIDTH VARIES

TOP OF BANK
DISTANCE VARIES

PLAN - STEP POOL COMPLEX

PROFILE - STEP POOL COMPLEX

TOP-OF-DOWNSTREAM GABION SHALL BE MAXIMUM 0.2m BELOW TOP OF UPSTREAM GABION. FIELD FIT AS REQUIRED

BACKFILL WITH NATIVE FINE MATERIAL UP TO EMBEDMENT OF 0.3m, COMPACTED WITH BUCKET

SEE GABION BASKET WEIR DETAIL

EXCAVATED RESTING POOL (MIN. 0.4m DEEP AND APPROXIMATELY 1.5m - 2x LONG)

GABION BASKET WEIR DETAIL

CHANNEL INVERT

0.5m THICK LAYER OF 2" MINUS CRUSHED ROCK

ES2 BITUMINOUS GEOMEMBRANE

SHAPE GABION BASKET DURING INSTALLATION SO THE MIDDLE IS LOWER (ABOUT 0.5m) THAN THE SIDES

FIELD FIT AS REQUIRED

BACKFILL WITH NATIVE FINE MATERIAL UP TO EMBEDMENT OF 0.3m, COMPACTED WITH BUCKET

ES2 BITUMINOUS GEOMEMBRANE

DISTANCE VARIES

0.2m THICK LAYER OF 2" MINUS CRUSHED ROCK

SHAPE GABION BASKET DURING INSTALLATION SO THE MIDDLE IS LOWER (ABOUT 0.5m) THAN THE SIDES

FIELD FIT AS REQUIRED

BACKFILL WITH NATIVE FINE MATERIAL UP TO EMBEDMENT OF 0.3m, COMPACTED WITH BUCKET

ES2 BITUMINOUS GEOMEMBRANE

DISTANCE VARIES

2" MINUS CRUSHED ROCK
PLACED AT ANGLE OF REPOSE

2" MINUS CRUSHED ROCK
PLACED AT ANGLE OF REPOSE
0.5m x 0.7m x 2m GABION BASKET FILLED WITH 8" MINUS CRUSHED ROCK, ALTERNATIVELY USE 0.3m DIAMETER (MIN.) BOULDERS, IF AVAILABLE

MIN. 0.45m EMBEDMENT

1m FLOW DEFLECTOR

0.3m x 0.5m x 1m GABION BASKET

0.2m THICK LAYER OF 2" MINUS CRUSHED ROCK (FILLED UP TO CHANNEL BED)

BACKFILL WITH NATIVE FINE MATERIAL COMPACT WITH BUCKET

FLOW DEFLECTOR 0.3m x 0.5m x 1m GABION BASKET

FLOW DEFLECTOR 0.2m THICK LAYER OF 2" MINUS CRUSHED ROCK (FILLED UP TO CHANNEL BED)

BANK TOE ARMOUR 0.5m x 0.8m x 2m GABION BASKET FILLED WITH 8" MINUS CRUSHED ROCK, EMBEDDED 1.4m AND KEYED INTO THE CHANNEL (BANK), MIN. 0.45m EMBEDMENT AND 0.3m DIAMETER (MIN.) BOULDERS, IF AVAILABLE

0.2m THICK LAYER OF 2" MINUS CRUSHED ROCK (FILLED UP TO CHANNEL BED)

1.5m LONG x 0.2m DEEP x 0.4m WIDE EXCAVATED POOL

TOP OF BANK WIDTH VARIES
APPENDIX II
Stream ws1 Survey (Provided by DDMI)
This sketch is not a design drawing and shall be used for planning purposes only.
At Golder Associates we strive to be the most respected global company providing consulting, design, and construction services in earth, environment, and related areas of energy. Employee owned since our formation in 1960, our focus, unique culture and operating environment offer opportunities and the freedom to excel, which attracts the leading specialists in our fields. Golder professionals take the time to build an understanding of client needs and of the specific environments in which they operate. We continue to expand our technical capabilities and have experienced steady growth with employees who operate from offices located throughout Africa, Asia, Australasia, Europe, North America, and South America.