Manitoba
Floodway Authority

Design of Fishway at the Red River Floodway
Inlet Control Structure
Preliminary Design Report

Final – Rev 01

KGS Group 10-1100-01
September 2014

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September 29, 2014 File No. 10-1100-01

Manitoba Floodway Authority
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Winnipeg, MB
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ATTENTION: Ms. Leanne Shewchuk
Manager Special Projects and Environmental Services

Re: Design of Fishway at the Red River Floodway Inlet Control Structure
Preliminary Design Report
Final – Rev 01, September 2014

Dear Ms. Shewchuk:

KGS Group is pleased to submit to you (1) copy including a CD of the Final – Rev 01, Preliminary Design Report. We have incorporated the requested changes to the report.

We would like to thank Manitoba Floodway Authority for the opportunity to work with you on this project.

Sincerely,

David S. Brown, P. Eng.
Senior Water Resources Engineer

DSB/mlb
Enclosure

EXECUTIVE SUMMARY

The Red River Floodway Inlet Control Structure (ICS) is an integral component of the Red River Floodway. The Red River Floodway flood protection infrastructure consists of four components, namely the Floodway Channel, the Inlet Control Structure, the dykes, and the Outlet Structure. Construction of the Red River Floodway was started in 1962 and completed in 1968.

Since the construction of the Floodway and associated flood protection infrastructure, the ICS gates have been raised in the spring for an average period of 22 days approximately every two of three years and recently in five of the past ten summers.

In 2009, North/South Consultants [Murray and MacDonell 2009] conducted a fish passage study at the ICS under existing operating conditions. The results of this study found that with the current operating rules fish movement was not inhibited during critical life stages. However, fish passage could be affected if the Floodway operating rules were changed so that the ICS were to be continually operated through the open water season

The objective of this study is to investigate design alternatives that could be incorporated to improve fish passage upstream of the ICS without affecting the critical flood protection infrastructure for the City of Winnipeg if the operating rules were to change.

Prior to the 2009 North/South study [Murray and MacDonell 2009], one of the potential compensation measures considered for the Floodway Expansion Project was the development of a fishway that would allow for the fish movement upstream of the ICS when the gates are raised. MFA subsequently contracted KGS Group to develop a preliminary design of a fishway, as documented within this report.

While the current operation does not require a fishway to provide for fish passage at critical periods, this study was to develop a preliminary design and cost estimate for a fishway should one be required as a result of ongoing operation of the floodway during open water season.

Review of Fishway Alternatives

The first stage of the preliminary design included a conceptual review of various fish passage concepts for suitability at the ICS. This concept review was carried out to update the information provided in the 2008 concept report [KGS 2008] and is documented in the "Evaluation of Fishway Alternatives – Draft Design Brief" [KGS 2010] and included a conceptual review of a number of fishway concepts based on a variety of different factors including:

- Applicability to various fish species
- Suitability to the ICS site and Red River
- Operational range
- Risk to integrity to flood protection infrastructure
- Construction, operation, and maintenance costs
- Effects of fishway to the operations of the ICS

Each one of the concepts was reviewed at a Fishway Alternative Review Workshop that was held on April 28, 2010. At this workshop, the project team along with fisheries experts and MFA selected the natural pool and riffle (or step pool) fishway as the preferred concept for fish passage. This option was considered the most reliable of the options considered and also the one to least interfere with the ICS.

The location for a proposed fishway is the east river bank, passing through the East Dyke. The fishway would penetrate through the East Dyke at an elevation higher than the upstream river water levels, and would therefore require a pump system to provide water to the fishway.

Biological Considerations

The biological considerations for fish passage as they relate to the preliminary design of the fishway at the ICS were reviewed as part of this study. The biological considerations were developed by North/South Consultants and are based on their expertise related to fish, fish habitat, and fish passage structures in North America, and specifically the Red River Basin, as well as, information available in the literature. Information documented in the 2009 fish movement study [Murray and MacDonell 2009] provided valuable background information for this study. The biological considerations reviewed as part of this study include:

- fish migration and the need for functional fishways;
- target fish species for the fishway at the ICS;
- motivation of the fish to migrate and use fishways;
- timing of critical fish movement; and
- fish swimming performance data relative to the fishway design criteria

These biological considerations formed the basis for some of the design criteria that were adopted for this project.

Design Criteria

The following general design considerations were identified and factored into the preliminary design of the fishway:

- The fishway would be designed to allow for hydraulic conditions to provide the opportunity for the successful passage of each of the identified target fish species.

- The fishway would be designed for upstream fish passage only. Downstream fish movements are accomplished through the openings in the ICS over the gates.

- The fishway would be designed with consideration for incorporation into the Duff Roblin Park situated to the east of the ICS. As there is a high likelihood of public interaction with the fishway, the design considered public safety concerns.

- The upstream side of the fishway would have a chute that conveys fish from the conduit that passes through the East Dyke to a recovery pool on the east bank of the river upstream of the ICS. The recovery pool would be connected to the river at a location upstream of the ICS so that fish are not immediately swept downstream of the ICS when they return to the river.

- Structural components of the fishway (concrete work, steel framework, etc.) would be designed so that they are structurally stable and have the ability to resist hydraulic and ice loadings.

Two criteria were initially considered for the elevation of the conduit that passes through the east dyke, as follows:

- Fishway designed with the conduit passing through the East Dyke above the 1 in 100 year upstream flood level. Referred to as the 1 in 100 year design in this report.

- Fishway designed with the conduit passing through the East Dyke above the 1 in 700 year upstream flood level. Referred to as the 1 in 700 year design in this report.

At the Failure Modes and Effects Analysis (FMEA) workshop, which focused on a risk based assessment of the fishway and ICS (i.e. dam safety associated with the fishway), it was concluded that the design of the fishway should be designed to be above the 1 in 700 flood level. The report has therefore been written to describe the preliminary design requirement for the 1 in 700 year event. Preliminary design information for the 1 in 100 year event has been provided as information, but is not recommended due to the potential risk factors

Project Description

The proposed fishway (1 in 700 year design) at the ICS consists of a pool and riffle type fishway situated on the downstream embankment slope of the East Dyke and climbs to El. 237.20 m, which is just above the 1 in 700 year headwater level, where it enters a transition structure. The transition structure is connected to a conduit that penetrates through the East Dyke and is connected to a chute that runs down the upstream slope to release the fish in an excavated recovery pool situated on the east bank upstream of the East Dyke. The recovery pool connects to the Red River by means of an excavated channel. The pool and channel are designed with a sloping gradient towards the river to prevent fish stranding when the fishway is not operated and the river levels recede below the invert of the pool.

The general arrangement of the fishway associated with the design above the 1 in 100 year level is generally similar to the one described for the 1 in 700 year design. The pool and riffle type fishway situated on the downstream embankment slope of the East Dyke would climb to approximately El. 234.50 m, which is just above the 1 in 100 year headwater level, where it enters a transition structure.

Since the the top of the fishway would be above the 1 in 700 year headwater level, water will need to be provided to the fishway by means of a pump system. The proposed pumping station will be located on the upstream side of the East Dyke. The water, pumped from the upstream side, would be released into the transition structure. The flow is then split in each direction to provide water to both the fishway channel and the chute. The pumping system for the 1 in 700 year design would need to be designed for the increased head differential.

The fishway consists of a number of different components as listed below.

- Fishway Entrance
- Fishway Channel

- Transition Structure
- Conduit through the Dyke / Chute
- Recovery Pool and Fishway Exit Channel
- Deflector Berm
- Pumping Station
- Electrical Housing Pad
- Pumping Station Access Road

All fishway components associated with the 1 in 700 year design would also be required for a 1 in 100 year design.

Operation and Maintenance of the Fishway

The fishway is designed to be operational only when the ICS is operated and for river water levels ranging from summer operation levels up to the 1 in 20 year flood event. The fishway could be operated during a flood event of a higher magnitude, once the peak of the flood is passed as the upstream water levels recede below the 1 in 20 year flood level. This design does not consider operation under ice-covered conditions since it is unlikely that the Floodway, and consequently the ICS, will be operated under these conditions.

Operating procedures are identified within this report, however, as part of the final design stage, a comprehensive Operation and Maintenance Manual would need to be developed. This Operation and Maintenance Manual would define the roles of various personnel and the activities that would be required for each of the operating and maintenance procedure identified within this report.

Due the complexity of the design of the fishway and the number of mechanical and electrical components, regular and annual maintenance is required to insure efficiency and reliability of the fishway. The report outlines the typical maintenance procedures that would be required.

Estimated Project Costs

The estimated cost for the fishway was based on preliminary quantities and unit rates derived and determined from the design and drawings as outlined this report. The cost for the favoured fishway design that considers an elevation above the 1 in 700 year level was estimated to be $11,010,000. For the design that considers an elevation above the 1 in 100 year level was estimated to be $9,615,000. However as stated previously due to the risk of infrastructure failure, the design based on the 1 in 100 year level is not favoured. Estimated operation and maintenance costs for the fishway were estimated to be approximately $95,000 per year.

Project Schedule

A project schedule was developed for the implementation of the fishway. It was divided in two main phases, (i) Engineering and Environmental Assessment and (ii) Construction, and extends over a total duration of 42 months from the commencement of the detailed design and environmental assessment to the completion of construction and commissioning of the fishway. The construction duration was estimated to be approximately 26 months.

Key Recommendations

These following key recommendations are made based on the work documented in the Preliminary Design Report and include specific items to be addressed in the final design stage if the project were to proceed to the next level of design.

- If the proposed fishway proceeds to final design, then the fishway should be designed to have the conduit pass through the East Dyke above the 1 in 700 flood level.

- The hydraulic conditions associated with the riffles were assessed in the preliminary design phase. Consideration should be given at the final design stage to confirmation of the hydraulic conditions as they relate to the successful passage of the key target species with the use of a physical model.

- Physical modeling of the transition structure with fish in a flume should be considered to supplement the final design to confirm the hydraulic conditions in the transition structure, and the means of introducing the flow into the riffle provides for the successful passage of the key target fish species.

- A comprehensive Operations and Maintenance Manual would be required to define and provides further details on the operating and maintenance procedures for the fishway including responsibilities.

ACKNOWLEDGEMENTS

This report is the product of the combined experience and expertise of KGS Group in association with North/South Consultants Inc. In addition to this project team, Dr. Bob Newbury, a well-known expert in the field of fish passage technologies, and Mr. Duncan Hay, a well-known expert in the fields of hydraulics and fish passage technologies, provided valuable technical input to the study.

STATEMENT OF LIMITATIONS AND CONDITIONS

THIRD PARTY USE OF REPORT

This report has been prepared for the Client to whom this report has been addressed and any use a third party makes of this report, or any reliance on or decisions made based on it, are the responsibility of such third parties. KGS Group accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions undertaken based on this report.

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1.0 INTRODUCTION

1.1 HISTORY

The Red River Floodway Inlet Control Structure (ICS) is an integral component of the Red River Floodway. The Red River Floodway flood protection infrastructure consists of four components, namely the Floodway Channel, the Inlet Control Structure, the dykes, and the Outlet Structure. Construction of the Red River Floodway was started in 1962 and completed in 1968.

The Manitoba Floodway Authority (MFA) is nearing completion of the Floodway Expansion project, which will increase the capacity of the flood protection for the City of Winnipeg to a 1 in 700 year level of protection.

The ICS is situated in the Red River a short distance downstream from the inlet to the Floodway Channel. The structure consists of two concrete abutments and a central pier with two large submersible gates, each 34.3 m (112.5 ft) wide. The gates are normally in the submerged position, however in flood conditions the gates are operated to restrict the flow into the Red River through Winnipeg. The crest of the Floodway channel inlet with an elevation of 228.6 m (750 ft) permits flows to enter the Floodway when the Red River discharge exceeds 850 m^3/s (30,000 cfs). As natural discharge increases above 850 m^3/s (30,000 cfs), there is a division in flow between the Floodway and the River. The purpose of the ICS is to counteract this drawdown and to regulate the division of flow between the Floodway and the River. The gates in the ICS are operated so as to maintain a water surface elevation upstream of the structure at the level that would occur under natural conditions. A more detailed description of the Red River watershed, the ICS, and its operating rules is presented in Section 2.0.

Since the construction of the Floodway and associated flood protection infrastructure, the ICS gates have been raised in the spring for an average period of 22 days approximately every two of three years and recently in five of the past ten summers.

Following summer operation of the ICS in 2004, concerns were raised with regard to the ICS blocking upstream movements of channel catfish. This prompted the MFA to undertake a study to monitor fish movements in relation to the ICS using acoustic telemetry [Murray and

MacDonell 2009]. Acoustic transmitters were implanted in a total of 87 fish including 31 channel catfish, 25 walleye, 24 northern pike and seven sauger. Fish movements were tracked over a three year period.

Results of the acoustic telemetry study suggested that the ICS did not act as a significant barrier to tagged channel catfish (Ictalurus punctatus), northern pike (Esox lucius), walleye (Sander vitreus), and sauger (Sander canadensis). Although congregations of tagged fish were detected below the ICS at various times throughout the study, including when the gates were in operation, these fish appeared to be utilizing the area downstream of the structure as opposed to being prevented from moving upstream. The observed lack of upstream or downstream movements through the ICS soon after the gates were lowered further suggested that fish were not waiting in the vicinity of the structure during operation until suitable conditions for passage occurred. No upstream movements of tagged fish were detected when the ICS gates were in operation and one channel catfish and one walleye moved downstream over the structure during that time. All four species moved through the ICS when it was not in operation, with the majority of movements occurring from late summer to early fall when the ICS is seldom in operation, and the direction of movement being approximately equally split between upstream and downstream.

In 2008, KGS Group and North/South Consultants carried out a conceptual design for a fish passage facility at the ICS [KGS 2008]. The scope of this study included the identification and screening of all potential fish passage concepts for headwater and tailwater levels that range over 20 feet in elevation difference with special consideration to construction, operation, maintenance, and dam safety issues. Conceptual designs were prepared for the preferred alternatives that could facilitate fish passage both when the radial gates are elevated and when they are lowered.

1.2 STUDY OBJECTIVE

The objective of this study is to investigate design alternatives that could be incorporated to improve fish passage upstream of the ICS without affecting the critical flood protection infrastructure for the City of Winnipeg if the operating rules were to change.

In 2009, North/South Consultants [Murray and MacDonell 2009] conducted a fish passage study at the ICS under existing operating conditions. The results of this study found that with the current operating rules fish movement was not inhibited during critical life stages. However, fish passage would be likely be affected if the Floodway operating rules were changed so that the ICS were to be continually operated through the open water season

MFA contracted KGS Group to develop a preliminary design of a fishway that would allow for the fish movement upstream of the ICS when the gates are raised if fish movements were deemed to be required.

Prior to the 2009 North/South study [Murray and MacDonell 2009], one of the potential compensation measures for the Floodway Expansion Project considered the development of a fishway that would allow for the fish movement upstream of the ICS when the gates are raised. MFA subsequently contracted KGS Group to develop a preliminary design of a fishway, as documented within this report.

While the current operation does not require a fishway to provide for fish passage at critical periods, this study was to develop a preliminary design and cost estimate for a fishway should one be required.

1.3 STUDY OVERVIEW

This report documents the preliminary design of the preferred concept for fish passage at the ICS. Due to the complexity of the site at the ICS, the importance of the flood protection infrastructure, and the range of target fish species, the design of the fishway required a number of innovative components.

The first stage of the preliminary design included a conceptual review of various fish passage concepts for suitability at the ICS. This concept review was carried out to update the information provided in the 2008 concept report [KGS 2008] and is documented in the “Evaluation of Fishway Alternatives – Draft Design Brief” [KGS 2010] and included a conceptual review of a number of fishway concepts based on a number of different factors including:

- Applicability to various fish species
- Suitability to the ICS site and Red River
- Operational range
- Risk to integrity to flood protection infrastructure
- Construction, operation, and maintenance costs
- Effects of fishway to the operations of the ICS

Each one of the concepts was reviewed at a Fishway Alternative Review Workshop that was held on April 28, 2010. At this workshop, the project team including fisheries experts and MFA selected the natural pool and riffle (or step pool) fishway as the preferred concept for fish passage based on scientific findings from projects with similar scope and objectives.

The proposed natural fishway would be situated on the east river bank and would pass through the East Dyke. The fishway would penetrate through the East Dyke at an elevation higher than the upstream river water levels, and would therefore require a pump system to provide water to the fishway. The general location of the proposed fishway is shown on Plate 01.

Target fish species and associated fish passage requirements were determined, as well as biological considerations for fish passage were reviewed in order to establish the design criteria for the pool and riffle fishway. These biological considerations are presented herein in Section 3.0.

The design criteria that were adopted for the preliminary design of the fishway were detailed in a document issued July 23, 2010 [KGS 2010]. These design criteria are summarized in Section 4.0 and a description of the design of the fishway is provided in Section 6.0 of this report.

Two elevation datums have been used in the study and in this report that have been commonly adopted by previous planners/designers. They are:

- Canadian Geodetic Vertical Datum, 1928 (1929 adjustment), with Horizontal North American Datum (NAD), 1983, referenced to June 1990.

- James Avenue Pump Station Datum (JAPSD) (gauge zero, El. 0.0 ft, or El. 727.57 ft Canadian Geodetic Vertical Datum). A common reference system that is used by the City of Winnipeg is based on the JAPSD, but represents water levels at other locations in Winnipeg that would be associated with the stated water level at James Avenue. This essentially represents a line parallel to the slope of the river that passes through the stated water level at James Avenue.

Unless elevations are specifically stated as JAPSD, they refer to Canadian Geodetic Vertical Datum (CGVD).

The Metric System of measure has been used throughout this report with the exception of stating elevations in the JAPSD.

2.0 BACKGROUND

2.1 RED RIVER WATERSHED

The Red River drainage basin encompasses an area of approximately 287 500 km^2 (101 500 km^2 of which is in the United States of America), including much of northern Minnesota, northern North Dakota, southeastern Saskatchewan and southern Manitoba (Rosenberg et al. 2005). The main stem of the Red River originates at the confluence of the Bois de Sioux and Otter Tail rivers near the North Dakota/South Dakota border, and flows north for 880 km before draining into the south end of Lake Winnipeg via the Netley-Libau Marsh. A number of urban centres are scattered along its course, including Fergus Falls and Moorhead (Minnesota), Fargo and Grand Forks (North Dakota), and Winnipeg and Selkirk (Manitoba).

Primary tributaries to the Red River include: the Red Lake, Otter Tail and Wild Rice rivers flowing in a westerly direction from Minnesota; the Sheyenne and Pembina rivers flowing in an easterly direction from North Dakota; the Rat and Roseau rivers flowing in a westerly direction; and the Assiniboine River flowing in an easterly direction in Manitoba. There are numerous other smaller tributaries converging with the Red River along its entire length. Approximately 44% of the Red River drainage basin lies upstream of Winnipeg. The Assiniboine River, which converges with the Red River in downtown Winnipeg, accounts for more than half of the total drainage area in the watershed (162 000 km^2) [Rosenberg et al. 2005]. At Lockport, approximately 45% of the flow originates from Manitoba, 46% from the United States and 9% from Saskatchewan [Gurney 1991].

Discharge from the Red River varies considerably from year to year and season to season. Typically, flows on the Red River are the highest during spring and lowest in winter. The mean annual flow of the Red River (including the Assiniboine River) is approximately 200 m^3/s. Historical weekly median flows at Lockport have ranged from 880 m^3/s in April to 53 m^3/s in February. River flows generally decline rapidly through May, June, and July. By August, the historical median river flows are approximately one-tenth those observed in April. From the beginning of August to the end of March, historical weekly median flows on the Red River ranged between 53 m^3/s and 108 m^3/s.

Within the United States portion of the valley, the flows and water levels in the Red River main stem are controlled by eight low head dams [US Army Corps of Engineers 2003] at the following locations:

Location	Distance from Red River Mouth
Wahpeton, North Dakota-Breckenridge, Minnesota	874 km
Christine Dam, near Wolverton, North Dakota	795 km
Hickson Dam, Fargo-Moorhead, North Dakota	772 km
South Dam, Fargo-Moorhead (32nd Avenue), North Dakota	733 km
Midtown Dam, Fargo-Moorhead (4th Street), North Dakota	724 km
North Dam, Fargo-Moorhead (12th/15th Avenue), North Dakota	718 km
Grand Forks, North Dakota-East Grand Forks, Minnesota	430 km
Drayton, North Dakota	331 km

Within Manitoba, flows and water levels are controlled by the St. Andrews Lock and Dam at Lockport (approximately 44 km upstream from the mouth) and during flood events by the ICS on the south side of Winnipeg (approximately 108 km upstream from the mouth).

The St. Andrews Lock and Dam operates to maintain water levels within and downstream of the City of Winnipeg, for recreation during ice-free periods. The normal summer control level for the Red River is El. 223.7 m at James Avenue Pumping Station. Beginning in mid-October, water levels within the city are drawn down at a rate of no more than 15 cm per day, until natural river levels are reached (usually by the beginning of November). This draw down generally results in winter water levels being approximately 2 m lower than summer water levels.

2.2 RED RIVER FLOODWAY INLET CONTROL STRUCTURE

The ICS is situated in the Red River a short distance downstream from the inlet to the Floodway Channel as shown on Plate 01. The structure consists of two concrete abutments and a central pier with two large submersible gates.

The gates of the ICS are normally in the submerged position, with about 2.5 m of water over them in the summer months. The crest of the Floodway Channel inlet is El. 228.6 m, which permits flow to enter the Floodway when the Red River discharge exceeds approximately 800 m^3/s. As the natural stage increases above 800 m^3/s there is a division in flow between the

Floodway and the River. The purpose of the ICS is to counteract this drawdown and to regulate the division in flow between the Floodway and the River. The gates in the ICS are normally operated so as to maintain a water surface elevation upstream of the structure at the level that would have occurred under natural conditions.

Photos 2-1 to 2-3 show typical flow conditions at the ICS during active operation of the gates.

PHOTO 2-1 – INLET CONTROL STRUCTURE DURING 1997 FLOOD (Q = 2200 m^3/S)

PHOTO 2-2 – INLET CONTROL STRUCTURE DURING SUMMER 2005 OPERATION ($Q=1340\ m^3/S$)

PHOTO 2-3 – INLET CONTROL STRUCTURE DURING SPRING 2004 OPERATION ($Q=1470\ m^3/S$)

2.3 OPERATION OF THE FLOODWAY FOR SPRING FLOOD EVENTS

2.3.1 History of Operation for Spring Flood Events

Construction of the Red River Floodway began in 1962 and was completed in 1968. The ICS was used for the first time to divert flows into the Floodway the very next spring and since, has been operated in 29 of 44 years (2 out of every three years) to protect the City of Winnipeg against spring flooding. The average duration of each spring operation is 22 days with the minimum duration being 3 days and the longest duration being 50 days. The majority of the spring operations occur from early to mid-April through to mid-May.

2.3.2 Rules of Operation for Spring Flood Events

The current Floodway Operation Rules (as recommended by the Red River Floodway Operation Review Committee [RRFORC, 1999]) are as follows (paraphrased and condensed from RRFORC, 1999):

Rule 1: The Floodway should be operated so as to maintain "natural" water levels on the Red River at the entrance to the Floodway Channel. This rule would be followed until either the water surface elevation at the James Avenue gauge reaches El. 24.5 ft JAPSD (El. 229.23 m) or the river level anywhere along the Red River within the City of Winnipeg reaches 0.6 m (2 ft) below the Flood Protection Level of El. 27.8 ft JAPSD (El. 230.24 m).

Rule 2: Once the river levels within Winnipeg reach the limits described in Rule 1, the water level in Winnipeg should be held constant while river levels south of the Floodway Inlet Control Structure continue to rise. Furthermore, if forecasts indicate that river levels south of Winnipeg will rise more than 0.6 m (2 ft) above natural, as defined by the state-of-nature rating curve at the Floodway Inlet, emergency raising of the dykes and temporary protection measures on the sewer systems must proceed in accordance with the flood level forecasts within Winnipeg. The water levels in Winnipeg should be permitted to rise as construction proceeds, but not so as to encroach on the freeboard of the dykes or compromise the emergency measures undertaken for protecting the sewer systems. At the same time, the Province should consider the possibility of an emergency increase in the height of the Floodway embankments and the West Dyke. At no time will the water level at the Floodway Channel entrance be allowed to rise to a level that infringes on the allowable freeboard on the Floodway West Embankment and the West Dyke.

Rule 3: For extreme floods, where the water level at the Floodway Channel entrance reaches the maximum level that can be safely retained by the Floodway West Embankment and the West Dyke (i.e. during a flood event greater than the 1 in 700 year event or El. 237.1 m at the Inlet), the river level must not be permitted to exceed that safe level. All additional flows must be passed through Winnipeg.

2.4 OPERATION OF THE FLOODWAY FOR SUMMER FLOOD EVENTS

Prior to 2002, the Floodway was only operated to protect the City of Winnipeg against flooding during the spring freshet. However, during the summer of 2002 the Provincial government approved a one-time deviation from the Floodway operating rules in order to reduce the risk of basement flooding in Winnipeg. Emergency operation of the Red River Floodway was authorized on June 28, 2002 when the Red River levels in Winnipeg were predicted to exceed El. 14 ft JAPSD until July 9, 2002 and to be above El. 12 ft JAPSD until July 14, 2002. This decision was based on the risk of basement flooding due to possible heavy rain over the City.

Since the summer operation in 2002, the Floodway has been operated in the summer in 2004 and 2005 to protect Winnipeg against basement flooding associated with high river levels and forecasted heavy rains. Subsequent to the 2004 summer operation, but prior to the 2005 summer operation, the Provincial Government adopted a new Floodway Operation Rule, termed Rule 4 that outlines emergency operation of the Floodway to reduce sewer flooding in Winnipeg. Key considerations of Rule 4 include the following:

- The rule applies after the spring crest from snowmelt runoff at Winnipeg, whenever high river levels substantially impair the capacity of the City of Winnipeg's combined sewer system. That is, when the river level in Winnipeg is at 14 ft JAPSD or higher.
- Prior to the operation, the Province will outline the forecasted river levels and durations and the risk of intense rain storms as well as the benefits and costs of the emergency operation. The operation will only be carried out if the benefits outweigh the costs.

As part of the summer operation, the Province of Manitoba is considering the potential for summer operation to control water levels within the City of Winnipeg, throughout the summer period to normal summer levels. This would mean that the gates in the ICS would be operated much more frequently during the summer than currently under Rule 4.

2.5 DAM SAFETY ISSUES

The ICS and adjacent dykes form a major part of the flood protection infrastructure for the City of Winnipeg and that when they are in use they act as a dam that holds water back upstream of the City of Winnipeg. Therefore the dam safety of the structure is a major concern and any modifications to this structure would have to ensure that the integrity of the flood protection infrastructure is not threatened.

A dam safety review was carried out on the Floodway infrastructure as part of the Floodway Expansion Preliminary Design [KGS-Acres-UMA 2004]. The Floodway was categorized as a "Very High Hazard" facility based on the substantial property damage predicted should a dam break of the structure occur. The results of the dam safety review showed that the design and condition of the ICS and related water retaining structures is generally in compliance with the Canadian Dam Association Dam Safety Guidelines.

Further to the dam safety assessment carried in 2004, a Failure Modes and Effects Analysis (FMEA) type workshop was carried out to review the potential dam safety issues associated with the preliminary design of the fishway as described in this report. The results of the FMEA workshop are described in Section 5.0.

3.0 BIOLOGICAL CONSIDERATION FOR FISH PASSAGE

The biological considerations for fish passage as they relate to the preliminary design of the fishway at the ICS, are outlined within this section. The biological considerations have been developed by North/South Consultants and are based on their expertise related to fish, fish habitat, and fish passage structures in North America, and specifically the Red River Basin, as well as, the wealth of information available in the list of references presented in Section 11.0. The biological considerations presented in this section outlines:

- The importance of fish migration and the need for functional fishways
- The target fish species for the fishway at the ICS
- The motivation of the fish to migrate and use fishways
- The fish swimming performance data that was used in the development of the fishway design criteria

3.1 FISH MIGRATIONS AND NEED FOR FUNCTIONAL FISHWAYS

Many northern temperate, non-diadromous freshwater fish make extensive migrations within river systems or from lakes into rivers. Sturgeon species, for example, have been known to migrate up to thousands of kilometres at a time. Movement is an important process that allows fish to meet their resource needs in temporally and spatially variable environments, such as to occupy the most suitable habitats for growth and survival. Movements among different habitats may be critical for species yearly life-history cycle. Most of the documented fish migrations are related to reaching and returning from spawning areas. However, there is increasing evidence that riverine species also regularly migrate considerable distances throughout the watershed during times other than at spawning and at different life-history stages. The reason(s) for these movements are not always entirely clear, but are likely related to feeding and growth, seeking refuge from adverse (winter) conditions, displacement compensation or re-colonization, and exploratory behavior and dispersal. Many endogenous and exogenous factors stimulate or otherwise affect fish migrations, and water temperature, river discharge, and photoperiod are prominent exogenous factors.

Dams and other obstacles to movement often severely compromise fish migrations. River barriers with and without fishways have been shown to substantially or indefinitely delay upstream movement of northern pike in Canada, barbel in England, and percid species in Australia. Some of the consequences of such delays include the re-absorption of gametes, as has been documented for several Eurasian species. Similarly, it was found that a delay in goldeye migration below a non-functional fishway in the Peace-Athabasca delta resulted in loss of spawning, in addition to loss of access to productive feeding areas by juveniles and increased predation by northern pike below the weir. In areas where spring runoff is rapid and water temperatures rise quickly, such as the North American prairies, delays at barriers may reduce spawning success due to unsuitable high water temperatures or result in high mortality of late developing fry trapped by rapidly receding water levels. Delays and crowding downstream from dams may also result in increased exposure to communicable diseases and may leave fish more vulnerable to angling. When a barrier completely removes access to upstream areas, gene flow within a population will be interrupted. This may lead to inter-population structuring or genetic divergence and reduced genetic diversity, although the latter effects can vary with fish species and region. Selection of barriers (and non-functional fishways) against part of the migrating population also can have negative effects. For example, size selection against large Alewife females at a pool and weir fishway led to a skewed sex ratio in upstream waters.

River barriers not only inhibit or prevent fish movements, but also result in the fragmentation of aquatic habitat, which has been associated with the local extinction of fish species and severe negative consequences at the ecosystem level.

Indirect evidence for some of the adverse effects of anthropogenic river barriers comes from the recent trend to remove dams and weirs that no longer serve an economic purpose, and to restore river conditions close to their natural state. The subsequent increase in fish abundance and biomass suggests that the barrier reduced the productive capacity of the upper river reaches by impeding colonization.

The above negative consequences of river barriers only partially apply to the situation at the ICS because under the current operation rules the ICS generally does not act as a significant barrier to the upstream movement of tagged, relatively large channel catfish, northern pike, walleye, and sauger. Even if there is a negative effect on younger conspecifics or on other species of the

Red River fish community, the impediment to movements occurs only during those times when the gates of the ICS are raised. A fishway at the ICS would eliminate these temporary impediments to fish passage.

Under a modified operation mode, as described in Section 2.4, that could result in continuous operation of the ICS gates to control water levels within the City of Winnipeg throughout the summer, the impediment could be much more than temporary. Under this type of modified operation, a fishway at the ICS would ensure that fish movements upstream of the ICS would not be impeded for the longer duration of operation.

3.2 TARGET FISH SPECIES

There are reported to be 62 native and non-native fish species in the Red River in Manitoba, the most abundant of these being channel catfish, sauger, goldeye, white sucker, and freshwater drum. Six of the 62 species (carp, goldfish, rainbow smelt, white bass, smallmouth and largemouth bass) are not native to the Red River. These species were introduced in other locations within the drainage basin and have now become established within the watershed.

Lake sturgeon were historically abundant in the Red River, but were essentially extirpated by the early 1900s. There is a concerted effort to reintroduce lake sturgeon to the Red River in the United States where the species has been stocked on an annual basis since 1997. Manitoba Fisheries Branch also has stocked numerous lake sturgeon fry and fingerlings into the Assiniboine River since 1996. The latest stocking of lake sturgeons in the Red River Watershed in Manitoba occurred in Lake Winnipeg in the fall of 2009.

The majority of fish species in the Red River spawn during spring, when discharges are high and water temperatures are rising, however some species spawn during late spring and into early summer, and others during the fall. A number of species are known to use habitat in the Red River main stem for spawning, although specific spawning locations within the main stem are generally unknown. Tributaries are known to provide important spawning habitat for many Red River fish.

The lower Red River supports the most important sport fishery in Manitoba. Freshwater drum, sauger, goldeye, channel catfish, walleye and northern pike are the predominant species in fishery. The channel catfish population in the Red River is recognized as one of the best channel catfish fisheries in North America.

For the purposes of the preliminary design of a fishway at the ICS, five key species (walleye, northern pike, channel catfish, goldeye, and lake sturgeon), have been identified based on their economic, ecological and heritage values. A summary of the characteristics of each of these target species is presented below.

Walleye – Walleye typically spawn in spring, and accomplish upstream movements into riffles and rapids to deposit their eggs over rocky/gravel substrate. They are attracted by ice-free moving water toward the spawning areas. Movements during the remainder of the year seem to be passive and random. One of the principal biological characteristics to be considered in the design of the fishway is that walleyes tend to stay away from light, except during the spawning act. As such, the fishway should be designed to provide enough depth and/or cover to be attractive to these species. In addition, and even if walleye can be classified as good swimmers, they generally avoid swimming up and over barriers.

Northern Pike – Northern pike generally move upstream into flooded areas and small tributaries to spawn in early spring. Moving water is understood to be a cue to access upstream flooded habitat. During the remainder of the year, movements are generally local and random. Since northern pike are considered to be weak swimmers, the velocity criteria for fish passage are often selected to accommodate this species.

Goldeye – Goldeye spawn in late spring and early summer. They are considered to be poor swimmers and are abundant in the Red River and its tributaries.

Channel Catfish – Channel catfish spawn in late spring/early summer throughout the river. Upstream movements are known to occur during summer and fall, but are primarily thought to be foraging movements. These fish are relatively large and consequently, the design of the fishway will account for it.

Lake Sturgeon – Lake Sturgeon is listed as endangered by the Committee On the Status of Endangered Wildlife In Canada (COSEWIC) and is under consideration for listing under the Species At Risk Act (SARA). The species was essentially extirpated from the Red River decades ago principally because of habitat degradation. A healthy sturgeon population still exists in the Winnipeg River system. Recent stocking in Minnesota and Manitoba has established a juvenile population in the Red River. However, since this fish matures at about 16 to 20 years of age, there are no real understanding of where fish might spawn and when movements might occur. The abundance of lake sturgeon in the Red River is limited to anecdotal reports from anglers and incidental catches during other fisheries studies (e.g. study of fish abundance below the ICS during summer operation). Spawning sites that may be adopted in the future are purely speculative, but are likely limited to the tributaries and to rock weirs in the American portion of the Red River which have recently replaced low head dams (e.g. at Grand Forks, Fargo, Wahpeton/Brekenridge). Mature fish are expected in 5 to 10 years. Lake sturgeons are large fish that require deep and large water for passage. Therefore, the fishway will be designed to pass mature-sized fish, which can be over 1.2 m long and don't usually jump over structures.

3.3 FISHWAY USE AND FISH MOTIVATION

Fishway use (i.e., passage) varies according to fishway design, water velocities within the fishways, water temperatures, time of day, fish size, and swimming ability. One component of fish behavior that is difficult to assess, but that is known to affect fishway use, is motivation. The motivation to enter and ascend zones of high-velocity flow such as a fishway may vary not only among species but also among individuals of the same species and even for the same individual depending on the type/purpose of the migration. A fish moving upstream to reproduce may be more motivated to take risks and spend energy in fast currents than a fish moving upstream in search of a more productive feeding area, particularly if (slightly less productive) alternatives are available downstream. The decision whether to expend energy by attempting to ascend a fishway at all, to stage a single or multiple attempts, or to choose alternative spawning sites or feeding areas represent trade-offs that defines a species' life history.

Some empirical data from experiments that allow fish to voluntarily enter flumes that mimic fishway hydraulic conditions, and observational data during fishway monitoring indicate that motivation has some physiological underpinnings and/or that willingness affects fishway passage. For example, Castro-Santos [Castro-Santos 2004] found that the rate of first time entry into an unfamiliar, high-velocity environment (>1.6 m/s) for the first time increased with increasing water temperatures for white sucker (range of means: 11.5-19.3ºC) and walleye (range of means: 10.1-13.4 ºC). However, the maximum distance of ascent within the flume was independent of temperature for these two species, suggesting a thermal optimum for swimming capacity [Castro-Santos 2004]. Higher water temperatures corresponded to later times during the spawning season of these river-caught fish and the author suggested that motivation and swimming capacity may be declining at the end of the spawning season of walleye and white sucker. Peake [Peake 2008] found a relationship between the probability (i.e., willingness) of walleye (15-61 cm length) and white sucker (27-64 cm length) entering a flume (0.35-1.20 m/s current speeds) and water temperature (5-22/23ºC). However, the correlation with temperature and fish length was negative, indicating that that small walleye and white sucker in cold water are better prepared physiologically for strenuous activity than large individuals in warmer water.

There have been several reports indicating that walleye do not enter and pass fishways readily. This lack of fishway use may be at least partially explained by the suggestion that walleye have a general behavioral disinclination to switch from low to high intensity activity. Similarly, observations of large aggregations of northern pike below Denil fishways have been interpreted as a lack of motivation necessary to overcome difficult obstacles. Large numbers (thousands) of post-spawned northern pike were also observed in unsuitable feeding habitat below Denil fishways at the Fairford (Manitoba) and Cowan (Saskatchewan) dams, and no or only relatively few made (unsuccessful) attempts to pass through the fishway [Katopodis 1991]. Clearly, motivation must be considered when assessing the potential for successful fishway passage.

For the fishway at the ICS, the main use is anticipated to occur in early to late spring (April to end of June) coinciding with the spawning seasons of the key fish species. For example, thousands of fish per day have been documented to move past the ICS on late April [TetrES 2004]. In the spring, the motivation of fish to find and ascend the fishway is expected to be highest, and larger numbers of fish may be passing the fishway over short periods of time according to the peak of the spawning migrations of each of the key species. A secondary peak in fishway use is expected to occur in late summer and fall (late August to mid-October) when fish may redistribute from feeding/rearing areas to overwintering areas. However, because at that time the floodway gates will most likely not be operational and river discharge will be relatively low, such that the ICS will not pose a barrier to fish migration and the fishway would not be operational. Under the fall conditions, even if the fishway were operational, most of the migrating fish would likely have no need and will not be motivated to choose the fishway route.

At present, the consequences of no or limited passage of fish through the ICS fishway for individual fish populations and the Red River fish community in general appear to be minor. However, as noted above, if the ICS were used regularly to maintain river levels in Winnipeg throughout the spring and summer, there could be major interruptions to fish movement upstream of the ICS. Although extensive movements of a (limited) number of acoustic-tagged northern pike, walleye, and, particularly, channel catfish have been documented in both directions through the ICS [Murray and McDonell 2009]. These migrations were not concentrated to one or a few locations, which would indicate that a spawning run of a large proportion of the population to an upstream location does not exist. Furthermore, there was evidence that sufficient spawning habitat is present in close proximity of overwintering locations for the northern pike, walleye, and channel catfish. The most severe effects of the ICS reported to date include a delay in the movement of some channel catfish and (less likely) freshwater drum, as well as, in the post-spawning movement of some walleye [Graveline & MacDonell 2005]. Overall, impediment of fish movement upstream of the ICS, even during the most sensitive times, is not expected to noticeably impact the presently abundant populations of most of the key species. This assessment is expected to remain relevant should a naturally reproducing population of lake sturgeon return to the lower Red River. Adult lake sturgeon, if not passed by the fishway, will be able to negotiate river flows through the ICS when not operational. Should passage of this fish be temporarily blocked or delayed by the ICS, lake sturgeon may have alternative spawning sites immediately downstream of the ICS [Lee Murray, NSC, pers. comm.] or at Lister Rapids, approximately three kilometres downstream from the City of Winnipeg.

3.4 FISH SWIMMING PERFORMANCE DATA FOR ESTABLISHING FISHWAY DESIGN CRITERIA

Appendix A contains data on fish swimming performance that were mainly generated in forced swimming tests using some form of the swim speed-fatigue time relationship. Forced swimming tests have been criticized on several grounds, as summarized below, when used uncritically to assess the capacity of fish species to ascend fishways.

- Selective use of cooperative individuals
- Fish are often of hatchery or cultured origin
- Fish are coerced into swimming by external forms of stimulation (e.g., prodding, e-shock, confinement)
- Fish are capable (and often require to do so) of staging multiple attempts; the time fish abandon swimming effort may not be an indication of fatigue (as used in swimming speed – fatigue time models, i.e., critical swimming speed), but an expression of behavioral plasticity, allowing to maintain energy reserves for future attempts
- The test set-up generates a very uniform flow profile, reducing turbulence structure and low-velocity zones (applies to all lab tests)

Furthermore, fishway designs that base maximum allowable current speeds and the location of resting pools on results from the swim speed-fatigue time relationships assume that fish swim at their optimum speed until they fatigue. This rarely is the case under natural conditions and fishway designs should take into account the expected variability around optimal conditions and the cost of such variability in terms of distance of ascent.

Finally, the velocities obtained from forced swimming tests represent current speeds against which a fish is holding position, not making progress. Non-leaping species must swim at least 30% faster than opposing flows to move upstream.

Recent results from experiments that allow fish a choice if and when to enter a raceway indicate that free-swimming fish are more capable of moving against a current than forced swim test indicate. Furthermore, observational evidence indicates that, for example, catfish, suckers and small cyprinids enter and ascend fishways in groups. This suggests that fishway passage in schools may confer fish a hydrodynamic advantage over moving as individuals and/or that such behavioral strategies during fish migrations may reduce the stress of exposure to confined spaces and shallow water in fishways because of the potential for social interactions. Thus, fishway dimensions and layout should consider the space required not just by individuals but also by species that commonly migrate in groups.

Although the above laboratory experiments offering fish a choice if and when to enter a high-velocity environment represent an improvement over forced swimming test, they do not duplicate the range of hydraulic conditions including zones of low flow that exist in most fishways. Also, volitional behavior is not governed exclusively by metabolism and biomechanics, but also reflects a fitness-maximizing response to both endogenous and exogenous cues. The total discharge or chemical signature may be as important in indicating the quality of upstream habitat (and motivate fish to migrate upstream) as flow velocity or temperature. Therefore, the swimming performance data presented in Appendix A, can provide only a crude indication of the hydraulic conditions conducive to successful passage of fishways.

Perhaps a more appropriate approach for the determination of maximum allowable water velocities and other hydrological design criteria of the ICS fishway is to consider empirical measurements of current speeds in fishways that have been shown to pass the key fish species in the Red River as indicated in Appendix A. Unfortunately, this approach also has a major drawback. To our knowledge only one study exists that provides hydraulic characteristics for a fishway that resembles the natural design of the proposed ICS fishway and that has passed any of the key fish species [Aadland 2010]. Thus, most data presented in Appendix A, are for Denil (mainly) and vertical slot fishways, i.e., substantially different designs compared to the ICS pool and riffle fishway. Consequently, the mean or even the range of current speeds obtained from a relatively small set of measurements in the Denil and vertical slot fishways not only provide a rather crude assessment of the true hydraulic conditions in these types of fishways, but also cannot be directly compared with similar means and ranges measured inside a pool and riffle fishway. The changing profile and heterogeneous sediment size structure of the riffles and pools result in highly variable current speeds across profiles along the length of the fishway, and this variability also changes according to fishway discharge. These conditions that provide fish of a large size range with opportunities to move upstream against relatively high cross-sectional flows, do not exist to the same degree inside structural fishways. Furthermore, trying to base estimates of passage success based on mean current speeds in Denil fishways may be obscured by negative behavioral responses of fish to turbulence, entrained air bubbles, and a high-velocity layer of water at the surfaces.

These biological considerations have been considered in the development of the design criteria as documented in Section 4.0.

4.0 DESIGN CRITERIA

4.1 GENERAL CONSIDERATIONS

The following general design considerations were considered in the preliminary design of the fishway:

- The fishway would be designed to allow for hydraulic conditions to provide the opportunity for the successful passage of each of the identified target fish species.
- The fishway would be designed for upstream fish passage only. Downstream fish movements are accomplished through the openings in the ICS over the gates.
- The fishway would be designed with consideration for incorporation into the Duff Roblin Park situated to the east of the ICS. As there is a high likelihood of public interaction with the fishway, the design will consider public safety concerns.
- The upstream side of the fishway would have a chute that conveys fish from the conduit that passes through the East Dyke to a recovery pool on the east bank of the river upstream of the ICS. The recovery pool would be connected to the river at a location upstream of the ICS so that fish are not immediately swept downstream of the ICS when they return to the river.
- Structural components of the fishway (concrete work, steel framework, etc.) would be designed so that they are structurally stable and have the ability to resist all hydraulic and ice loadings.

Two criteria were initially considered for the elevation of the conduit that passes through the east dyke, as follows:

- Fishway designed with the conduit passing through the East Dyke above the 1 in 100 year upstream flood level. Referred to as the 1 in 100 year design in this report.
- Fishway designed with the conduit passing through the East Dyke above the 1 in 700 year upstream flood level. Referred to as the 1 in 700 year design in this report.

At the Failure Modes and Effects Analysis (FMEA) workshop, it was concluded that the design of the fishway should be designed to be above the 1 in 700 flood level. The report has therefore been written to describe the preliminary design requirement for the 1 in 100 year event and the 1 in 700 year event.

4.2 DAM SAFETY CONSIDERATIONS

Since the ICS and associated dykes (East and West Dykes) are critical components of the flood protection infrastructure for the City of Winnipeg, dam safety considerations are an important part of the preliminary design criteria. The following dam safety considerations would be considered in the preliminary design:

- ***Integrity to Flood Protection Infrastructure*** – The components of the fishway would be designed so that the fishway does not reduce the level of flood protection provided to the City of Winnipeg up to levels exceeding the 1 in 700 year flood.

- ***Operation of Flood Protection Infrastructure*** – The components of the fishway would be designed so that they do not interfere or alter the operations of the gates in the ICS in a manner that would either increase the maintenance required to the ICS infrastructure or increase the likelihood of failure of any components of the ICS.

- ***Passage of Fishway Through East Dyke*** – The fishway would need to have a conduit passing through the East Dyke to convey fish to the upstream side of the fishway. This conduit will be situated at an elevation that is not less than the 1 in 100 year water level (El. 234.54 m) on the upstream side of the fishway. The design of the conduit through the dyke will consider all geotechnical requirements necessary to ensure that the seepage would not occur associated with the conduit, as outlined in Section 4.5. Although it was not considered practical to design for levels exceeding the 1 in 700 year flood, temporary procedures should be developed to ensure that the integrity of the flood control system is not compromised should the water levels exceed the 1 in 700 year level.

- ***Erosion Protection*** – Erosion protection of the fishway both upstream and downstream of the Inlet would be a key design component. The upstream side of the Inlet and East Dyke are currently designed to function under extreme conditions of high upstream river levels combined with a severe wind event. The upstream portion of the fishway would be designed in recognition of the erosion protection requirements for the Inlet without compromise for its performance. Similarly, the downstream portion of the fishway would be designed with recognition of the erosion requirements adjacent to the river and along the East Dyke.

- ***Freeboard*** – The fishway would not reduce the level of freeboard that is incorporated into the flood protection infrastructure, namely the East Dyke.

4.3 FISH CONSIDERATIONS

The design criteria associated with fish considerations have been developed by North/South based on their experience and literature on fish passage. The following sub-sections describe the adopted design criteria for the passage of fish in the fishway.

- ***Target Fish Species*** – The target fish species for which the fishway would be designed to provide the opportunity for fish to pass upstream of the ICS include:

  - Channel Catfish
  - Goldeye
  - Lake Sturgeon
  - Northern Pike
  - Walleye

- ***Minimum Pool Length*** – The minimum pool length in the fishway would be 4.0 m between riffles / steps.

- ***Minimum Pool Top Width*** – The minimum pool top width in the fishway would be 3.0 m.

- ***Minimum Pool Depth*** – The minimum pool depth in the centre of the fishway channel would be 1.5 m.

- ***Maximum Gradient (Water Level) Drop between Pools*** – The maximum water level drop between pools in the fishway would be 0.30 m.

- ***Burst Velocities Between Pools*** – The range of burst velocities for which the riffle / steps between pools would be designed is from 1.2 m/s to 2.6 m/s.

- ***Riffle / Step Design*** – Alternate riffle / step designs would be considered to provide velocities and depths over the riffle that will accommodate the range of maximum burst speeds for the target species.

- ***Attraction Flows*** – The fishway entrance will be located in a manner to utilize the high velocity exiting the ICS as the attraction flows. To do this the entrance shall be situated as close to the ICS as practically possible.

- ***Power dissipation in pools*** – The flow in the pool would not exceed a “turbulence” or power dissipation per unit of volume of 100 W/m³, which is calculated from:

$$P = \frac{\rho \cdot g \cdot Q \cdot \Delta h}{LWY_m}$$

Where,

g is gravitation acceleration (m/s)
Q is the fishway flow (m^3/s)
ρ is the water density (kg/m)
Δh is the water surface elevation difference from one pool to the next (m)
L is the pool length (m)
W is the pool width (m)
Y_m is the average depth in pool (m)

A detailed summary of the design criteria for each of the target fish species for which the design criteria defined above has been based is provided in Appendix A. As noted in Table 1 of Appendix A, there is limited information related to fish performance in fishways for many of the target fish species. The design criteria stated above considers the limiting velocities and pool dimensions that would provide potential for the use of the fishway for each of the target fish species.

4.4 OPERATING CONSIDERATIONS

The operation considerations associated with the design criteria define the range of river conditions for which the fishway will be designed to be operable and are listed below. These levels are well below the design water level for the passage of the conduit through the East Dyke (i.e. 1 in 100 year or 1 in 700 year levels).

- ***Fishway Operation*** – The fishway would be designed so that it is operational during both spring and summer floodway operation. As part of the summer operations, the Province of Manitoba is considering the potential for summer operation to control water levels within the City of Winnipeg, throughout the summer period to normal summer levels.

- ***Range of Red River Levels for Fishway Operation*** – Due to the range of upstream and downstream water levels that occur at the ICS as a result of operation, the fishway would be designed to be operational over a wide range of flow and water level conditions.

  The minimum levels for which the fishway would be operational would be associated with the ICS operation for summer water level control. For this operation, the water level upstream and downstream of the ICS would be as follows:

  - The water level on the downstream site of the ICS would be El. 224.90 m (737.9 ft), which corresponds to the minimum controlled water level in the City of Winnipeg.

  - The water level on the upstream side of the ICS would be El. 229.21 m (752.0 ft), which corresponds to the minimum level upstream of the ICS that can effectively convey flow into the Floodway channel.

  The maximum water levels for which the fishway will be operational would be associated with the ICS operation for large spring events. Since fish passage would not be required for all flood events, it has been selected that the limiting flood for which the fishway would be operational would be associated with the 1 in 20 year spring flood. The maximum spring flood for which the fishway would be operational was discussed at the Fishway Alternative Review Workshop. The consensus of the group was that the 1 in 20 year flood event was considered appropriate for the maximum flood event for which fish passage would be operated. For this operation, the water level upstream and downstream of the ICS would be as follows:

- The water level on the downstream side of the ICS would be El. 229.24 m (752.1 ft), which corresponds to the water level downstream of the ICS, in the City of Winnipeg, associated with a 1 in 20 year flood with an average Assiniboine River contribution to the flood.

- The water level on the upstream side of the ICS would be El. 233.24 m (765.2 ft), which corresponds to the natural water level upstream of the ICS for a 1 in 20 year flood.

• ***Water Supply for Fishway*** – The water supply to the fishway would be provided by means of a pump system. The water supply system will consider the following:

  - The water supply would pump river water to the fishway

  - The intake for the pump system would be on the upstream side of the ICS

  - The pump would be an electrical driven pump

  - The pump house would include a backup pump system of equal capacity as the main pump system, to ensure that the fishway does not dry out if the main pump system fails during operation of the fishway

  - The pump intake would include an intake screen that meets DFO guidelines

• ***Isolation of the Fishway Conduit*** – The conduit that passes thought the East Dyke would be designed so that both the upstream and downstream ends can be isolated from the river. The means of isolation on the upstream and downstream side are outlined below.

  - The upstream end of the conduit would have a positive slide gate. The gate would be capable of being closed for winter, maintenance to the fishway, or in times of extreme floods with a recurrence interval greater than the 1 in 100 year level, when the upstream levels are above the fishway exit.

  - The downstream end of the conduit would have stoplog slots with stoplogs and a manual hoist. The stoplogs would be used to as a backup measure to the slide gate on the upstream end of the conduit.

4.5 GEOTECHNICAL CONSIDERATIONS

The geotechnical considerations associated with the design criteria are outlined below:

• ***Slope Stability*** – The overall and local slope stability of all related components (including the East Dyke embankment, Red River bank slope, Floodway entrance channel slope, and the fishway structure) would be designed to satisfy the geotechnical slope stability criteria as noted below. These criteria are consistent with the geotechnical criteria adopted for the Floodway Channel Expansion Project, and consistent with accepted dam safety standards (e.g. CDA Guidelines).

- *End-of-Construction Conditions* – Given the relatively long term for dissipation of excess porewater pressures induced by fill loading on the impervious foundation (assuming a B-bar value of 1.0), the minimum estimated safety factor at the end of construction will be designed to 1.5, consistent with the long term normal groundwater conditions. In addition, the works should not cause any detrimental impacts or reductions to the current stability conditions of the existing structures.

- *Extreme Groundwater Conditions* – Extreme groundwater conditions with prolonged flooding or precipitation events combined with river level drawdown would be determined, with consideration of the embankment and fishway materials. Full saturation of the clay-filled portion of the embankment will be assumed. Groundwater levels within the fishway structure would be dependent on the selected material types. The minimum estimated safety factor under the extreme groundwater conditions would be designed to 1.2. In addition, the works should not decrease the current stability conditions or cause any detrimental impacts to the existing structures. Note that consideration was given to increasing the minimum stability conditions under the extreme conditions. However, this would not be consistent with the design of the existing structures and would require extensive additional works. This was not included in the design.

- *Normal Long Term Conditions* – Normal conditions would occur after full dissipation of any construction-induced porewater pressures within the foundation soils. Representative piezometric levels would be determined from monitoring within the vicinity. The minimum estimated safety factor under the normal groundwater conditions would be designed to 1.5, with no decrease in the stability of the existing structures.

The proposed works associated with the fishway should have no detrimental impacts to the existing structures or reduction in estimated safety factors from current conditions.

- ***Seepage*** – The fishway would be designed to contain seepage flows through the East Dyke embankment. Appropriate measures would be incorporated into the design of conduit passing through the dyke to protect against unacceptable seepage along the conduit (i.e. and impermeable cut-off measures).

- ***Settlement*** – The fishway would be designed to accommodate any potential settlement associated with new fill placement to ensure there is no unacceptable performance of the existing structures or the new fishway. Key design considerations would be to evaluate potential settlements and ensure the structure can accommodate this possible movement without water loss from the pools or seepage through the East Dyke.

5.0 FAILURE MODES AND EFFECTS ANALYSIS

5.1 OBJECTIVE

As part of the design process for the preliminary design of the fishway at the ICS, a Failure Modes and Effects Analysis (FMEA) workshop was held. FMEA is an assessment of potential failure modes in which designers of the various components, as well as, owner representatives, participate in a workshop led by a facilitator who guides the process. This assessment considered the issues associated with the construction and operation of the proposed fishway, as described in Sections 6.0 and 7.0 relative to the risk of a component failure that could affect the safety of the flood protection system. The 1 in 100 year and 1 in 700 year designs are shown on Plates 01 and 02 respectively.

This FMEA focused on the potential effects of the proposed fishway structure and not those associated with the existing infrastructure. It considered only those potential failures modes directly associated with the proposed fishway works.

The objective of the FMEA workshop was to “brainstorm” and discuss potential failure modes, the risk of failure, the magnitude of failure, and the associated effects of that failure.

5.2 CONCLUSIONS OF THE FMEA WORKSHOP

5.2.1 Suggested Design Modifications

During the FMEA workshop a number of design considerations, related to the provision of reduced risk of failure, were discussed and identified for inclusion in the preliminary design. Each of the considerations identified as part of the FMEA was incorporated into the design presented in Section 6.0.

- The downstream end of the conduit through the East Dyke should include a slide gate rather than a manually operated flap gate. The slide gate would isolate the pipe during flood conditions and limit potential risk of an uncontrolled flow through the dyke. The slide gate would be more robust and could be opened and closed with less effort than the previously adopted flap gate.

- The bedding for the conduit through the East Dyke should not include granular materials. Rather, the bedding, and cover, should consist of clay.
- A subsurface wick drain system should be installed prior to construction. This would be accompanied by a monitoring program carried out during construction to ensure that the construction reaches a maximum safety factor that meets the CDA Guidelines at the end of the construction period.
- A geomembrane liner should be incorporated in the fishway channel between the rockfill and the clay to eliminate potential risk of seepage through the rockfill.
- The water supply line, as it passes through the East Dyke, should consist of a double wall pipe to minimize risks of pipe failure.
- The bentonite plugs at each end of the conduit as it passes through the East Dyke should be extended along the entire length of the pipes and constructed to an elevation at least to the mid height of the conduit.

In addition to the above recommendations, the discussions at the FMEA workshop concluded that the conduit through the East Dyke should be situated at an elevation above the 1 in 700 year flood level on the upstream side of the dyke to reduce the risk related to dam safety. This recommendation was tentatively accepted providing that the increase in fishway length does not negatively affect the successful movement of fish through the proposed fishway. This design would result in the invert of the last pool above El. 237.1 m and would increase the maximum head differential across the fishway to 13.2 m. The fishway channel would, as a result, be lengthened to approximately 420 m. The 1 in 700 year design would therefore be 85 m longer than the 1 in 100 year design Both designs are presented in Section 6.0 with the recommended conduit level above the 1 in 700 year flood level.

Unlike structural fishways (e.g. Denil fishways) fishway length per se has not been identified as a limiting factor in the literature on nature-like fishways and their effectiveness for fish passage. While most fishways (particularly of structural design) measure between 10 and 70 m in length, most fishways that emulate nature-like features are longer, reaching lengths up to 1000 m on larger rivers.

Nature-like fishways are known to generally have high passage efficiency even at relatively steep average slopes (e.g., 3.8% for a pool and riffle bypass on a Portuguese lowland River) [Santos et al. 2005]. A study of fishway passage efficiency of a 150 m and 370 m long nature-like bypass located less than a kilometer apart on the Swedish River found that both fishways were similarly effective [Calles and Greenberg 2007]. Furthermore, nature-like fishways usually provide fish not only with a passage route past an obstacle but also with habitat, allowing migrating individuals to remain inside the fishway should conditions for upstream movement be temporarily less suitable, instead of aborting their migration.

The literature indicates that the length of a nature-like fishway is not typically a factor for the successful passage of fish motivated to move upstream. This conclusion would apply to the fishway at the ICS.

The findings in the literature, as described above, concur with the expert opinions of the Project Team members, Dr. Bob Newbury and North/South Consultants in that the increase of channel length and head differential would not compromise fish passage associated with the proposed design.

A comparison of the constructed footprint for pool and riffle fishway with the conduit passing though the East Dyke at an elevation above both the upstream 1 in 100 year flood level and above the 1 in 700 flood level is illustrated on Plate 04.

With the exception of the Plate 03, all drawings have been prepared for the 1 in 100 year design. Differences in the design requirements between the 1 in 100 year and the 1 in 700 year designs are relatively minor and have been noted within the text in Section 6.0.

If the proposed fishway proceeds to final design, then the fishway should be designed to have the conduit pass through the East Dyke above the 1 in 700 flood level.

6.0 PRELIMINARY DESIGN OF FISHWAY

6.1 DESIGN OVERVIEW

6.1.1 General Arrangement

As previously indicated, at the FMEA workshop it was concluded that the fishway should be designed to be above the 1 in 700 year flood level. Both the 1 in 100 year and 1 in 700 year designs are described in this section, for information; however, the 1 in 100 year option is not recommended due to potential risk factors. The proposed fishway (1 in 100 year design) at the ICS consists of a pool and riffle type fishway situated on the downstream embankment slope of the East Dyke and climbs to El. 234.50 m, which is just above the 1 in 100 year headwater level, where it enters a transition structure. The transition structure is connected to a conduit that penetrates through the East Dyke and is connected to a chute that runs down the upstream slope to release the fish in an excavated recovery pool situated on the east bank upstream of the East Dyke. The recovery pool will be connected to the Red River by means of an excavated channel. The pool and channel are designed with a sloping gradient towards the river to prevent fish stranding when the fishway is not operated and the river levels recede below the invert of the pool. The general arrangement of the proposed fishway for the 1 in 100 year design is shown in Plate 02.

The general arrangement of the fishway associated with the design above the 1 in 700 year level is generally similar to the one described for the 1 in 100 year design. The pool and riffle type fishway situated on the downstream embankment slope of the East Dyke would climb to approximately El. 237.20 m, which is just above the 1 in 700 year headwater level, where it enters a transition structure. The general arrangement of the proposed fishway for the 1 in 700 year design is shown in Plate 03.

Since the top of the fishway would be above either the 1 in 100 year or 1 in 700 year headwater level, water will need to be provided to the fishway by means of a pump system. The proposed pumping station will be located on the upstream side of the East Dyke. The water, pumped from the upstream side, would be released into the transition structure. The flow is then split in each direction to provide water to both the fishway channel and the chute. The pumping system for the 1 in 700 year design would need to be designed for the increased head differential.

The fishway consists of a number of different components as listed below. Each of these components is shown on Plates 02 and 03 and described in the following sub-sections.

- Fishway Entrance
- Fishway Channel
- Transition Structure
- Conduit through the Dyke / Chute
- Recovery Pool and Fishway Exit Channel
- Deflector Berm
- Pumping Station
- Electrical Housing Pad
- Pumping Station Access Road

All fishway components associated with the 1 in 700 year design would also be required for the 1 in 100 year design.

6.1.2 Operating Conditions

Due to the range of upstream and downstream water levels that occur at the ICS as a result of its operation, the fishway was designed to be operational over a wide range of flow and water level conditions that accompany both spring and summer Floodway operation as defined in the Design Criteria presented in Section 4.4.

The minimum levels for which the fishway would be operational would be associated with the ICS operation for modified summer operation, as defined in Section 2.4, that would control the water levels to normal summer levels within the City of Winnipeg over the summer. The water levels upstream and downstream of the ICS would be El. 229.21 m and El. 224.90 m respectively. The post-project inundation limits corresponding to the minimum operating levels are shown in Figure 6-1.

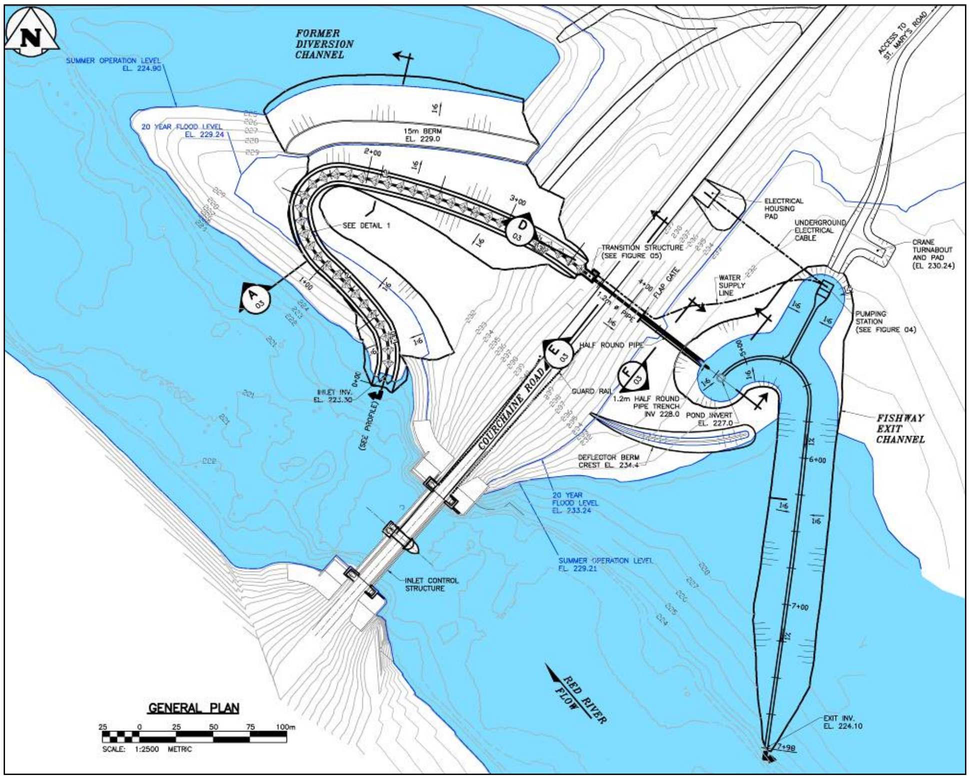


FIGURE 6-1: INUNDATION LIMITS UNDER MINIMUM OPERATING CONDITIONS

The maximum water levels for which the fishway will be operational correspond to the 1 in 20 year flood event. Under these conditions, the water levels upstream and downstream of the ICS would be El. 233.24 m and El. 229.24 m respectively. The post-project inundation limits corresponding to the maximum operating levels are shown in Figure 6-2.

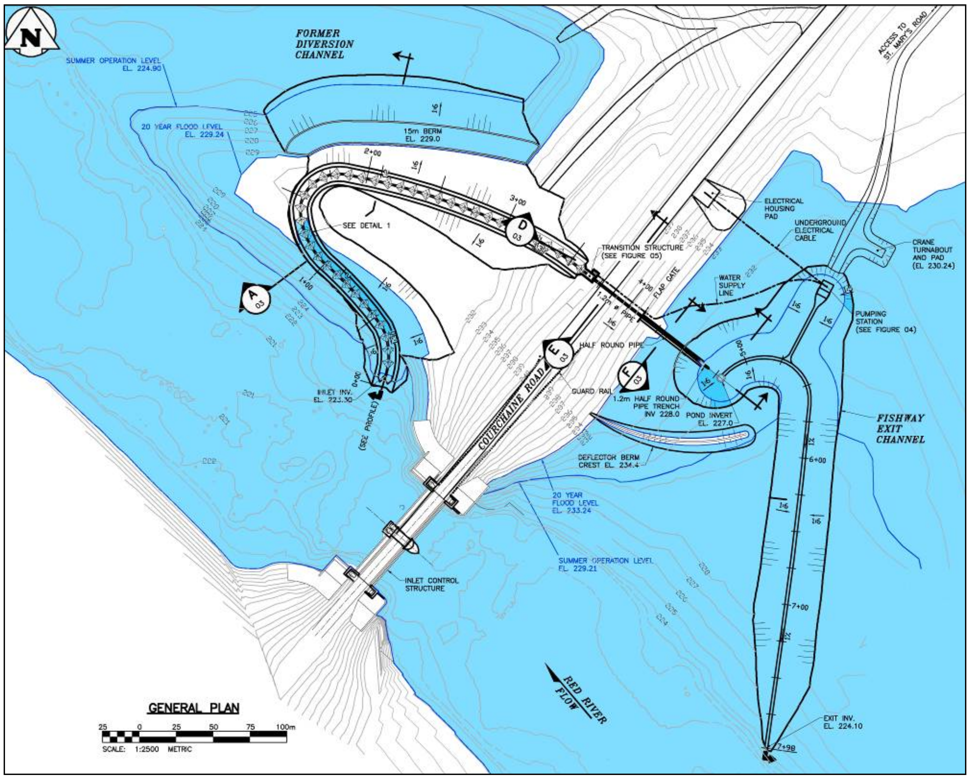


FIGURE 6-2: INUNDATION LIMITS UNDER THE MAXIMUM OPERATING CONDITIONS (1 IN 20 YEAR FLOOD)

The wide range of water levels that can potentially occur during operation of the fishway was incorporated in the design to insure an optimum functioning of the fishway within the defined operation range. Although the design has been based on the maximum operating level of the 1 in 20 year flood event, as this was considered to be a reasonable upper limit for the provision of fish passage at the ICS, the fishway could be operated under floods with a greater magnitude and it would not compromise the integrity of the various components of the fishway nor the flood protection infrastructure. The total flow delivered to the fishway is controlled by the pumping station as described in Section 6.8, so increased headwater levels would not result in increased flow to the fishway.

The operating conditions are identical for the 1 in 700 year design as those for the 1 in 100 year design.

6.1.3 General Geotechnical Considerations

The main geotechnical considerations for the design of the proposed fishway include the following:

- Slope stability conditions of the fill and excavation slopes, as well along the riverbank of the Red River at the inlet and outlets of the channels
- Stability, settlement, and seepage considerations of the fishway chute, including the conduit through the East Dyke embankment
- Erosion protection

Details of the design considerations are provided in the following sections. Slope stability analyses were completed on typical sections of the proposed fishway components to estimate the factor of safety (FS) against instability to ensure that the work will not compromise the stability and performance of the fishway and the flood protection infrastructure. All analyses were performed to determine the requirements to satisfy the geotechnical design criteria identified in Section 4.5 and the dam safety considerations identified in Section 4.2.

The slope stability analyses were completed using the two-dimensional computer model SLOPE/W, developed by GeoSlope International Ltd. of Calgary, Alberta. The model is capable of analyzing numerous iterations of both circular and composite slip surfaces to analytically identify the worst-case potential slip surfaces. Representative groundwater conditions were assumed in the analyses, including excess porewater pressures that could be induced by the fill construction, as well as the impact from any foundation drainage improvement measures (e.g. wick drains) necessary to satisfy the stability requirements of the design criteria.

The same geotechnical considerations would apply to the 1 in 700 year design. However, slope stability analyses were not carried out for the 1 in 700 year design during the preliminary design stage. Detailed stability analyses would be required during final design for both the 1 in 100 year and 1 in 700 year designs.

6.2 FISHWAY ENTRANCE

6.2.1 Description

The entrance of the pool and riffle fishway would be located approximately 50 m downstream of the ICS on the east bank of the Red River. A number of locations for the fishway entrance have been considered during the design; however, the location shown in Plate 05 provided the best position when considering both attraction flows and constructability. The entrance is located far enough downstream from the abutment wall of the ICS so as not to create any adverse concerns related to both the operation of the ICS and the construction of the fishway. The entrance is still considered to be located in the vicinity of the back eddy that exists downstream of the ICS during operation to provide sufficient attraction for fish to enter the structure.

The fishway entrance and the lower reach of the fishway are located within the range of tailwater levels that will be experienced during operation and are situated in a manner to limit the excavation required in or at proximity of the East Dyke. In periods of high tailwater levels, the end of the fishway channel (fishway entrance) will be submerged. However, the lower reach of the fishway has been designed so that fish can enter the fishway, on the riverside of the fishway, over a range of elevations and still have sufficient attraction flows.

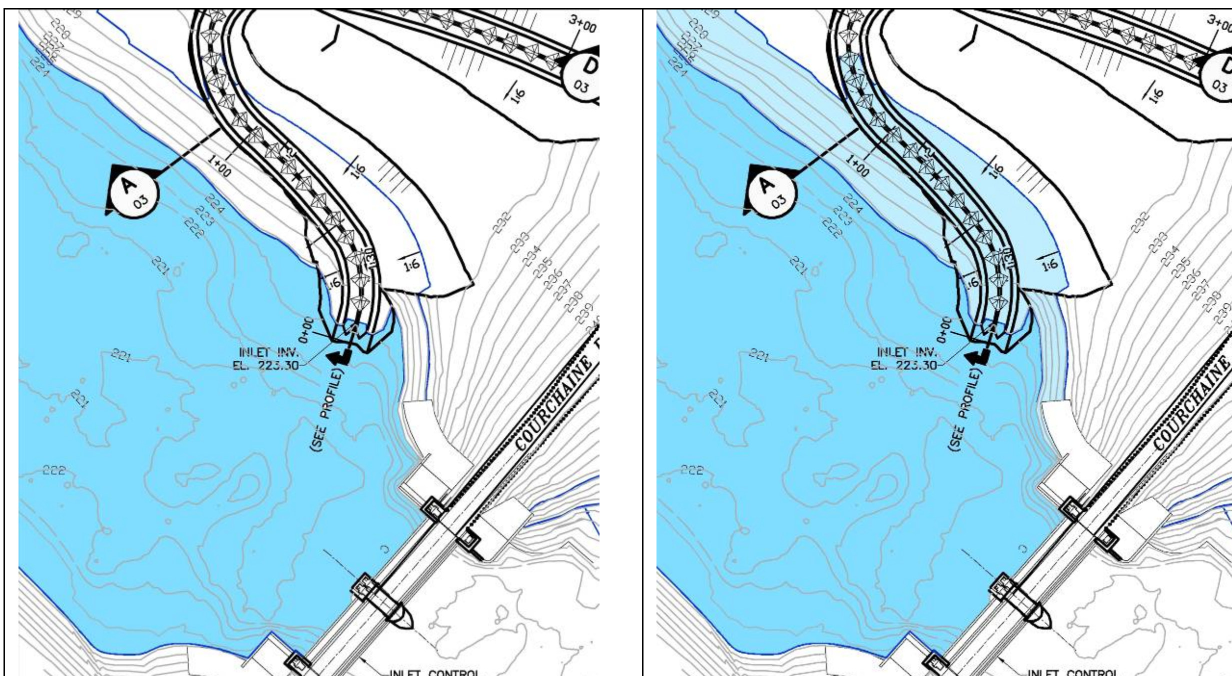
The configuration of the fishway entrance would be the same for the 1 in 100 year and 1 in 700 year designs. The location, hydraulic conditions and geotechnical considerations of the fishway entrance would not change and are independent of the flood protection level adopted for the fishway design.

6.2.2 Hydraulic Conditions at the Fishway Entrance

As noted above, the fishway entrance is located downstream of the ICS on the east embankment approximately 50 m of the abutment wall to benefit from the large back eddy created by the flow across the ICS. The back eddy provides a resting area for fish that are attempting swim into the turbulent, high velocity water flowing over the ICS gates. When the fish cannot swim into and past the raised gates, they will swim into the backwater area to rest. Once in the backwatered area, the flow from the fishway channel will attract them to the fishway.

The fishway is designed to operate for river water levels on the downstream side of the ICS for the range between El. 224.90 m and 229.24 m; a total water level variation of 4.34 m at the fishway entrance.

During summer operating conditions (i.e. at the minimum operating level), attraction flow is provided at the first riffle, as shown in Figure 6-3. As the water level rises with the increasing flow through the ICS, the downstream pools and riffles of the fishway become successively submerged, however, the attractive flow conditions would remain at the first riffle situated above the river level. The fishway has been designed to function in this manner for all flow conditions up to the 1 in 20 year level, also shown in Figure 6-3. Since the fishway channel is not isolated from the river along the riverbank, fish would be able to access the fishway from the side of the channel at any level within the operating range of the fishway.



Minimum Operating Range (El. 224.90 m) | **Maximum Operating Range (El. 229.24 m)**

FIGURE 6-3: WATER LEVEL CONDITIONS AT THE FISHWAY ENTRANCE

6.2.3 Geotechnical Considerations of the Fishway Entrance

Slope Stability

The slope stability was assessed along the bank of the Red River at the inlet to the fishway, downstream of the ICS. The fishway channel will be excavated into the existing riverbank slope, resulting in net offloading and an overall improvement to the stability from the existing conditions. The estimated FS against overall slope failure was increased by approximately 10 to 15% over the existing conditions, and was greater than 1.5 under normal summer river and groundwater conditions, and approximately 1.2 under extreme conditions of full bank saturation, which satisfies the design criteria. Given that the construction consists of net offloading from the existing conditions, there will be no excess porewater pressures (PWP's) induced from the construction, resulting in no decrease to the stability for the end-of-construction case.

Erosion Protection

The existing shoreline in the vicinity of the fishway entrance currently is protected with rockfill riprap. This erosion protection must be re-established once the fishway entrance has been constructed.

6.3 FISHWAY CHANNEL

6.3.1 Description

The fishway channel consists of a series of pools and rock riffles as shown on Plates 05 and 06. The fishway contains 39 riffles, spaced equidistantly over the length of the fishway channel, to overcome the total elevation difference of 11.1 m. Each pool along the fishway is designed to be approximately 9 m long. The fishway channel has a trapezoidal section with a 1.0 m base width, 2H:1V side slopes, and is 2.2 m deep. The associated top width of the channel would be 9.8 m. The fishway channel has a 30H:1V slope along the entire 336 m length. The fishway channel has been designed for a discharge of 0.6 m^3/s. A description of the hydraulic conditions for these flows is presented in Section 6.3.2.

The 1 in 700 year design would require that the invert of the last pool above El. 237.1 m and would increase the maximum head differential across the fishway to 13.2 m. The fishway channel would, as a result, be lengthened to approximately 420 m, which is 85 m longer than that for the 1 in 100 year design, while remaining at a 30H:1V slope. The number of riffles would be increased to approximately 40. The 1 in 700 year design would also require larger volumes of fill and rockfill than that for the 1 in 100 year design.

Typically the design of pool and riffle fishways has considered that fish migrate through a fishway in a burst and sustained swimming mode over each riffle. However, experience has shown that some fish will migrate through the fishway using their burst swimming mode to migrate over a number of riffles and then require a larger more calm velocity resting pool to recuperate. Due to the relatively large size of the pools that have low velocities with the presence of back eddies, resting pools were not considered in the design as the hydraulic conditions in the pools are considered to be adequate for the fish to rest.

The riffles have been designed with a combination of a typical V-shaped riffle shifted to one side with a deeper notch in the centre, as shown in Figure 6-4. This riffle configuration creates adequate hydraulic conditions for passage of both the smaller and larger fish species and is required to provide the range of flow conditions for each of the target fish species. The larger species of fish, including sturgeon and channel catfish, require both a greater depth over riffles and larger width of notch compared to the smaller fish species. However, for the smaller fish species, the hydraulic conditions within the deep notch may be too severe to allow them to pass upstream. The shallower section of the riffles, or more traditional V-shaped riffle, is designed to provide passage for smaller fish. Younger channel catfish would likely use the V-shaped riffles, but adults may also use the notch. Details and typical dimensions of the riffles are shown in Plate 05.

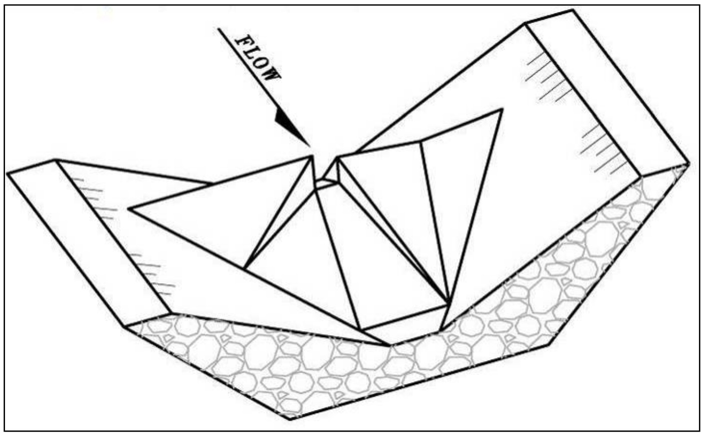


FIGURE 6-4: ISOMETRIC VIEW OF RIFFLE

This design as illustrated in Figure 6-4, is not intended to perfectly represent the final configuration of the riffle with the "neat" line geometry, but rather represent the general proportions of the notch and riffle sizes. The riffles would be constructed to a geometric shape as represented in Figure 5-4 with large size boulders and rockfill. The final design of the riffles structures should consider the natural irregularity of the boulders and rockfill that form the riffles, while maintaining the key dimensions shown on Plate 05.

As an alternate to constructing the riffles from large boulders and rockfill, the defined shape of the deep notch could be constructed with concrete units (e.g. jersey barriers). The concrete units could be placed along the centreline of the riffle to define the deep notch and v-notch. Rockfill could then be placed around the concrete units to make up upstream and downstream slopes of the riffle.

The proposed design of the riffles and the configuration of the pools and riffles in the fishway channel would be the same for the 1 in 700 year design.

6.3.2 Hydraulic Conditions in Fishway Channel

Numerical hydraulic models were developed to represent the fishway channel and were used to assist in the design and optimization of the configuration of the pools and the riffles, and define the hydraulic conditions in the proposed fishway channel.

The one-dimensional model that was used as a design tool was the commonly used HEC-RAS model, developed by the US Army Corps of Engineers (USACE). The one-dimensional model was used to design the fishway channel to meet the design criteria described in Section 4.0.

Due to the complex nature of the proposed riffle structure, the one-dimensional model was not capable of adequately assessing the complex hydraulics associated with the riffle. Therefore, a three-dimensional model was also prepared to assist the design process. The three-dimensional model that was used was a computational fluid dynamics (CFD) model named FLOW-3D. FLOW-3D, developed and supported by Flow Science, Inc. of Santa Fe, New Mexico, USA and is a well-tested, and proven, commercial software used in CFD modeling. Using numerical techniques, FLOW-3D solves the equations of fluids motion (mass, momentum and energy) to obtain transient three-dimensional solutions to multi-scale problems. The three-dimensional model was used to assess the hydraulics of the riffle

Water surface profiles that would occur in fishway channel were estimated with the one-dimensional model and then confirmed with the three-dimensional model. A water surface profile for the design flow condition of 0.6 m^3/s, over a short reach of fishway channel analysis, along the centreline of the fishway (through the deep notch) is shown in Figure 6-5 and along the centreline of the V-notch riffle is shown in Figure 6-6. The design of the riffles was developed to limit the head drop across each riffle to 0.3 m between each of the pools.

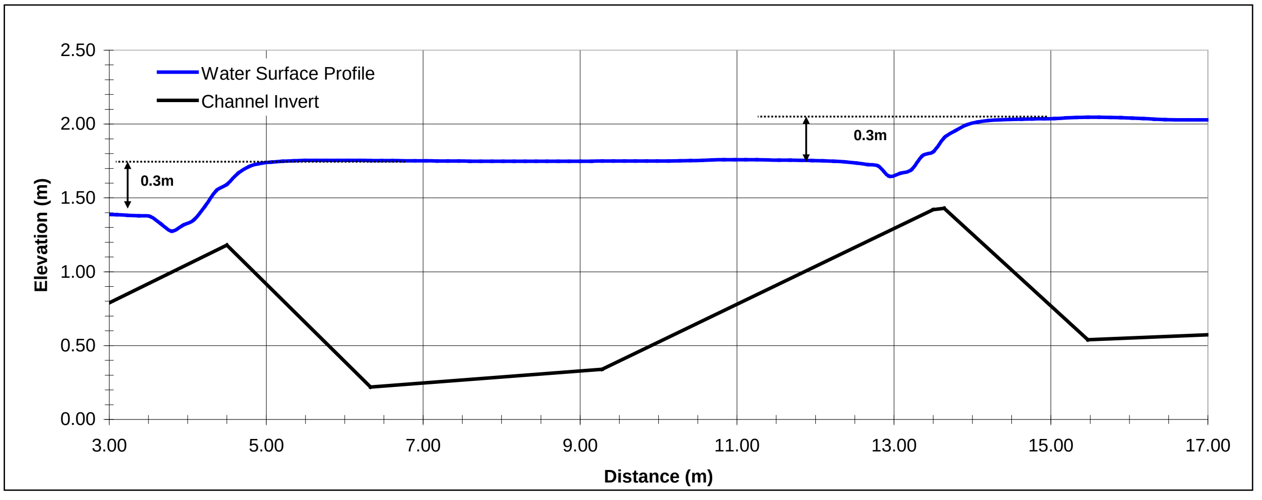


FIGURE 6-5: WATER SURFACE PROFILE AT CENTERLINE OF RIFFLE (ALONG DEEP NOTCH)

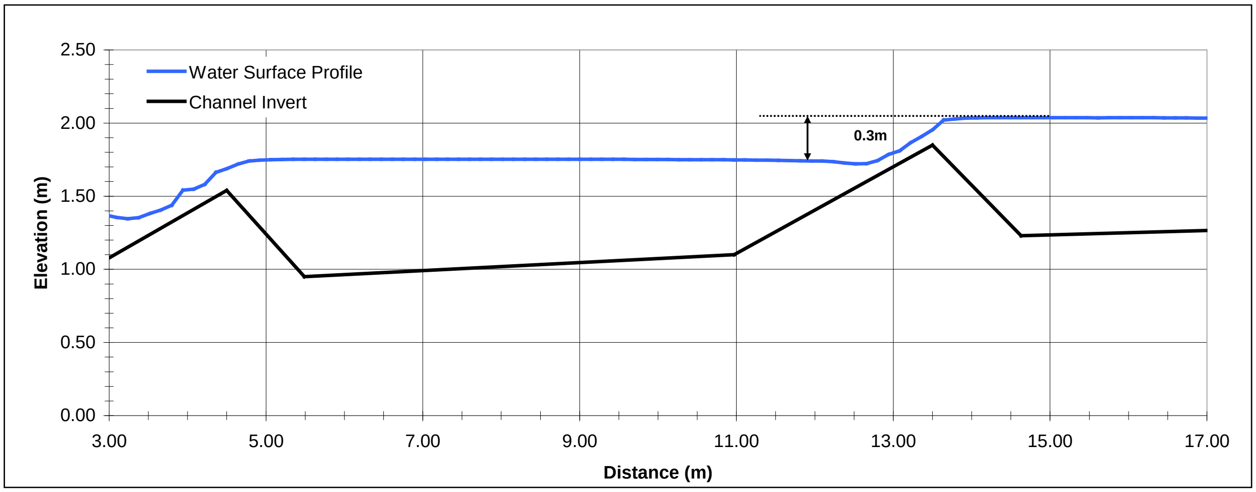


FIGURE 6-6: WATER SURFACE PROFILE AT CENTRELINE OF V-NOTCH RIFFLE

The complex hydraulics associated with the riffles, assessed with the three-dimensional model, are shown in Figure 6-7. Figure 6-7 shows the water depth, depth averaged velocity, and flow direction that would occur over each riffle and within the pool for the design flow of 0.6 m^3/s. The FLOW-3D analysis shows that the water velocities through the deep notch and over the shallower V-notch riffle are within the range required for the successful passage for each of the target fish species. Figure 6-7 also shows the large back eddy that occurs with the pool. This back-eddy defines a zone with low velocities that provide suitable conditions for the fish to rest. Due to the large dimensions of each pool and the presence of such conditions in all of them, resting opportunities are provided in every pool, and therefore dedicated resting pools were not included in the design.

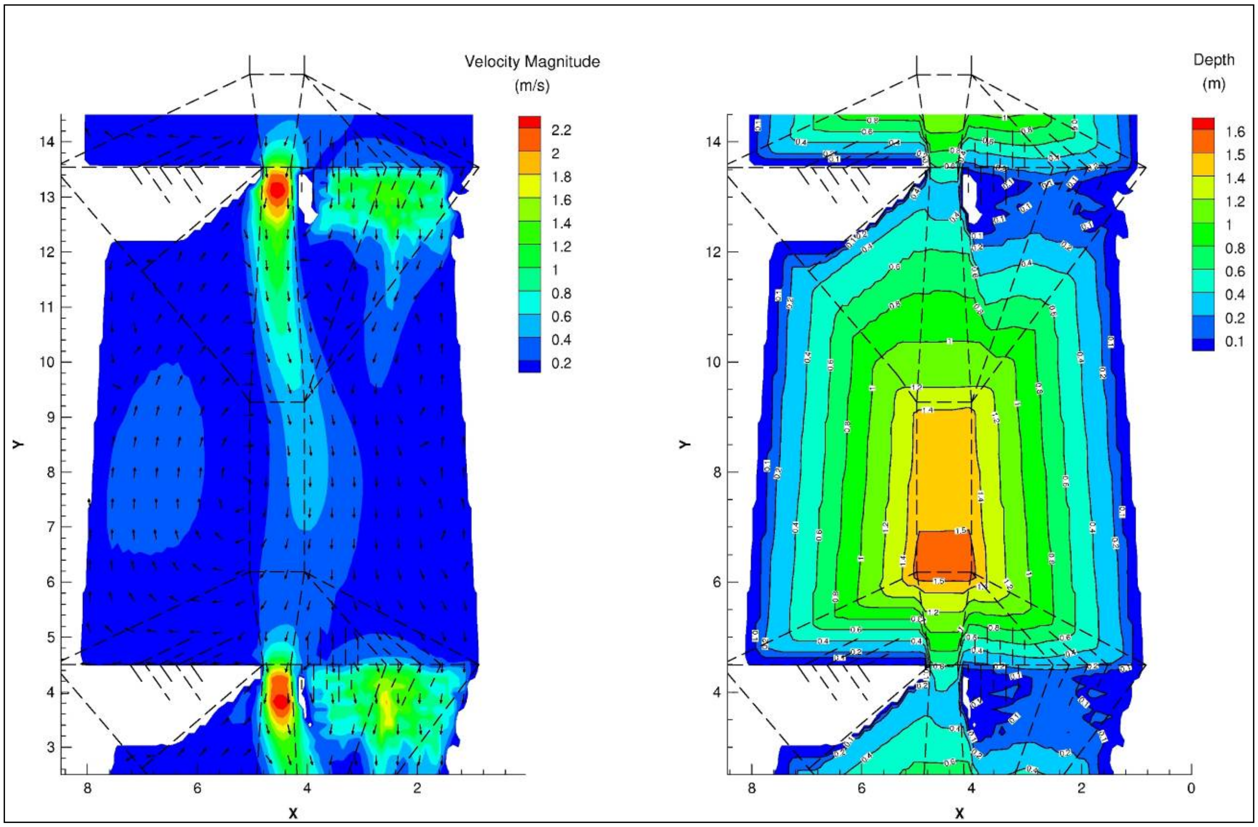


FIGURE 6-7: ESTIMATED HYDRAULIC CONDITIONS ACROSS RIFFLE AND WITHIN POOL

Under the design flow conditions, the depth averaged velocities would range from 0.1 m/s in the pool to 2.5 m/s in the deep notch, where a minimum depth of 0.4 m is maintained. The approximate water depth over the V-notch riffle is 0.15 m with a maximum flow velocity of 1.7 m/s.

A maximum power dissipation in the pool of 100 W/m^3 is required to provide suitable conditions for fish passage, as defined in Section 4.3. This defines the “turbulence” created in the pool due to the dissipation of energy after the water flows over the riffles. Based on the hydraulic assessment, the power dissipation in the pools for the proposed design is estimated to be approximately 45 W/m^3 under the design flow conditions, which is well below the criteria.

The design of channel and riffles has been considered to be functional over a range of flow conditions in the fishway. Although the fishway channel design flow is 0.6 m^3/s, the flow rate delivered to the fishway will be controlled with a pressure-regulating valve. This will allow for design flows to be either increased or reduced should the conditions observed in the pools or over the riffles be unsatisfactory for the successful passage of one or more of the target fish species. If required, actions would be taken by the owner, with input from the designer and fish biologist, to modify the flow conditions in the fishway and tentatively improve fish passage. The design of the water supply system and the control of flow rates are described further in Sections 6.4 and 6.8. Therefore, the pool and riffle fishway was designed to consider operating flows ranging from the design flow of 0.6 m^3/s up to 1.0 m^3/s. The hydraulic conditions that would occur for a flow up to 1.0 m^3/s would not differ too much from those for the design flow condition as shown in Table 6-1.

TABLE 6-1
COMPARISON OF HYDRAULIC CONDITIONS IN FISHWAY FOR FLOWS RANGING FROM 0.6 M^3/S AND 1.0 M^3/S

Hydraulic Parameter	Total Fishway Flow of 0.6 m^3/s	Total Fishway Flow of 1.0 m^3/s
Flow in Fishway (m^3/s)	0.6	1.0
Water Level drop per riffle (m)	0.3	0.3
Minimum Velocity in Pool (m/s)	0.10	0.15
Average Velocity over V-Notch Riffle (m/s)	1.2	1.7
Maximum Water Depth over V-Notch Riffle (m)	0.20	0.25
Average Velocity through Deep Notch (m/s)	1.7	1.8
Water Depth through Deep Notch (m)	0.60	0.70

As the proposed design of the riffles and the general arrangement of the pools and riffles in the fishway channel would be the same for both the 1 in 100 year and 1 in 700 year designs, the hydraulic conditions within the fishway channel would be the same for both designs.

6.3.3 Water Temperature in Fishway Channel

Water temperature is one of the parameters that relate to successful fish passage in fishways, as stated in Section 3.0. A significant difference in the temperature between the main river channel and the water flowing out of the fishway could limit attraction to the fish and reduce the efficiency of the fishway.

Water that is supplied to the fishway is pumped from the upstream side of the East Embankment Dam, which is directly connected to the Red River. Water temperature is not expected to significantly increase with pumping and travel through the water supply line. As a result, water in the fishway would have the same characteristics and temperature than the river water that can be found downstream of the ICS in the vicinity of the fishway entrance and will therefore not reduce the effectiveness of fish movement through the fishway.

Water would be pumped in the Red River upstream of the East Embankment for the 1 in 700 year design as it is for the 1 in 100 year design. Therefore, there will be no change in the water temperature in the fishway channel associated with either the 1 in 100 year or the 1 in 700 year designs.

6.3.4 Geotechnical Considerations of the Fishway Channel

Slope Stability Considerations

The slope stability was assessed for two components of the fishway channel as described below.

- ***The local fill and overall bank stability conditions into the river and the former diversion channel related to the fill placement for the fishway*** – The most critical section for overall stability for the fishway channel is through the embankment fill into the former diversion channel. The proposed embankment geometry includes a 15 m wide and 5 m high toe berm at the base of the slope. Under normal river and groundwater conditions, the estimated FS was 1.6, and under extreme conditions of full saturation, the estimated FS was 1.3. Both satisfy the design criteria. The critical case for the fishway channel is at the end-of-construction, when PWP's induced in the foundation soils from fill placement would act to decrease the overall stability. With B-Bar values of the native clay materials near unity, the FS at the end-of-construction without additional stability improvements were estimated to be below unity (approximately 0.9). In order to meet the design criteria of minimum FS of 1.5 at the end of construction, additional stabilization measures would be necessary. The base-case design assumption includes installation of sand / wick drains combined with staged fill placement to allow dissipation of construction-induced PWP's. The majority (and possibly all) of the embankment fill would be placed during the initial year of construction. The final shaping and construction of the fishway riffles would then be completed during the second construction season, allowing dissipation of PWP's from the fill placement over the fall and winter period. The estimated FS would then be approaching the normal conditions with PWP dissipation, satisfying the design criteria. Installation and monitoring of geotechnical instrumentation (piezometers) would be required to confirm the PWP conditions before completing the fishway structure.

- ***The local stability of internal slopes of the fishway channel*** – The inside slopes of the fishway channel were designed at 2H:1V with rockfill material varying between 1 and 2 m thick. The FS of these internal slopes was estimated to be approximately 1.7 with full saturation of the clay fill and the rockfill material drained. This would be representative of conditions immediately after operation of the fishway. Installation of a geomembrane to reduce seepage / infiltration and minimize saturation of the clay fill would further improve the stability conditions. The 2H:1V slope on the rockfill will also minimize the potential for unraveling and rockfill movement.

Seepage Conditions

Only minor seepage / infiltration is anticipated with the use of high plasticity clay material to construct fishway embankment channel on the north side of the ICS below the rockfill material. To further reduce the potential for infiltration that could cause some decrease to the stability conditions, a geomembrane liner was included in the design. Installation of a geomenbrane liner would result in negligible loss / infiltration of water flowing within the channel during operation of the fishway, and virtually no detrimental impact to the stability of the structure during operation.

Settlement of Embankment Fill

Some settlement of the embankment fill for the fishway on the north side of the ICS is anticipated. The settlement would be from consolidation of both the fill and foundation soils. With the proposed sand / wick drain installation and staged construction, it is anticipated that the majority of the settlement will occur prior to the end of construction and completion of the riffles. This would then result in no detrimental impacts to the performance of the fishway components or the East Dyke.

6.4 TRANSITION STRUCTURE

6.4.1 Description

The transition between the last riffle at the upper end of the fishway and the conduit that passes through the East Dyke is a critical component of the fishway. The transition structure, situated at the top of the fishway, is designed to distribute the required flow from the pumping system into the fishway and the conduit, as well as to provide a structural means of connecting the earthfill fishway channel and the structural conduit and chute. Details of the transition structure are shown in Plate 07.

The transition structure consists of a concrete structure that connects the earthen fishway channel to the conduit that passes through the East Dyke. Water is provided to the transition structure from a water supply pipeline from the pumping station with the flow being regulated with the use of control valves. The inflowing water is introduced to the fishway through two pipes that are controlled with control valves, one pipe provides flow to the fishway channel and the other provides flow to the conduit and chute. The flow is distributed across the fishway through a series of smaller pipes that are constructed into the last riffle of the fishway channel. By introducing the flow within the last riffle a natural flow condition can be reproduced to replicate the flow that passes over the other riffles in the fishway channel. On the downstream side of the last riffle is a slight vertical drop and transition into the conduit. The intention of the design of this last riffle is to essentially "trick" the fish into swimming over the last riffle and into the conduit. The last riffle is designed to restrict the movement of fish backwards once the fish have passed over the last riffle.

The design of the transition structure combines the requirements to provide the adequate discharge into the fishway and those to provide successful fish passage through beyond the last and into the conduit through the dyke. The transition structure has been designed to create hydraulic conditions similar to those that occur in the fishway channel (i.e. depth and velocities). However, due to the complexity of the means of introducing flow to the fishway, further detailed studies should be carried out in the detailed design stage to ensure that the hydraulic conditions would not result in the unsuccessful migration of fish into the conduit.

The unique nature of this structure makes difficult the prediction of fish behaviour in the approach of the last riffle and in the transition from the riffle to the chute. Fish behaviour might also change depending of the species. Physical modeling of the transition structure with fish in a flume would also be recommended to supplement the detailed design phase of this project to confirm the effectiveness of the design presented within this report.

Due to the unique nature of the design of the transition structure, special consideration was taken in the design to develop a system that could split the flow provided by the pumping system to the fishway channel and to the conduit / chute. The design team is not aware of any other structures that operate like the proposed fishway that requires a pump system to provide the water to the fishway. Therefore, the design has based on engineering and biological principles with no other structures to compare designs to. The design of the transition structure and means of splitting the flow in the fishway should be studied in further detail during final design.

The transition structure includes a vertical slide gate attached to the south concrete wall of the transition structure that can be used to isolate the conduit from the transition structure. The gate would be operated by means of a manual screw-stem hoist that is fixed to the top of the wall. This slide gate will be used to close off the conduit over the winter, as well as for closing the conduit during extreme floods greater than the 1 in 100 year level so that water does not flow through the fishway uncontrolled.

As a backup feature to the vertical slide gate, in terms of flood protection, the design includes a set of stoplog guides located in the sidewalls of the structure near the downstream end of the transition structure. The stoplog slots will allow for the installation of stoplogs in case the slide gates malfunction and cannot fully close and seal the pipe opening. The top height of the stoplogs is set to retain the 1 in 700 year flood water level.

The timber stoplogs would be stored on an offsite location and could be brought in for emergency scenarios. A mobile crane similar to the one suitable for removing the pumps from the pumping station would be used to install the stoplogs from a parked position on the existing roadway.

The functionality of the transition structure would be the same for both the 1 in 100 year and 1 in 700 year designs.

Due to the longer fishway associated with the 1 in 700 year design, the concrete transition would be shifted approximately 80 m to the east along Courchaine Road.

As the 1 in 700 year design would consider the infrastructure through the East Dyke at an elevation above the 1 in 700 year water level, the conduit through the East Dyke would, as a result, be situated at an elevation of approximately El. 237.3 m. The concrete base slab of the transition structure would therefore be raised to El. 237.1 m.

6.4.2 Structural Design Considerations of the Transition Structure

The transition structure consists of reinforced concrete soil retaining walls on a structural base slab supported on grade. Its purpose is to house the fishway water supply outlets and control valves, as well as to provide a transition from the earthen pool and riffle fishway to the structural conduit and chute.

The transition structure is situated on the north side of the East Dyke and the walls are designed to retain compacted soil around the exterior perimeter and will sit on a compacted granular base layer. The maximum allowable bearing pressure that the structure can exert on the soil is limited to 100 kPa in accordance with typical geotechnical engineering design practice.

The water supply pipe and control valves for the fishway are housed in a concrete enclosure rigidly attached to the east side of the main transition structure. The enclosure has a structural steel framed roof with checker plate and is accessed through a roof hatch and an interior fixed ladder. The steel roof is designed to support snow loads. The roof can be detached in order to replace pipe sections or valves during future maintenance when required.

A viewing door has been incorporated into the wall of the structure between the fishway and the valve room, which can be opened from inside the valve enclosure. This door allows for the operator to view the changes in the water flows associated with the adjustments to the valves facilitating the valve setting.

As noted above, the 1 in 700 year design would consider the infrastructure through the East Dyke at an elevation just above the 1 in 700 year water level, the conduit through the East Dyke would, as a result, be situated at an elevation of approximately El. 237.3 m. The concrete base slab of the transition structure would therefore be raised to El. 237.1 m. The approximate height of the sidewalls would be reduced to 2.8 m or El. 239.9 m. This would reduce the total volume of concrete required to construct the structure.

Other structural components and general design considerations are anticipated to remain generally unchanged for either the 1 in 100 year or 1 in 700 year designs. Access to the valve room could be provided from the top since the sidewalls would not provide enough height. Stoplogs guides on the sidewalls of the structure would still be required in case of an emergency closure of the conduit through the dyke.

Detailed design of the structural components of the concrete structure should be refined during Final Design.

6.4.3 Mechanical Design Considerations of the Transition Structure

At the transition structure, the water supply piping would consist of stainless steel pipe. Pipe fittings in the transition structure valve room would be coupled using victaulic style couplings. This will simplify installation and disassembly if required, particularly given the small space available.

Two control valves are provided in this valve room. Their purpose is to split the flow into two flow streams. One is directed to the downstream section of the fishway, and the other to the upstream side. Butterfly valves with gear operators would be suitable for this application where they can be used as shut-off valves or as throttling valves.

Upstream of the butterfly values would be a pressure-regulating valve capable of controlling the flow delivered to the fishway over the range of headwater levels. The pressure regulating valve will allow for the rate of flow delivered to the fishway from the pumping station (described in Section 6.8) to be controlled to the design flow. The valve settings could be changed to either increase or reduce the flow to the fishway should the conditions observed in the pools or over the riffles be unsatisfactory for the successful passage of one or more of the target fish species.
Operation of the transition structure is described in Section 7.0.

The proposed mechanical design of the concrete structure will be the same for both the 1 in 100 year and the 1 in 700 year designs.

6.5 CONDUIT / CHUTE THROUGH THE DYKE

6.5.1 Description

The conduit that is connected to the transition structure and passes through the East Dyke under Courchaine Road is 45 m in length with a 1% slope and consists of a smooth wall, coated steel pipe with a diameter of 1.2 m. The downstream end of the conduit (south side of East Dyke) is connected to a concrete headwall with a vertical slide gate. The chute that connects the conduit concrete headwall to the recovery pool consists of half pipe with a diameter of 1.2 m. The chute is also constructed of a smooth wall, coated steel pipe and is set into the upstream slope of the dyke at a 12% slope. Coating of the inside wall of the conduits will prevent corrosion and reduce abrasion which could hurt fish as they are conveyed through the conduit and chute. Details of the conduit, concrete headwall, and chute are shown in Plates 05, 06, and 07.

Since fish have a natural tendency to swim against the flow of water during the migration period, velocities in the chute must exceed the maximum velocity that fish can sustain, to prevent the fish from turning around and swimming back up to the top of the fishway. The flow that was required to create these limiting velocities was equal to 0.4 m^3/s.

The slope and diameter of the conduit through the dyke and of the chute would be the same for both the 1 in 100 year and 1 in 700 year designs. However, as the conduit would be raised to El.237.3 m for the 1 in 700 year design, the conduit would be shortened to a total length of approximately 25 metres. As well, the chute would be lengthened by approximately 15 metres, for a total length of 70 metres for the 1 in 700 year design.

Raising the invert of the conduit above El. 237.1 m, for the 1 in 700 year design, on the upstream side of the East Dyke may require to locally raising Courchaine Road to provide enough cover above the conduit. This should be reviewed during the final design stage.

6.5.2 Hydraulic Conditions in the Conduit and Chute

During the design, the flow depths and velocities within the conduit and chute were estimated for a range of pipe sizes. The configuration described above in Section 6.5.1, provided the design configuration that gave the minimum depth and velocity requirements for the fish while minimizing the total flow discharge from the pumping system.

The hydraulic conditions that would occur in the conduit and chute for the design flow conditions of 0.4 m^3/s are summarized in Table 6-2.

TABLE 6-2
HYDRAULIC CONDITIONS IN FISHWAY CONDUIT AND CHUTE FOR DESIGN FLOW OF 0.4 M^3/S

Hydraulic Parameter	Conduit through East Dyke	Chute
Slope	1%	10%
Water Depth	0.40	0.20
Maximum Velocity (m/s)	1.45	3.30

The velocity ranges noted in Table 6-2, combined with the uniformity of the flow in the chute will force the fish to “slide” down into the recovery pool and prevent them from moving back into the fishway.

The design flow through the conduit and chute would be the same for both the 1 in 100 year and 1 in 700 year designs.

As the slope and diameter of the conduit through the dyke and of the chute will be for both the 1 in 100 year and 1 in 700 year designs, the hydraulics of the conduit and chute would be the same.

6.5.3 Geotechnical Considerations for the Conduit through Dyke

One of the critical design components is to protect against seepage through the existing East Dyke where the fishway conduit would be located. In order to minimize the risk of seepage and potentially compromise the dyke protection, the following measures have been proposed:

- Backfill material around the conduits will consist of a mixture of granular and bentonite clay fill. The granular portion of the backfill will provide good support for the conduits and overlying road. The bentonite clay will fill the void spaces of the granular and will swell when exposed to water. This will serve as low permeability seal and minimize the potential for seepage and internal erosion along the length of the pipe.
- Under the base case conditions, the invert of the conduit through the East Dyke was located at approximately the 1 in 100 year flood level. Under higher flood events or during wind setup/wave run-up, a differential head would be applied over the length of the conduit. The bentonite and granular bentonite will help to protect against seepage and internal erosion / piping along the outside edge of the pipe.

Seepage for the 1 in 700 year design will not be a concern, as the conduit would be situated above the 1 in 700 year water level. Therefore, seepage risks along the conduit would be reduced. However, since seepage could be a concern if the upstream level rose above the 1 in 700 year design level or due to wind and wave effects at the 700 year level, the seepage control measures incorporated for the 1 in 100 year design should be considered for the 1 in 700 year design.

6.5.4 Geotechnical Considerations for the Chute

Slope Stability Considerations

Slope stability analyses were completed to assess the overall stability of the south slope of the East Dyke with fill placement for the fishway chute and the recovery pool excavation.

A minor amount of fill is necessary at the base of the existing East Dyke slope to support the lower portion of the fish discharge conduit. The excavation slope of the recovery pool downslope immediately from the dyke was set at 12% (8.3H:1V) and was offset from the toe of the existing slope by approximately 10 m. The minor fill combined with the offset excavation results in negligible change to the overall stability of the existing East Dyke, with the estimated

FS greater than 1.5 for the normal conditions and greater than 1.2 for extreme groundwater conditions.

Seepage Conditions

Negligible seepage / infiltration of water into the fishway exit channel and foundation soils during operation is anticipated, resulting in no detrimental impacts to the stability conditions.

6.6 RECOVERY POOL AND FISHWAY EXIT CHANNEL

6.6.1 Description

The recovery pool is situated on the upstream side of the ICS approximately 25 m south of the toe of the East Dyke. The recovery pool is connected to the Red River via a fishway exit channel. A deflector berm is located between the recovery pool and the Red River at the ICS approximately 20 m west of the recovery pool to isolate the area where fish are released from the fishway and the main river channel. A more detailed description of the deflector berm is provided in Section 6.7.

The exit channel is excavated around the deflector berm and connects to the Red River approximately 250 m upstream of the ICS and has a constant slope of 1% towards the Red River to facilitate natural drainage of the recovery pool and exit channel when the Red River water levels recede. The exit channel connects to the Red River far enough upstream of the ICS so that the fish returning to the river channel are outside of the range of high velocities at the inlet of the ICS that could cause the fish to be swept downstream through the ICS. Details of the recovery pool and fishway exit channel are shown on Plates 05 and 06.

The configuration (i.e. dimensions and invert elevations) of the recovery pool and exit channel will generally be the same for both the 1 in 100 year and the 1 in 700 year designs.

For the 1 in 700 year design, the recovery pool would be placed in line with the penetration through the dyke and therefore would be located approximately 250 m east of the ICS along the

East Dyke 25 metres from its toe (Plate 03). The location where the channel connects to the Red River would be in the same location for both the 1 in 100 year and 1 in 700 year designs.

6.6.2 Hydraulic Conditions in the Recovery Pool and Fishway Exit Channel

The invert of the recovery pool is set at El. 227.0 m to provide a minimum depth of 2.0 m under the minimum operating conditions. The top width of the flooded area in the exit channel would be approximately 5 m under the minimum operating conditions and the velocities in the release pool and the exit channel will be near zero.

Under the maximum fishway operating conditions (1 in 20 year flood), the entire area upstream of the ICS would be submerged, as shown in Figure 6-2, which would provide up over 6.0 m of depth in the exit channel.

The water that would be drawn by the pumping station would be greater than the flow that is returned to the river from the chute. This results in water flowing from the river into the exit channel towards the pumping station. Flow being conveyed from the river to the pumping station will promote fish migration back to the river against the flow, and will also ensure a continuous turnover of the water in the area.

As the configuration (i.e. dimensions and invert elevations) of the recovery pool and exit channel will generally remain the same for both the 1 in 100 year and 1 in 700 year designs, the hydraulic conditions in the pool and channel would be the same.

6.6.3 Geotechnical Considerations for the Recovery Pool and Fishway Exit Channel

Slope Stability Considerations

Slope stability analyses were completed to assess the overall stability of the internal slopes of fishway exit channel.

The interior slope of the fishway exit channel were designed at 6H:1V, with a maximum slope height of approximately 5 m. This slope is consistent with the typical excavation slopes for the entire Floodway Channel (although the channel slopes are typically 8 to 190 m high), which have performed very well since the original construction in the 1960s. This geometry essentially satisfies the design criteria for stability conditions.

Erosion Protection

Rockfill riprap has been included within the fishway exit channel to protect against erosion. Key areas that require protection include at the discharge of the conduit, around the pump station intake, and where the channel discharges into the Red River. In addition, riprap protection must be reinstated on the south slope of the East Dyke along the location of the conduit and chute.

As the configuration (i.e. dimensions and invert elevations) of the recovery pool and exit channel will generally be the same for both the 1 in 100 year and 1 in 700 year designs, slope stability and erosion considerations would remain the same for each design.

6.7 DEFLECTOR BERM

6.7.1 Description

A deflector berm will be located on the south embankment slope of the East Dyke, between the main river channel and the recovery pool of the fishway, as shown on Plates 02 and 03. This 110 m long berm (1 in 100 year design) defines a physical barrier between the outlet of the chute and the main flow path in the river during operation of the fishway. This would form an area of still water at the end of the fishway chute where fish can recover before swimming back to the Red River, which minimizes the risk for the fish to be immediately carried downstream of the ICS by relatively high river velocities.

The location of the deflector berm was defined based on a minimum distance from the Red River channel to eliminate risks of reduction of capacity of the ICS structure or a general impact on ice formation/break-up on the river in the vicinity of the ICS.

The crest elevation was set to El. 234.4 m, which corresponds to the maximum fishway operating level of El. 233.24 m plus a freeboard allowance of approximately 1.2 m. Due to the well-known potential risk for erosion by wave action on the upstream embankment slope of the East Dyke, the defector berm will require appropriate permanent erosion protection measures. It is proposed to construct the deflector berm with rockfill.

The general characteristics and dimension of the deflector berm associated with the 1 in 700 year design would the same as that for the 1 in 100 year design. The berm for the 1 in 700 year design, would however, be located further east along the East Dyke approximately 210 metres from the ICS as shown on Plate 03.

6.8 PUMPING STATION

6.8.1 Description

The pumping station was designed according to the range of operation levels that the fishway will be operated. It is located on the upstream side of the East Dyke, approximately 75 m south of the toe of the embankment slope (1 in 100 year design), as shown on Plate 05. The pumping station will pump water from the Red River to the transition structure. The pumping station has been situated on the south side of the East Dyke to reduce the total head that the pump would have to overcome, as well as reduce potential negative visual and sound effects for the future Duff Roblin Park.

This pumping station consists of a screened water intake, a structure housing the pumps and two pumps to allow for a 100% redundancy, as well as other mechanical and structural components. A permanent road provides access to the station under non-flooding conditions from St Mary’s Road for operation and maintenance.

The elevation of the pumping station is set to satisfy the submergence criteria for the pumps as soon as the water starts spilling into the floodway. An excavated channel conveys flows to the water intake when water levels rise above El. 226.30 m. When the river water levels are below the minimum operating level of the fishway, the pumping station will stay dry and will not be operated. The details of the pumping station are shown on Plate 08.

The configuration of the pumping station would be the same for both the 1 in 100 year and the 1 in 700 year designs; however, the station would be situated approximately 350 metres east of the ICS for the 1 in 700 year design.

6.8.2 Design of the Pumping System

The pumping system for the fishway will need to deliver a total design flow of 1.0 m^3/s (0.6 m^3/s to the fishway and 0.4 m^3/s to the chute) to the fishway. The pump selection has been based on providing the design flow over a range of upstream water levels that vary from El. 229.21 m to El. 233.24 m. As the headwater level varies within this range, the pump will tend to increase and decrease its output flow. However, as described in Section 6.4, the flow delivered to the fishway will be controlled with the use of a pressure-regulating valve at the transition structure.

To allow for future adaptive management to the fishway, as described in Section 6.4, the pump station design considered a range of flow conditions from the design discharge of 1.0 m^3/s to a maximum flow of 1.4 m^3/s.

During the design process, various pump arrangements were considered. These considerations included:

- ***Mounting the pumps in a building above the upstream water level –*** This configuration would require the pumps be primed before startup. Drawing sufficient water from the river up to the pumps would require a vacuum pumping system. The pumps would then operate under a negative pressure, as the pump inlet water level would be lower than the pump itself. This option was not adopted, as this is generally not a desirable design condition, particularly for pumps of this size. As well, providing a pump house for this arrangement would require a significant sized building.

- ***Installing pumps in a dry well in the river*** – This configuration would include the pumps being located below the operating water level. This option was not adopted, as this would be a costly arrangement.

- ***Installation of submersible pumps in an inlet structure in the river*** – This configuration would require the pumps to be submerged below the minimum operating water level. The actual depth of the pumping station would be determined by the submergence required by the pump, which requires a minimum depth of submergence to ensure it will not draw air under normal operating conditions. This configuration was adopted for the design of the pumping station, as shown on Plate 08, as it provided the most flexible alternative at a reasonable cost.

In reviewing various submersible pumps proposed by pump suppliers it was determined that there are a number of pumps available that can operate within the water level variations and maintain their output flow between the required design flow of 1.0 m^3/s and the maximum flow of 1.4 m^3/s.

The pump station was designed to have 100 percent redundancy for pumps, to limit failure of the system during utilization of the fishway by fish and insure a constant supply of water. Therefore, the design was developed to include two pumps in the pumping station, each capable of providing the total design flow independent of the second pump. Providing two pumps each at 50% capacity was considered but rejected as the fishway will not work with only half the design flow available in case of a failure of one of the pumps.

In order for only one pump to work at a time, check valves must be installed on the discharge pipe of each pump. When one pump is running the check valve for the other pump must be closed to prevent water from re-circulating within the inlet structure and not being pumped to the top of the fishway. Separate pump isolation shut-off valves, as commonly provided in water or wastewater pumping stations, have not been provided to allow the pump to be isolated for maintenance or for check valve repair work. Given the fact that one pump is on standby while one will be running and also considering the long off-season when maintenance can be more easily addressed, it was felt they were not required. Note that even without a shut-off valve, the check valve still permits the second pump to be removed while the other pump is operating. However if the check valve requires maintenance, this work would have to be done when the station is not in operation. The need for access to the check valves should be very low.

When a pump is removed for any reason, it would be lifted out of the pumping station using a mobile crane through the access hatch in the roof of the pumping station. The pump would travel on guide rails to the access hatch above. When the pump is reinstalled it would ride down the guide rails provided and latch into position against a special fitting that connects the pump with the piping system. This arrangement is commonly used in wastewater or stormwater pumping stations.

The piping system inside the pumping station would consist of schedule 10 stainless steel pipe instead of standard steel. This eliminates the need for painting and the related long-term maintenance issues. The piping in the pumping station would include a 100 mm drain valve to permit the water in the pipeline to be drained at the end of the operating season.

The electrical controls for the pumping station will be housed in a separate building constructed on the electrical housing pad. A detailed description of the electrical components of the fishway is provided in Section 6.9.

The design discharge of the pump would be the same for both the 1 in 100 year design and the 1 in 700 year design (1.0 m^3/s), however the maximum head that the pump would have to deliver for the 1 in 700 year design would be increased to approximately 9.5 m.

6.8.3 Structural Design of the Pumping Station

The enclosure for the pumping station is sized to house two large pumps along with all appurtenances. The enclosure is comprised of a reinforced concrete raft-type structural slab-on-grade and surrounding perimeter walls. The roof consists of structural steel framing covered by steel checkered plating and has a gradual 2% slope to promote surface drainage.

The top-of-floor elevation of the raft slab is set at an elevation such that the minimum required submergence depth for the pumps is achieved under the specified minimum operating water level of El. 229.21 m.

The earth fill around the foundation perimeter is set at a depth of 2.4 m and the buried exterior wall surfaces and underside of base slab will be insulated with 100 mm thick rigid Styrofoam insulation. This is intended to prevent frost penetration to the foundation soil under a dewatered winter condition (prevent frost heaving).

The walls and structural steel roof will be designed to resist differential hydrostatic pressures between the interior and exterior of the pumping station during operation. The structure will be designed conservatively assuming that the minimum operating water level (for pump submergence) exists inside the pumping station during the maximum exterior operating level (1 in 20 year flood level of El. 233.24 m). This results in a maximum differential downward water load on the roof equal to 3 m of water. The walls will also be designed for the equivalent differential. At higher exterior water levels, the pumps will be shut-down and the water pressures will balance. Snow load is expected on the roof of the enclosure during winter, however, the water load on the roof during operation will exceed the snow load and therefore govern the design.

The maximum allowable bearing pressure that the structure can exert on the soil having a compacted granular base is 100 kPa (2000 pounds per square foot) in accordance with typical geotechnical engineering design practice in order to limit potential settlement.

The pumping station is situated alongside a crane pad at a maximum specified distance to suit a common mobile crane's capacity to remove a pump through the roof of the structure. Steel-framed removable hatch covers are provided directly above each pump to permit pump removal by the crane. The hatch covers will be fitted with rigging accessories so that the crane can handle them. Another roof hatch will be provided for access to the structure's interior by way of caged ladder.

The pumping station must be fully dewatered during the winter. This will prevent potential for internal horizontal pressures on the walls due to significant ice formation. A sump pit with cover will be provided in the floor for draining the structure in preparation for winter. Water in the sump pit would be drained from the pumping station using a small portable sump pump installed in the sump pit.

A water intake opening (3.4 m wide by 1.8 m high) will be provided in the centre of the concrete wall adjacent to the water intake structure. A ladder will be provided to access the intake structure through this opening.

The intake structure will be founded on a concrete structural slab resting on concrete perimeter walls and a strip footing. This foundation will be rigidly attached to the pump enclosure to prevent differential movement and ensure a long term proper seal between the intake screen and the pump enclosure.

Four locator poles will be fixed to each corner of the pumping station. The purpose of the poles will be to provide an indication as to the location of the operating station when submerged up to the maximum operating level of El. 233.24 m (1:20 year flood). The poles will be rigidly anchored to the concrete structure.

Operation and annual commissioning and decommissioning procedures of the pumping station are described in Section 7.0.

6.8.4 Pumping Station Intake Screen

The Department of Fisheries and Oceans (DFO) Guidelines were followed for the design of the fish screen at the pump intake. The requirement for fish screening has stated in Section 30 of the Fisheries Act, requires that every water intake constructed for conducting water from any Canadian fisheries waters must provide for a fish guard or a screen over the intake so as to prevent the passage of fish into such water intake [DFO 1995].

The fish screen design criteria are based on the approach velocity that should not exceed certain values based on the swimming mode of the fish present in the watercourse. In the Red River, the fish species governing the sizing of the fish screen is northern pike, which is considered to be close to the anguilliform group. Consequently, approach velocities of 0.038 m/s will be satisfied at the intake.

The intake fish screen will be attached to a cage of protective structural steel bars spaced approximately 200 mm on center to prevent debris and trash from damaging the screens. The trash bars will be connected to a framework of structural steel beams and columns attached to the concrete foundation. The panels of the fish screen are designed to be removable for maintenance as required.

6.8.5 Water Supply Pipeline

A water supply pipeline connects the pumping station to the transition structure. The pipeline consists of a 210 m long, 0.6 m diameter high-density polyethylene pipe. This type of pipe is commonly used in underground applications. It would be connected to the pumping station underground and would be buried approximately 0.8 m below the ground surface. The penetration through the East Dyke will be at the same elevation than the conduit, above the 1 in

100 year level). The water supply pipe will be separated from the fishway conduit by a minimum distance of 2m to allow for optimum compaction during the reconstruction of dyke.

The total length of the water supply line would generally be the same for the 1 in 100 year and 1 in 700 year designs, however, since the penetration of the pipeline through the East Dyke for the 1 in 700 year design would occur at a higher elevation, the length of the section through the dyke would be reduced to approximately 25 metres.

6.8.6 Geotechnical Considerations for the Water Supply Line Through Dyke

Design considerations to protect against seepage through the East Dyke are similar to those for the fish passage conduit. An additional item included in the design related to the water supply line includes using a double-walled pipe. This will minimize the risk of pipe leakage during operation that could result increased saturation of the East Dyke or internal erosion piping that could jeopardize the integrity of the dyke.

6.9 ELECTRICAL SYSTEM & HOUSING PAD

6.9.1 Description

The electrical systems for the fishway will be independent of any other electrical system in the area, and dedicated solely for the fishway pumping and control system.

A new electrical services building will be constructed, near Courchaine Road, above the 1 in 700 year flood level and set back from the roadway to allow space for normal traffic flow and snow clearing operations. This location is shown on Plate 05 and labeled as the electrical housing pad. A small graded area around the electrical service building will allow for occasional parking for maintenance.

Adjacent to the building will be a Manitoba Hydro owned and operated, pad-mounted transformer feeding a dedicated 600A, 600V 3 phase 4 wire electrical service within the building. A metering enclosure will be provided on the outside of the building, for a utility supplied meter.

Manitoba Hydro will supply and install the transformer and transformer pad, with the contractor providing a flat graded gravel pad location and two 100mm PVC ducts; running due north from the pad location, under Courchaine Road and emerging on the north side of the road, in the vicinity of an existing Manitoba Hydro buried 25kV feeder line. A minimum burial depth of 1 m below the roadway is required. Care will be used to ensure that the conduit is as deep as possible without penetrating the "core" of the dam.

Manitoba Hydro will provide a tap from the 25kV feeder, conductors under the road to the transformer and back to maintain a loop feed to the existing transformer at the east side of the Inlet structure.

The pumping station will be located within a yearly flood-prone area. Therefore, with the exception of level detectors for pump control and water-ingress protection for the junction boxes, no electrical equipment or controls will be located at the pumping station. Instead, motor controls and alarm and detection will be located in the electrical services building. In order to ensure electrical lock-out safety for work within the pumping station, a key interlock will be implemented such that the electrical feeders for both pumps will have to be locked out in the off position before access to the pump pit or electrical junction boxes will be allowed. Additionally, a window will be provided in the electrical services building with line-of-sight to the pumping station, for a final verification before energizing pumps.

Due to the size of the pumps, and the desire to optimize the service size, the pumps will be controlled using manually operated solid state "soft start" starters. The pumping system is designed for 100% backup, therefore; only one pump will be operating at any time. A simple alternating system will be incorporated so that each pump will, over time, see equal service. A variable speed operation is not required and the pump will be either on or off for a period of time starting with a manual "run" operation in the electrical services building. The pumps will turn off automatically if the wet well water level is insufficient or on high level alarm, and upon manual "off" signal.

Simple float switches inside the pump pit will enable a pump to run only when there is sufficient water within the wet well. A high water alarm (float switch) will provide a signal at the motor control center when the water level is at or near the top of the wet well. This signal will be used to inhibit electrical pump operation, since it will indicate a water level within 1.5 m of the bottom of the junction boxes at the pumping station.

To allow for the occasional disconnection and removal of the pumps or controls, and to allow factory installed pump cables to be terminated at the pumping station, three weatherproof and water-tight junction boxes will be located on steel support channels such that they will be above “normal” high water levels, but occasionally be submersed in a 1 in 20 year flood condition or greater. Occasional submergence requires the use of NEMA 6P or IP68 enclosures, which are submersible and are also built to withstand ice formation and ingress of dust and other elements.

Since these boxes will not contain controls or equipment requiring maintenance, there will be no requirement to ventilate the enclosures, and they will be bolted closed for a tight gasketed seal. To provide additional protection, water presence alarms will be provided in each of the three boxes, with a common alarm at the electrical services building.

Cables from the pumps and controls will enter the boxes via gland type connectors within a rigid conduit sleeve to the wet well (for mechanical protection). TECK90 cables will also be terminated into the bottom of the junction boxes, and run directly back to the motor starters in the electrical services building, underground and without interruption to eliminate any moisture from entering the cables or junction boxes.

There will be one junction box for each pump/power cable, and one for combined controls, as well as one TECK cable from each box to the electrical service building in an underground trench.

Inside the electrical services building, there will be a service entrance rated panel, one “soft-start” starter for each pump, a small dry-type transformer and a 120/208V panel for controls. All of this equipment may be located in one integrated motor control centre, or as separate components. The building will be one room, with fluorescent lighting and several receptacles. A 600V-3P electrical unit heater will be provided to keep the building free of condensation.

A 50W HPS, “wall pack” light fixture will be provided over the entrance door, and be arranged so as not to provide glare into the roadway. The fixture will have a dusk-to-dawn photocell control, and an astronomical time clock to allow the light to program to stay off for extended periods of time (say during the winter) or off at a certain time of night.

Alarms will be local only. An amber (LED) flashing light on the outside of the building facing the ICS will be provided to signal a common alarm from any of the motor controls or level controls. Should additional communications be required in the future, a wireless transmitter or cell-phone type service could be implemented.

The electrical system would be the same for both the 1 in 100 year design and the 1 in 700 year design. The electrical housing pad for the 1 in 700 year design would be shifted approximately 80 metres east along the East Dyke from the location for the 1 in 100 year design.

6.9.2 Geotechnical Considerations for the Electrical Housing Pad

Slope Stability Considerations

Slope stability analyses were completed to assess the overall stability of the south slope of the East Dyke with fill placement for electrical housing pad.

The fill configuration for the electrical housing pad has been design to result in a negligible change to the overall stability of the existing East Dyke, with the estimated FS greater than 1.5 for the normal conditions and greater than 1.2 for extreme groundwater conditions.

Erosion Protection

Erosion protection must be reinstated around the pad fill once the pad is completed.

6.10 PUMPING STATION ACCESS ROAD

6.10.1 Description

The pumping station will require a permanent access road for operators to access the station during operation and for routine maintenance, as well as to provide accessibility to install and remove the pumps for maintenance.

Access would be provided to the pumping station from St Mary's Road, east of the project area. A lockable gate at the entrance of the pumping station access road prevents unauthorized public access to the upstream area of the site. The access road, shown on Plate 02, is approximately 700 m in length and is designed as a single lane roadway that will allow passage of a crane and truck required to transport the pumps at the pumping station. A turnabout area is provided at the pumping station for a crane or other large equipment manoeuvre.

This permanent access road will be built above the existing ground but will require some limited excavation to reach the elevation corresponding to the top of the pumping station.

The section of the access road (including the turnabout and pad) at proximity of the pumping station could partially or totally under water during operation, which would impede access to the pumping station. However, operation and maintenance at the pumping station are not anticipated to be required under these high water level conditions.

Erosion protection will be required along the roadway. The current conditions in the area of the access road indicate vegetation on the ground with no apparent signs of erosion, which would suggest that re-vegetation of the disrupted area would suffice to limit erosion on the side slope embankments of the roadway. The road surfacing would consist of granular material that would be resistance to erosion and durable for the heavy truck loadings.

The general characteristics of the pumping station access road would be the same for both the 1 in 100 year and the 1 in 700 year designs. The total length of the road associated with the 1 in 700 year design would however be shorter than that of the 1 in 100 year design by approximately 80 metres.

6.11 PUBLIC SAFETY AND INTEGRATION TO DUFF ROBLIN PARK

The proximity of the ICS fishway to the future Duff Roblin Park development area could represent an additional site of interest for the Park and create educational and recreational opportunities for the public. At the time this preliminary design study was completed, the layout of the Duff Roblin Park had not been finalized.

During preliminary design stage, an effort was made to reduce the negative visual impacts on the existing environment. This included the limitation of use of massive above ground concrete structures that would not fit with the proposed concept of a nature-like fishway. However, due to the complexity of the design, such components are still necessary but negative associated effects were mitigated. For example, the pumping station and the housing for the electrical components being located on the upstream side of the East Dyke, will reduce noise and aesthetic nuisance in the vicinity of the Park.

Due to the proximity to the future Duff Roblin Park and the nature of structure itself, the fishway channel would likely attract public, particularly during operation, but also at times when it is not operated. During operation, the pool and riffle structure will be filled with flowing water with a maximum water depth of 1.5 m in the channel, which is constituted of relatively steep side slopes (2H : 1V). Local high velocities will also exist which could potentially increase the risk for the public. In order to minimize the risks to public safety, access should be restricted to safe areas only. Fencing of the transition structure and the pumping station, as well as lockable gates at the entrance of the access road to the pumping station would be required.

Under the current mode of operation of the ICS, access to Courchaine road is typically blocked between Turnbull Drive and St. Mary's Road when the ICS is operated. This would also correspond to times when the fishway is operated. However, should the development of the Park allow public access during operation of the ICS via St. Mary's Road and Courchaine Road, fencing along the fishway channel or fencing of the entire area would be required. This would prevent the public from having a dedicated access to the site, on the south side of the East Dyke but also along the fishway channel. This appears to be conflicting with the idea of incorporating the fishway into the Park. This concept of integration of the fishway to the Park versus public safety should be better defined during final design, in consultation with the Park developers and the designers.

During non-operation of the fishway, all components of the fishway are designed to be dry. The public safety concern would be limited, but the structures could still be subject to vandalism. This could compromise operation of the fishway if key components get damaged, and could also increase potential risks associated with dam safety.

Fencing upstream and downstream of the ICS would be prone to damage by ice or debris in the event of a flood, which would create ongoing maintenance costs for repair or replacement of the damaged fencing.

These security measures (i.e. fencing) are not shown on the preliminary design drawings, as the location of these measures should consider the design of Duff Roblin Park. Costs for the public safety measures have, however, been included in the cost estimate presented in Section 8.0. Fencing repair or replacement costs have also been included in the maintenance costs. These costs should be revised during final design stage, once the integration of the fishway to the Duff Roblin's Park has been discussed and addressed in the design.

7.0 OPERATION AND MAINTENANCE OF THE FISHWAY

7.1 OPERATION

The fishway is designed to be operated only when the ICS is operated and for river water levels ranging from summer operation levels up to the 1 in 20 year flood event as defined in Section 4.4. The fishway could be operated during a flood event of a higher magnitude, once the peak of the flood is passed as the upstream water levels recede below the 1 in 20 year flood level. This design does not consider operation under ice-covered conditions since it is unlikely that the Floodway, and consequently the ICS, will be operated under these conditions.

The operation of the fishway will be by means of manually turning the pump equipment on and off. Procedures that could be followed for the initiation and cessation of fishway operation are defined in the following sub-sections.

Once the water levels at the inlet to the Red River Floodway recede below the elevation of the inlet plug and the ICS gates are lowered into their inactive position, the upstream river levels will begin to recede below the invert of the excavated fishway exit channel. When the river level is below the invert of the fishway exit channel, the pumping station cannot be operated anymore. If the running pump were not manually stopped by an operator prior to the natural drainage of the release pool and channel, water level sensors in the pumping station would automatically disconnect the pumps and prevent damage due to air entertainment.

The fishway would not be operated if there were still ice on the river, even if the headwater levels are high enough for operation, as the design has not considered the effect of operating under ice flow conditions. In these times, operation of the fishway would be delayed until the ice has moved past the ICS. This is not a typical condition, as the ICS is not typically operated when there is still ice on the river, however, history has shown that there is the chance of this occurring.

Details of typical operating procedures and during major flood events (greater than a 1:20 year) are provided in the following subsections.

The procedures identified in this report would generally be the same for both 1 in 100 year design and the 1 in 700 year design. As part of the final design stage, a comprehensive Operation and Maintenance Manual would need to be developed. This Operation and Maintenance Manual would define the roles of various MIT personnel and the activities that would be required for each of the operating and maintenance procedure identified within this report.

7.1.1 Typical Operating Procedures

Given the location of the fishway relative to the ICS and its incorporation into the East Dyke, the fishway should be carefully operated to ensure it does not negatively impact the integrity of the flood protection system.

A summary of the recommended actions to be taken every year prior to the first operation of the fishway and at the end of the season (before winter) is presented below. These operating procedures are based on the preliminary design presented in Section 5.0.

Proposed Procedure for Annual Commissioning of Fishway

1. Complete a visual inspection of the fishway and all components, with an emphasis on potential damages that might have occurred in the fishway channel, rockfill riffles, chute, release pool and channel and the presence of debris.

2. Complete a visual inspection of the pumping station and the electrical system, including the fish screen, the valves and other miscellaneous mechanical components. Remove the insulation in the opening of the pumping station. Inspection of the water supply pipeline and conduit would also be carried out to look for any potential leakage.

3. Complete a visual inspection of the transition structure, including the valves and other mechanical components.

4. Move both fishway slide gates into the open position.

5. As ICS gates are raised and when upstream water level provides the minimum submergence required for the pumping system, one of the pumps can be activated and tested.

6. Confirm that the flow distribution in the transition structure is correct by checking the control valves.

Procedure for Annual Decommissioning of Fishway

1. Stop and disconnect the pumps.
2. Dewater pumping station and remove silt that might have accumulated in the Pumping Station during operation.
3. Install the insulation in the opening of the Pumping Station
4. Complete a visual inspection and complete a high pressure cleaning of the fish screen if required.
5. Complete a fish salvage program in the fishway channel, if required. The need for fish salvage would be decided with input from the owner, operator and fish biologists.
6. Remove excess silt or material that might have been accumulated in the pools, if required.
7. Turn off the valves in transition structure.
8. Close the slide gate in the transition structure, then the slide gate at the south end of the fishway chute.
9. Lock slide gates in closed positions.
10. Lock the doors of the pumping station, valve room and electrical housing and the gate at the entrance of the pumping station access road.

7.1.2 Procedures in Preparation of a Major Flood (Greater than a 1 in 20 year Flood)

The fishway was designed for operation during flood events of a 1 in 20 year recurrence or less. In case of a flood of a lower recurrence, the operation of the fishway shall stop when the river water levels upstream of the ICS rise above the 1 in 20 year flood level. During such floods event, each component of the fishway shall be checked to make sure the integrity of the flood protection system is not jeopardized. A detailed checklist of the procedures should be developed as part of the Operation and Maintenance Manual that would be prepared during the final design stage.

The procedure to be followed in the event of a flood surpassing the operation range of the fishway is as follows:

1. Stop the pump,
2. Turn off the valves in the transition structure.
3. Close the slide gate in the transition structure, then the slide gate at the south end of the fishway chute.
4. Lock slide gates in closed position.
5. If the closing of one or both gates failed, stoplogs shall be inserted in the transition structure.
6. Providing that water levels and flow velocities downstream of the fishway do not compromise crew safety, fish salvage should take place to remove fish potentially stranded in the fishway pools above the river water level.

Once the peak of the flood is passed, as water levels upstream of the ICS recede below the 1 in 20 year flood level, the fishway operation can be resumed. Since components of the fishway could have been damaged or displaced when submerged by high water levels, the same procedures as described for the annual commissioning should be followed as long as it is safe to do so.

In preparation of spring flood, the Province of Manitoba regularly publishes flood forecasts. These forecasts would help the operator in the organization in determining if a closure of the fishway is required during a flood event, and allow for ample time to plan the closure. As described in Section 6.0, the invert of the chute is located above either the 1 in 100 year or 1 in 700 year flood level. Even if water levels are not expected to reach this stage during a particular flood event, both slide gates shall be closed as soon as the operation of the fishway is stopped for a significant duration of time.

7.2 MAINTENANCE

Due the complexity of the design of the fishway and the number of mechanical and electrical components, regular and annual maintenance shall be performed to insure efficiency and reliability of the fishway.

The annual maintenance of the fishway could essentially be performed during the preparation of the first annual operation of the fishway. Maintenance and detailed inspection of the pumps, gates, valves and other mechanical components shall also be performed as required by the respective manufacturers.

The arrangement of the riffles and the distribution of flow in the transition structure shall be regularly checked in the first five years following construction to insure that fish passage occurs. If it is decided to use boulders or large rocks to build the riffles, these can be manually adjusted to create better hydraulic conditions and improve fish passage efficiency.

Annual maintenance would also include potential repairs on fencing, to the access road or any other components of the fishway due to damages that have occurred during a flood event.

Estimates of the maintenance costs are defined on an annual basis and include allocations for repairs due to flood damages and normal wear of the fishway components and are described in Section 8.2.

The general maintenance requirements would generally be the same for both the 1 in 100 year and 1 in 700 year designs.

8.0 ESTIMATED PROJECT COSTS

8.1 ESTIMATED CAPITAL COST

The cost estimate for this preliminary design was based on preliminary quantities and unit rates derived and determined from the design and drawings as outlined in Section 6.0. The unit rates were estimated based on recent experience and available information for the site, as well as current prices and market conditions in 2010.

8.1.1 Direct Costs

The direct project costs that were considered in the cost estimate include those associated with the construction for the various permanent and temporary components of the development, as well as the supply and installation of equipment. The various components considered in the cost estimate include:

- ***Mobilization and Demobilization*** – This includes all costs associated for the contractor to mobilize on site to carry out the construction of the fishway. This would also include the cost for the contractor to remove all construction equipment from the site and restore any temporary work areas to natural conditions prior to leaving the construction site.

- ***Fishway Entrance and Channel*** – This considers all costs associated with the construction of the fishway channel, from the fishway entrance to the transition structure and includes quantities and placement of fill and rockfill in the channel, as well as rockfill and boulders that compose the riffles.

- ***Transition Structure*** – This considers all costs associated with the construction of the transition structure and includes all civil work, the supply and installation of the mechanical components and stoplogs required in case of emergency closure. Excavation and fill placement associated with the construction of the transition structure is included in the work associated with the installation of the conduit. This also includes the supply and installation of the slide gates that isolate the conduit on the north side of the East Dyke.

- ***Conduit through the Dyke / Chute*** – This includes all costs associated with the installation of the conduit through the East Dyke, as well as the section of the chute above ground that runs from the slide gate to the recovery pool. This component comprises all costs associated with the installation and supply of the slide gate at the south end of the conduit, including the concrete structure. The excavation combine the excavated volumes associated with the placement of the conduit and the water supply line and with the construction transition structure.

- ***Recovery Pool and Fishway Exit Channel*** – This includes all costs associated with the excavation of the release pool and the exit channel, as well as the channel conveying water to the pumping station.

- ***Deflector Berm –*** This includes the supply and placement of rockfill for the deflector berm on the south embankment slope of the East Dyke.

- ***Pumping Station and Water Supply Line*** – This includes all costs associated with the construction of the pumping station, as well as the supply and installation of the pumps and the water supply line. Supply and installation of the fish screen is also included in this section.

- ***Electrical System and Housing Pad*** – This considers all costs associated with the supply and installation of the electrical equipment, including the placement of rockfill for the electrical housing pad on the upstream side of the East Dyke.

- ***Pumping Station Access Road*** – This includes excavation costs and rockfill associated with the construction of the Pumping Station Access Road.

- ***Public Safety and Integration to Duff Roblin Park*** – This considers all costs related to public safety, and includes fencing of the entire area, signage and an allowance for miscellaneous items related to public safety.

- ***Construction Access and Care-of-Water*** – This includes an allowance for the construction of temporary access roads as well as the installation and removal of the cofferdam required during construction of the fishway entrance.

- ***Construction Activities and Site Restoration*** – This comprises an allowance for geotechnical instrumentation and monitoring (piezometers to measure dissipation of construction induced porewater pressures, as noted in Section 6.3.4), and temporary sediment and erosion control measures. This also includes site restoration after construction, such a re-vegetation of the disturbed areas.

8.1.2 Indirect Costs Components

The indirect project costs that were considered in the cost estimate include:

- **Contingency on Construction Costs** – This includes a contingency of 15% of the direct construction costs excluding the pumps and connection to the water supply line.

- **Detailed Engineering** – This includes the costs related to the detailed design and construction specifications, equivalent to 5% of the direct construction costs plus contingency.

- **Construction Supervision** – This includes the costs related to the supervision during construction, equivalent to 10% of the direct costs plus contingency.

- **Permitting/Consultation/Environmental** – This includes an allowance for the permitting process, the environmental approvals and all the necessary consultations. It is estimated at 4.0% of the direct costs.

- ***Compensation Measures for HADD*** – This includes compensation to DFO for harmful alteration, disruption or destruction (HADD) of fish habitat associated with the partial infilling of the former diversion channel. This would represent a maximum area of 2000 m^2 of assumed prime habitat directly connected to the Red River. The amount of the compensation is estimated at this stage to $250,000. However, this is typically defined on a case-by-case basis by DFO, from a final design and a proposed compensation plan. Final design should include the definition of a compensation plan to be submitted to DFO for review.

- ***Fish Passage Monitoring Program*** – As part of DFO's review process of the final design, fish passage monitoring could also be required after construction during an amount of time to be defined by DFO. An allowance of $150,000 is included in the preliminary cost estimate.

8.1.3 Total Estimate Project Costs

The estimated capital cost for the fishway, in 2010 dollars, associated with both the 1 in 100 year and 1 in 700 year designs, as described in Section 6.0, are presented below in Table 8-1. Detailed cost estimates are provided in Appendix B for the 1 in 100 year design and Appendix C for the 1 in 700 year design.

TABLE 8-1
ESTIMATED CAPITAL COSTS FOR FISHWAY

ITEM	ESTIMATED COST (2010 DOLLARS)	
	1 IN 100 YEAR DESIGN	1 IN 700 YEAR DESIGN
CAPITAL COST		
Direct Costs		
Mobilization and Demobilization	$ 200,000	$ 200,000
Fishway Entrance and Channel	$ 2, 080,000	$ 3,150,000
Transition Structure	$ 427,000	$ 386,000
Conduit through the Dyke / Chute	$ 545,000	$ 473,000
Recovery Pool and Fishway Exit Channel	$ 420,000	$ 510,000
Deflector Berm	$ 375,000	$ 375,000
Fishway Pumping Station & Water Supply Line	$ 1,310,000	$ 1,330,000
Electrical System and Housing Pad	$ 363,000	$ 363,000
Pumping Station Access Road	$159,000	$122,000
Public Safety and Integration to Duff Roblin Park	$ 48,000	$ 48,000
Construction Access & Care-of-Water	$ 800,000	$ 800,000
Construction Activities and Site Restoration	$ 100,000	$ 100,000
Subtotal	**$ 6,830,000**	**$ 7,850,000**
Indirect Costs		
Contingency on Construction Costs	$ 950,000	$ 1,100,000
Detailed Engineering	$ 390,000	$ 450,000
Construction Supervision	$ 780,000	$ 895,000
Permitting/Consultation/Environmental	$ 275,000	$ 315,000
Compensation Measures for HADD	$ 250,000	$ 250,000
Fish Passage Monitoring Program	$ 150,000	$ 150,000
Subtotal	**$ 2,785,000**	**$ 3,160,000**
TOTAL CAPITAL COST	**$ 9,615,000**	**$ 11,010,000**

8.2 ESTIMATED OPERATION AND MAINTENANCE COSTS

Operation and maintenance costs for the fishway as described in Section 6.0 were defined on an annual basis and based on the activities that require operation and maintenance as described in Section 7.0. However, the duration of fishway operation will vary from year to year with the flood conditions. Should the Floodway be used in summer to control water levels within the City of Winnipeg, the fishway would be operated for a longer duration than if used during flood events only. The operation and maintenance costs were therefore conservatively estimated based on an average continuous operation of 4 months per year to reflect the summer operation of the ICS to control river levels within the City of Winnipeg. Operation and

Maintenance costs should be revised under Final Design Stage to incorporate any addition or modification to the procedures identified in the Operation and Maintenance Manual to be prepared as part of the Final Design.

The operating and maintenance costs for the fishway would generally be the same for both the 1 in 100 year and 1 in 700 year designs.

8.2.1 Operation Costs

Operation costs were defined on an annual basis and include the commissioning and decommissioning of the fishway at the beginning and the end of the season, as well as the regular operation of the fishway. Costs related to the preparation in the event of a flood exceeding the operating range of the fishway and that would require immediate shutdown were also included.

Annual Operation of Fishway

Operation costs associated with the annual commissioning of the fishway include:

- ***Fishway Commissioning*** – This would include an inspection the pumping station (including fish screen), transition structure, conduit/ chute, gates, and the fishway channel (including riffles and entrance) prior to commissioning. We have included an allowance of two days of work by a two person crew to complete these inspections. Fishway commissioning per se would require the presence of a two person crew during a day.

- ***Fishway Decommissioning –*** This consists of the costs of the activities associated with the decommissioning of the fishway, which includes closing of both slide gates as well as decommissioning, dewatering and de-silting of the pumping station and cleaning of the fish screen, if required. The decommissioning of the fishway may also require fish salvage if fish using the fishway when the water supply is shut down get stranded in the pools. Approximately one week of work for a three-person crew was allowed for these activities. This could be reduced to 3 days, if separate crews carried out the activities simultaneously.

- **Regular Operation** – This consists of the time for a regular operator on the basis of 1 day per week and the average energy consumption during a typical fishway operation of 4 months per year.

Special Operation of Fishway for Events Greater than 1 in 20 Year Flood

The maintenance costs associated with the preparation in the event of a flood with a lower recurrence than 1 in 20 year. These costs will only be considered in those years when such event occurs. Essentially, the operation costs associated with a flood include the general inspection of the pumping station and fishway channel, along with the closing of both slide gates at each extremity of the conduit through the dyke, and/or the installation of stoplogs in case of a gate failure or improper sealing. This would also require an operator to manually shut down the pumps.

8.2.2 Maintenance Costs

The maintenance costs, in 2010 dollars, were defined on an annual basis and include the following components:

- ***Repair of Potential Damages to Fishway Components*** – This includes the costs associated with the repair or replacement of structures that could have been damaged during winter or flood conditions. The average annual cost was estimated based on the replacement of approximately 10% of the total fencing and allowed an annual $5,000 for miscellaneous repairs

- ***Routine Maintenance and Cleaning*** – This includes all costs associated with the routine maintenance, cleaning of the site and landscaping. The average annual cost was estimated on the basis of one workday per week over a typical four month period of operation of the fishway.

- ***De-silting of Fishway Pools*** – De-silting of the fishway pools was estimated to be required every 2 years. It was assumed that de-silting campaigns would mobilize a 3 person-crew for approximately 4 days.

- ***Pump Inspection*** – This concerns the pump inspection as part of the recommended pump maintenance, which should be performed every 12,000 hours or 3 years. It will mobilize a three person crew during 3 days, which represents a total of 48 man-hours.

- ***Major Overhaul of Pump***s – This includes replacement and supply of major pump components as part of the recommended pump maintenance, which should be performed every 24,000 hours or 6 years. It would mobilize a 3 person crew during approximately 3 days.

The estimated operation and maintenance costs for the fishway, on an annual basis and based on the design described in Section 6.0 and the maintenance procedures described in Section 7.0, are presented in Table 8-2.

TABLE 8-2
ESTIMATED OPERATION AND MAINTENANCE COSTS FOR FISHWAY

ITEM	ESTIMATED COST (2010 DOLLARS)
OPERATION AND MAINTENANCE COSTS	
Operation Costs	
Annual Operation of Fishway	**$70,000**
Special Operation of Fishway for Events Greater than 1 in 20 Year Flood	**$4,000**
Maintenance Costs	**$25,000**
TOTAL O&M COSTS (Annual Basis)	**$95,000**

9.0 PROJECT SCHEDULE

A project schedule was developed for the implementation of the fishway and is shown in Plate 09. The total project duration would generally be the same for both the 1 in 100 year and 1 in 700 year designs, although durations of certain tasks (i.e. fill placement for fishway channel) associated with the 1 in 700 year design might be slightly longer.

The schedule is divided in two main phases, as listed below and extends over a total duration of 42 months from the commencement of the detailed design and environmental assessment to the completion of construction and commissioning of the fishway. The construction duration was estimated to be approximately 26 months.

- Engineering and Environmental Assessment
- Construction Phase

The timings and durations of the activities are based on the recent experience of KGS Group related to the detailed design, environmental approvals, and construction of various projects in Manitoba. The schedule was developed with the following considerations:

- The engineering studies and the environmental assessment were assumed to be completed in 17 months. Engineering studies include final design, tender preparation and bid process/contractor procurement.

- The construction activities were scheduled to respect with the flood windows. The flood window, which is defined between March 15th and May 15th, relates to the period of time were high water levels could submerge the work area. In-water construction activities were not scheduled to occur in flood window. If a flood does not occur in the year of construction, activities could be take place at this time, which could potentially reduce the total project duration.

- Overlapping the flood window is a fish window, which corresponds to the typical spawning period for most of the fish species present in the Red River. The fish window is defined from April 15th to June 15th. In-water work cannot be carried out within the fish window; however, the construction activities that take place above the water line could still be completed.

- Fill placement for the fishway channel was staged over two seasons to account for the required staging, dissipation of fill induced porewater pressures, and to avoid freezing conditions, especially during the clay compaction phase. Other geotechnical activities that do not require fill placement or clay compaction such as placement of erosion protection measures can be performed in winter.

- The installation of the pumps and electrical equipment is scheduled in the summer of Year 3, after construction of the pumping station and the electrical housing in completed.

- Re-vegetation would take place in the spring early summer once most of the construction activities have been completed.

- Commissioning of the pumping station and of the fishway must successively take place during flood conditions of the year following the installation of the equipment. It is possible that the fishway may not be able to be commissioned in the first year following its completion, if the spring freshet does not require the operation of the ICS. If this occurs, commissioning would have to wait until the next flood event that initiates the operation of the ICS.

10.0 RECOMMENDATIONS

The following key recommendations are made based on the work documented in the Preliminary Design Report and include specific items to be addressed in the final design stage if this project were to proceed to the next level of design.

- The final design of the fishway components should be based on the configurations proposed in the preliminary design described in this report.

- If the proposed fishway proceeds to final design, then the fishway should be designed to have the conduit pass through the East Dyke above the 1 in 700 flood level as described in Section 6.0 of this report.

- During the final design stage, the design of the riffle structures, should consider the natural irregularity of the boulders and rockfill that form the riffles, while maintaining the key dimensions described in this report.

- The construction materials to be used for the riffles should be reviewed in final design in terms of whether the riffles should be constructed solely from rockfill and boulders, or whether a combination of concrete units (e.g. jersey barriers) and rockfill should be used.

- The requirement for a geomembrane in the fishway channel to reduce potential infiltration should be confirmed during final design.

- The hydraulic conditions associated with the riffles were assessed in the preliminary design phase. Consideration should be given to at the final design stage to confirmation the hydraulic conditions as they relate to the successful passage of the key target species with the use of a physical model.

- Physical modeling of the transition structure with fish in a flume should be considered to supplement the final design to confirm the hydraulic conditions in the transition structure, and the means of introducing the flow into the riffle provides for the successful passage of the key target fish species.

- The security measures (i.e. fencing) were not developed in detail during the preliminary, as the location of these measures should consider the design of Duff Roblin Park which was not developed at the time of this work. Costs for the public safety measures were, however, included in the cost estimates. The configuration of the fencing, etc. should be developed and integrated with the plan for Duff Roblin Park during the final design.

- A comprehensive Operations and Maintenance Manual should be developed during the final design stage. The Operation and Maintenance Manual would define and provide further details on the operating and maintenance procedures as identified in Section 7.0. This manual should also define the responsibilities of the different entities in the operation and maintenance of the fishway.

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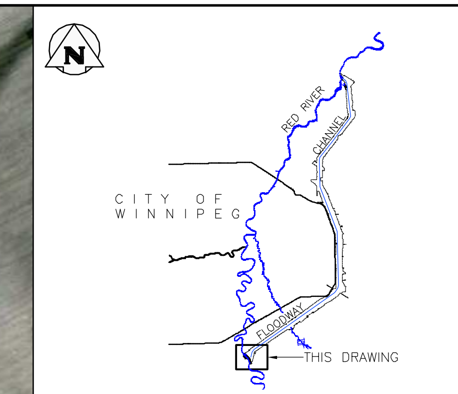
PLATES



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NO.	DATE	REVISIONS	BY	CHK.	APP.
0	31/03/11	ISSUED WITH FINAL REPORT	JS	APP	DSB

KGS GROUP

DESIGNED BY: APP	DRAWN BY: PEC	SCALE: AS NOTED
CHECKED BY: DSB	APPROVED BY: DSB	DATE: FEBRUARY 2011

PRELIMINARY
NOT TO BE USED FOR CONSTRUCTION

THIS DRAWING SHOWS THE DESIGN ABOVE THE 1 IN 100 YEAR FLOOD LEVEL. THE LAYOUT OF THE 1 IN 700 YEAR DESIGN IS SHOWN IN PLAN VIEW ON PLATE 03. DETAILS PERTAINING THE 1 IN 700 YEAR DESIGN ARE PROVIDED IN SECTION 6.0 OF THE PRELIMINARY DESIGN REPORT.

MANITOBA FLOODWAY AUTHORITY

RED RIVER FLOODWAY EXPANSION

INLET CONTROL STRUCTURE FISHWAY

SITE LOCATION PLAN

10-1100-01	PLATE 01	REV 0

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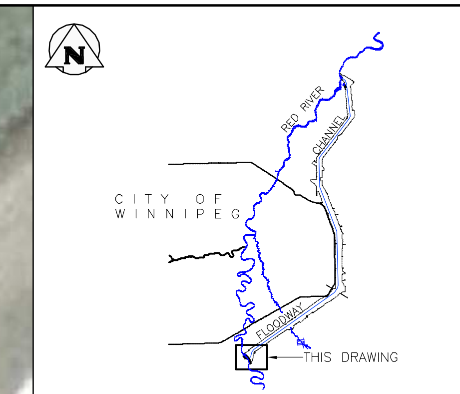

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NO.	DATE	REVISIONS	BY	CHK.	APP.
0	31/03/11	ISSUED WITH FINAL REPORT	JS	APP	DSB

KGS GROUP

DESIGNED BY: APP	DRAWN BY: PEC	SCALE: AS NOTED
CHECKED BY: DSB	APPROVED BY: DSB	DATE: FEBRUARY 2011

MANITOBA FLOODWAY AUTHORITY

RED RIVER FLOODWAY EXPANSION

INLET CONTROL STRUCTURE FISHWAY

FISHWAY PROJECT PLAN
1 IN 100 YEAR DESIGN

PRELIMINARY
NOT TO BE USED FOR CONSTRUCTION

10-1100-01 | PLATE 02 | REV 0

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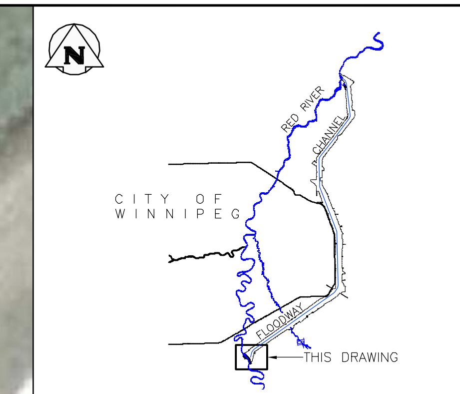

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NO.	DATE	REVISIONS	BY	CHK.	APP.
0	31/03/11	ISSUED WITH FINAL REPORT	JS	APP	DSB

KGS GROUP

DESIGNED BY: APP — DRAWN BY: PEC — SCALE: AS NOTED
CHECKED BY: DSB — APPROVED BY: DSB — DATE: FEBRUARY 2011

MANITOBA FLOODWAY AUTHORITY

RED RIVER FLOODWAY EXPANSION

INLET CONTROL STRUCTURE FISHWAY

FISHWAY PROJECT PLAN
1 IN 700 YEAR DESIGN

PRELIMINARY
NOT TO BE USED FOR CONSTRUCTION

10-1100-01 | PLATE 03 | REV 0

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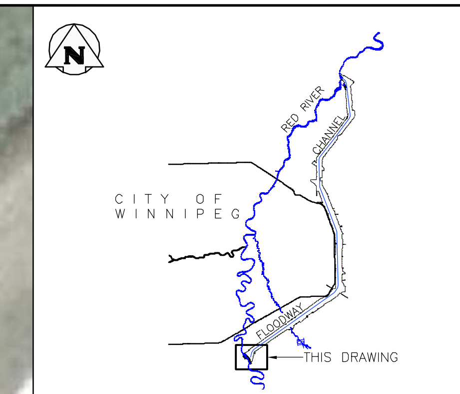

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NO.	DATE	REVISIONS	BY	CHK.	APP.
0	31/03/11	ISSUED WITH FINAL REPORT	JS	APP	DSB

KGS GROUP

DESIGNED BY: APP	DRAWN BY: PEC	SCALE: AS NOTED
CHECKED BY: DSB	APPROVED BY: DSB	DATE: FEBRUARY 2011

MANITOBA FLOODWAY AUTHORITY

RED RIVER FLOODWAY EXPANSION

INLET CONTROL STRUCTURE FISHWAY

COMPARISON OF FISHWAY DESIGNS
1:100 YEAR VS 1:700 YEAR

PRELIMINARY
NOT TO BE USED FOR CONSTRUCTION

10-1100-01 | PLATE 04 | REV 0

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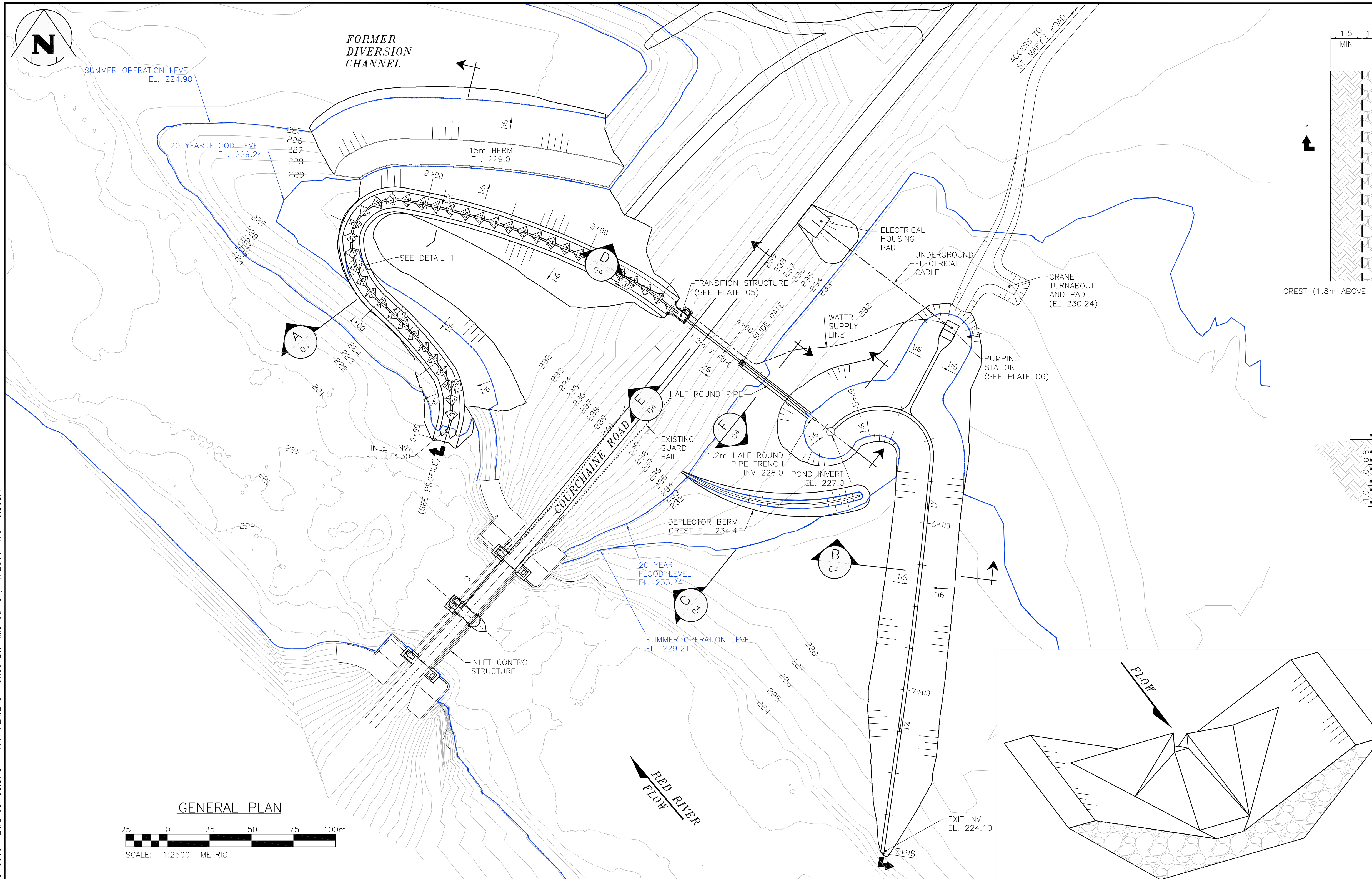

GENERAL PLAN

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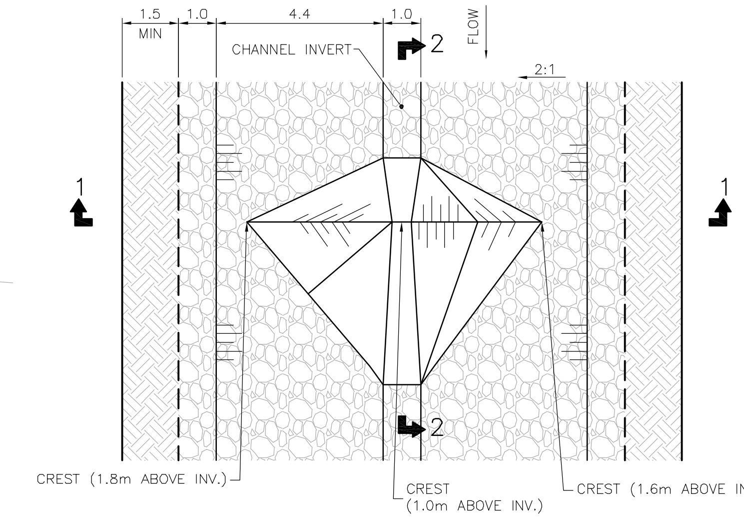

DETAIL 1 (ROCKFILL RIFFLE)

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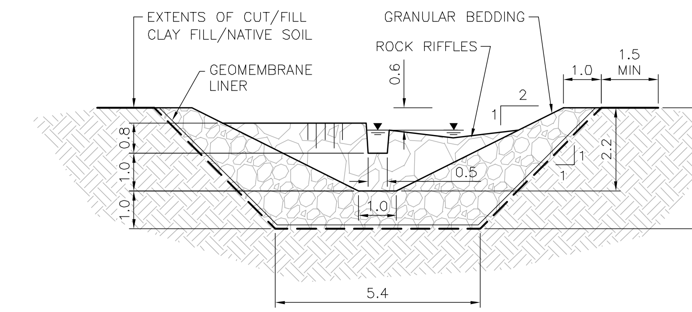

SECTION 1

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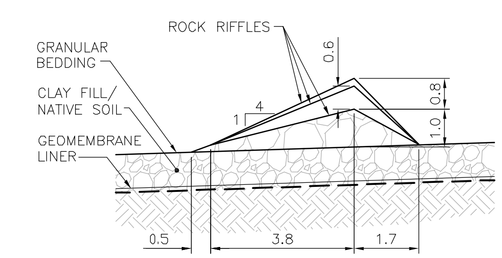


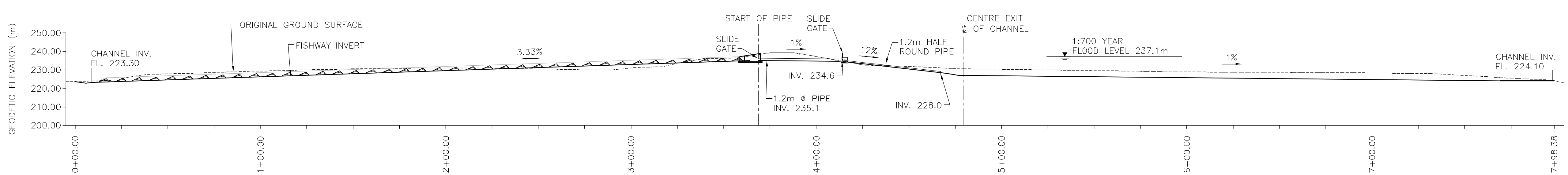
SECTION 2

SCALE: 1:200

ISOMETRIC VIEW OF RIFFLE

SCALE : NTS

THIS DRAWING SHOWS THE DESIGN ABOVE THE 1 IN 100 YEAR FLOOD LEVEL. THE LAYOUT OF THE 1 IN 700 YEAR DESIGN IS SHOWN IN PLAN VIEW ON PLATE 03. DETAILS PERTAINING TO THE 1 IN 700 YEAR DESIGN ARE PROVIDED IN SECTION 6.0 OF THE PRELIMINARY DESIGN REPORT.



PROFILE (℄ OF FISHWAY)

SCALE 1:2500

NO.	DATE	REVISIONS	BY	CHK.	APP.
0	31/03/11	ISSUED WITH FINAL REPORT	JS	APP	DSB

DESIGNED BY: APP | DRAWN BY: PEC | SCALE: AS NOTED

CHECKED BY: DSB | APPROVED BY: DSB | DATE: FEBRUARY 2011

MANITOBA FLOODWAY AUTHORITY

RED RIVER FLOODWAY EXPANSION

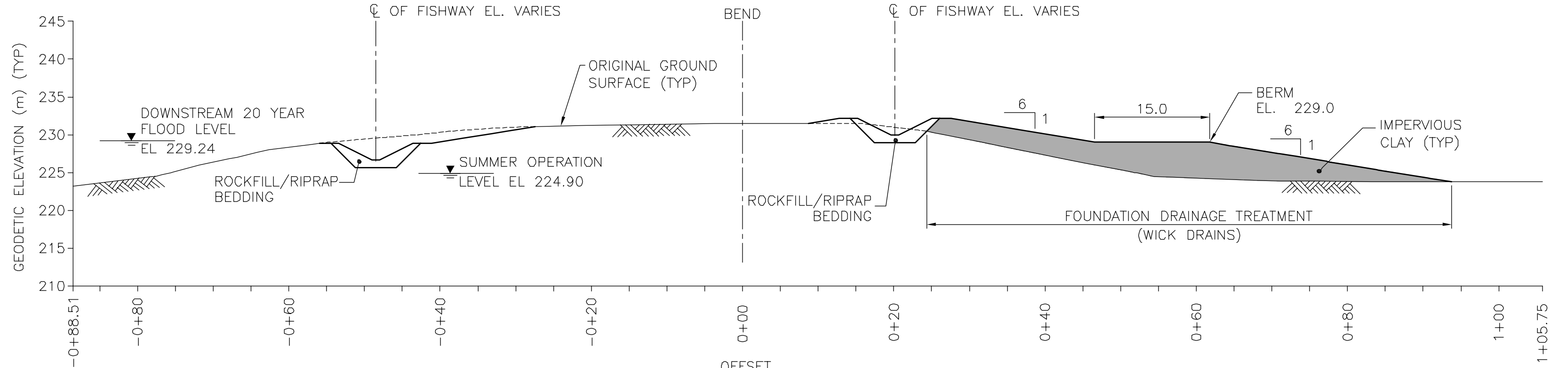
INLET CONTROL STRUCTURE FISHWAY

FISHWAY GENERAL ARRANGEMENT

PRELIMINARY

NOT TO BE USED FOR CONSTRUCTION

10-1100-01 | PLATE 05 | REV 0



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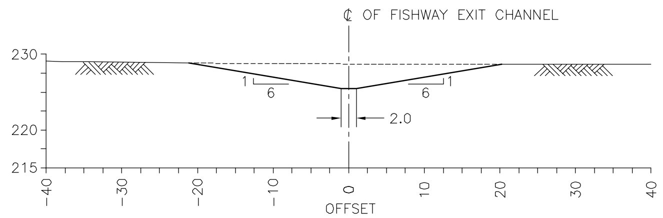

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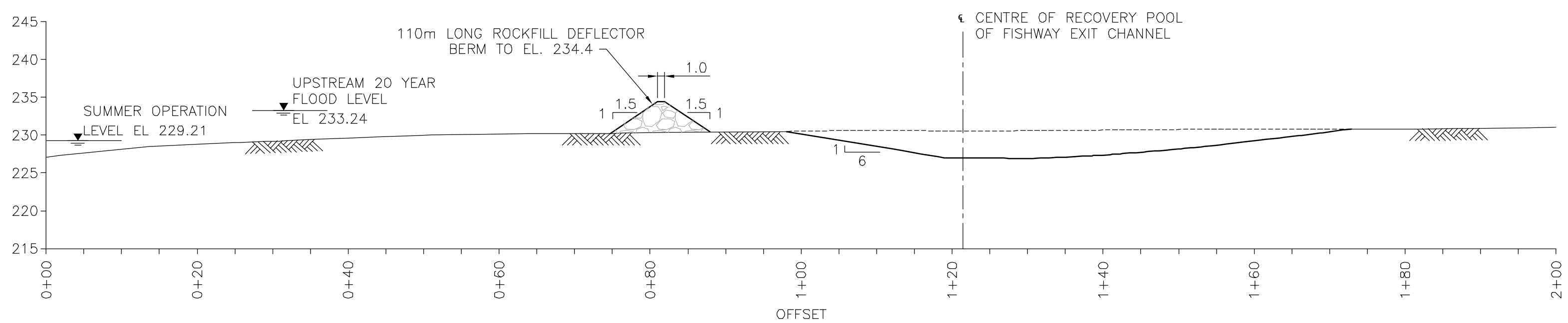

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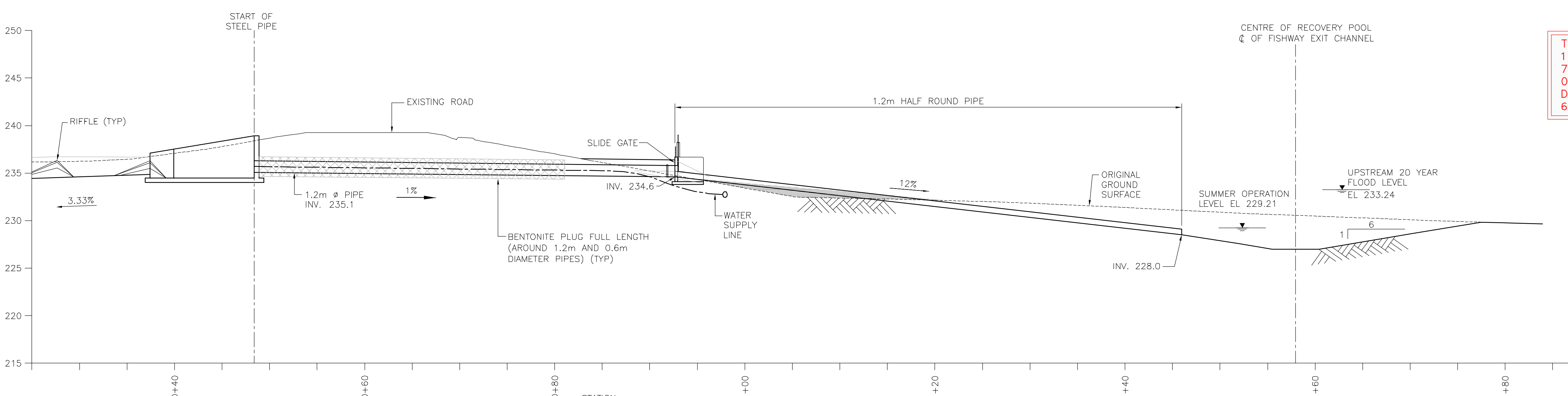

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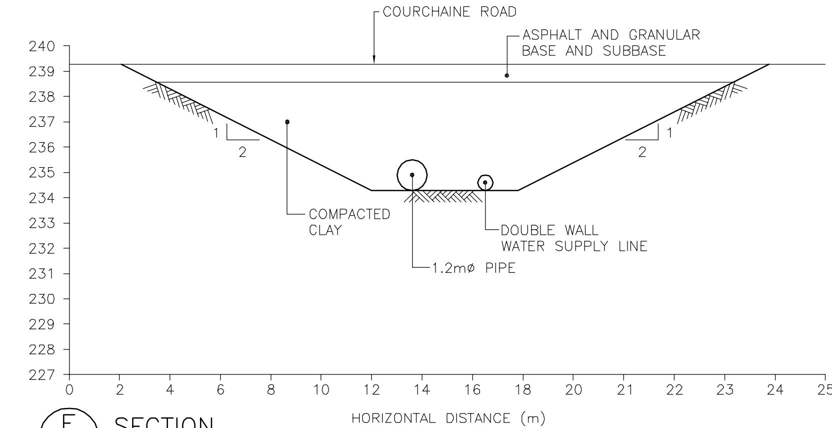

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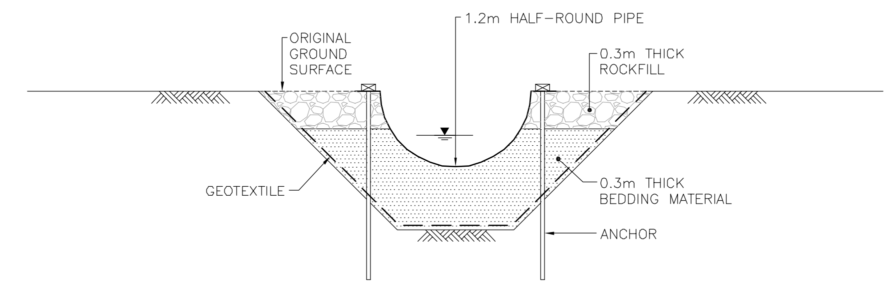

F 03 SECTION
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SCALE: 1:60 11"x17"

THIS DRAWING SHOWS THE DESIGN ABOVE THE 1 IN 100 YEAR FLOOD LEVEL. THE LAYOUT OF THE 1 IN 700 YEAR DESIGN IS SHOWN IN PLAN VIEW ON PLATE 03. DETAILS PERTAINING TO THE 1 IN 700 YEAR DESIGN ARE PROVIDED IN SECTIONS 6.2, 6.3, 6.5, 6.6 AND 6.7 OF THE PRELIMINARY DESIGN REPORT.

10 0 10 20 30 40m
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NO.	DATE	REVISIONS	BY	CHK.	APP.
0	31/03/11	ISSUED WITH FINAL REPORT	JS	APP	DSB

DESIGNED BY: APP	DRAWN BY: PEC	SCALE: AS NOTED
CHECKED BY: DSB	APPROVED BY: DSB	DATE: FEBRUARY 2011

MANITOBA FLOODWAY AUTHORITY

RED RIVER FLOODWAY EXPANSION

INLET CONTROL STRUCTURE FISHWAY

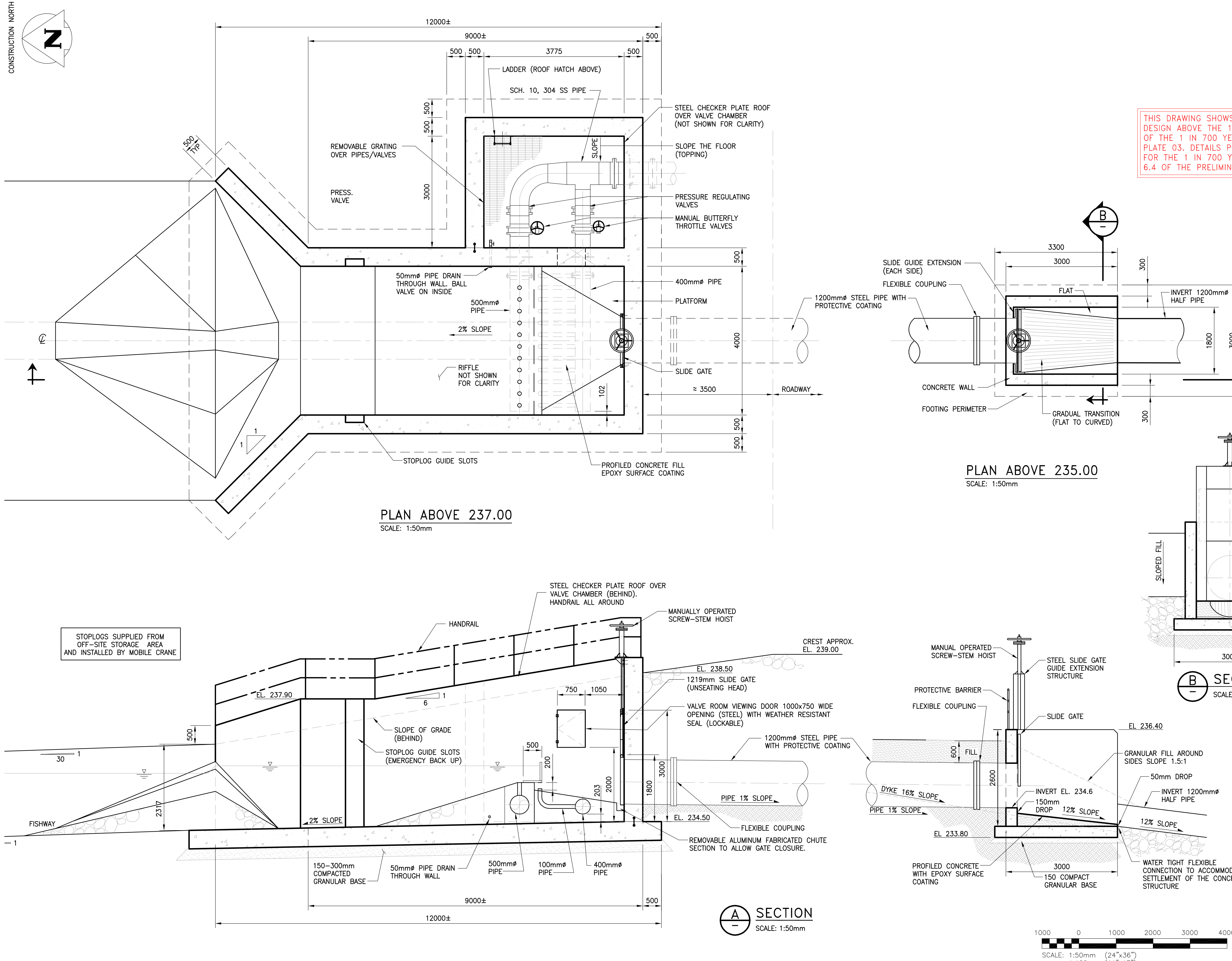
FISHWAY SECTIONS

10-1100-01 | PLATE 06 | REV 0

PRELIMINARY
NOT TO BE USED FOR CONSTRUCTION

PRELIMINARY
NOT TO BE USED FOR CONSTRUCTION

THIS DRAWING SHOWS THE TRANSITION STRUCTURE FOR THE DESIGN ABOVE THE 1 IN 100 YEAR FLOOD LEVEL. THE LAYOUT OF THE 1 IN 700 YEAR DESIGN IS SHOWN IN PLAN VIEW ON PLATE 03. DETAILS PERTAINING TO THE TRANSITION STRUCTURE FOR THE 1 IN 700 YEAR DESIGN ARE PROVIDED IN SECTION 6.4 OF THE PRELIMINARY REPORT.



NO.	DATE	REVISIONS	BY	CHKD	APP.
0	31/03/11	ISSUED WITH FINAL REPORT	PZS	WSM	DSB

KGS GROUP

DESIGNED BY: WSM/APP — DRAWN BY: CJS — SCALE: AS NOTED
CHECKED BY: DSB — APPROVED BY: DSB — DATE: FEBRUARY 2011

MANITOBA FLOODWAY AUTHORITY

RED RIVER FLOODWAY EXPANSION

INLET CONTROL STRUCTURE FISHWAY

FISHWAY TRANSITION STRUCTURE
PLAN AND ELEVATION

10-1100-01 | PLATE 07 | REV 0

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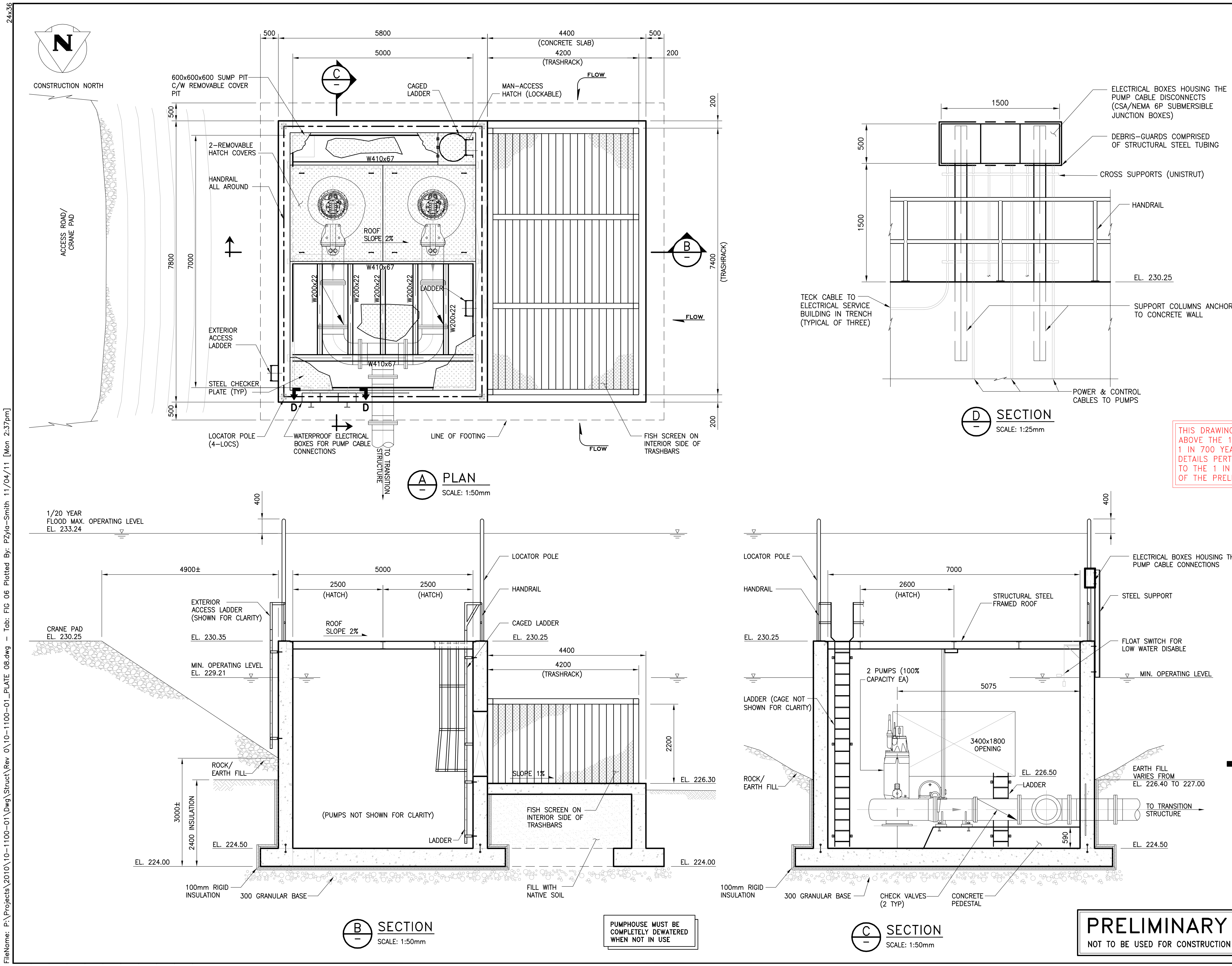
24x36



PRELIMINARY
NOT TO BE USED FOR CONSTRUCTION

NO.	DATE	REVISIONS	BY	CHKD	APP.
0	31/03/11	ISSUED WITH FINAL REPORT	PZS	WSM	DSB

KGS GROUP

DESIGNED BY: WSM/RED — DRAWN BY: CJS — SCALE: AS NOTED
CHECKED BY: DSB — APPROVED BY: DSB — DATE: FEBRUARY 2011

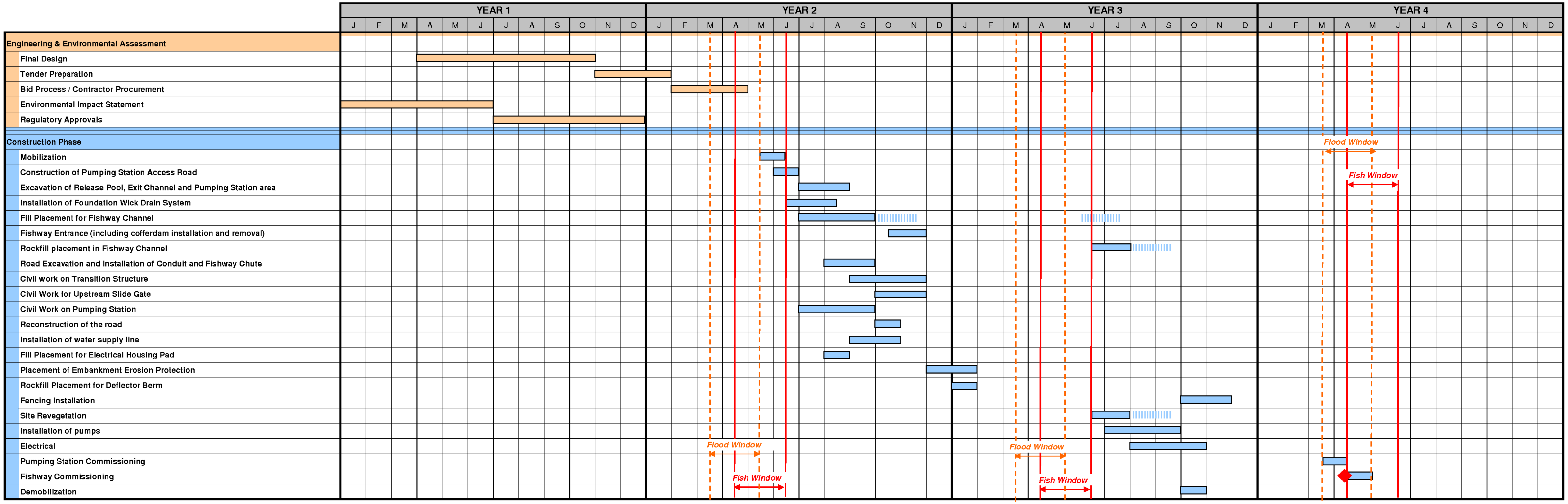
MANITOBA FLOODWAY AUTHORITY

RED RIVER FLOODWAY EXPANSION

INLET CONTROL STRUCTURE FISHWAY

FISHWAY PUMPING STATION
PLAN AND SECTIONS

10-1100-01 | PLATE 08 | REV 0



THIS SCHEDULE CORRESPONDS TO THE 1 IN 100 YEAR DESIGN. THE LAYOUT OF THE 1 IN 700 YEAR DESIGN IS SHOWN IN PLAN VIEW ON PLATE 03. DETAILS PERTAINING TO THE SCHEDULE FOR THE 1 IN 700 YEAR DESIGN ARE PROVIDED IN SECTION 9.0 OF THE PRELIMINARY DESIGN REPORT.

PRELIMINARY
NOT TO BE USED FOR CONSTRUCTION

NO.	DATE	REVISIONS	BY	CHKD	APP.
0	31/03/11	ISSUED WITH FINAL REPORT	PZS	APP	DSB

KGS GROUP

DESIGNED BY: WSM/RED | DRAWN BY: CJS | SCALE: 1:1
CHECKED BY: DSB | APPROVED BY: DSB | DATE: FEBRUARY 2011

MANITOBA FLOODWAY AUTHORITY

RED RIVER FLOODWAY EXPANSION

INLET CONTROL STRUCTURE FISHWAY

PROJECT SCHEDULE

10-1100-01 | PLATE 09 | REV 0

FileName: P:\Projects\2010\10-1100-01\Dwg\Struct\Rev 0\10-1100-01_PLATE 09.dwg – Tab: PLATE 07 Plotted By: PZyla-Smith 11/04/11 [Mon 2:39pm]

24x36

APPENDICES

APPENDIX A

SUMMARY OF BIOLOGICAL PARAMETERS FOR KEY FISH SPECIES

Table 1
Summary of Biological Parameters for Key Fish Species Relevant for the Design of a Fishway at the Floodway Inlet Control Structure
(Prepared by North/South Consultants Inc.)

Common Name	Scientific Name	Season of main movement[1]	Red River Temp (ºC)[2]	Fish length (range, cm)[3]	Swimming Performance: Critical velocity (m/s), measured[4]	Swimming Performance: Max allowable velocity (m/s), calculated[5]	Swimming Performance: Velocities in fishway successfully ascended (m/s)	Swimming Performance: Burst speed (m/s)	Fishway design criteria: Minimum pool length (cm)	Fishway design criteria: Minimum pool depth (cm)	Fishway design criteria: Maximum gradient (%) or drop height (cm)	Comment	Reference
Channel Catfish	*Ictalurus punctatus*	June - early July, late Aug - mid Oct	15-28	40-110	-				300	100	20 cm		
								1.2				• For 1-year old fish of 20 cm fork length.	Beecham et al. 2007
												• Swimming performance has not been determined for catfish within the size range of mature fish (> 50 cm). Critical velocities for juvenile fish (14-15 cm) have been measured at 0.32-0.61 m/s.	Hocutt 1973 (cited in Beamish 1978) Beecham et al. 2007
						0.24-0.54						Sustained (>200 s) and prolonged (>20s, <200 min) swimming speeds of 0.4 m/s and 0.9-1.0 m/s, respectively have been measured for 1-year old fish of 20 cm fork length.	Hocutt 1973 (cited in Beamish 1978)
							<0.24-2.05					• For fish of 14-15 cm length at water temperatures ranging from 15-35ºC	Bunt et al. 2001
			11-23				Unknown					• From an assessment of two Denil FWs on the Grand River, ON; Stonecat (*Noturus flavus*) and Brown Bullhead (*Ameiurus nebulosus*) assumed to be representative of channel catfish.	Nicols 1968
							Unknown					• Large numbers of fish of unknown size (likely spawners) successfully passed a 37 m long "vertical baffle" FW consisting of 12 concrete pools (3 x 2.4 m) with 23 cm drops; a 37 m long concrete attraction flow channel with velocities of 0.6-0.9 m/s had to be passed before reaching the FW; water temperatures: 15-24ºC in May and June (Nicols 1968).	Willis 1994
							1.8-3.4 at 31cm depth; 0.1-1.0 at 125 cm depth					• 374 fish, i.e, 4.1% of all fish of all species (total length range: 51-92 cm, mean= 76 cm) captured within a 58 m long concrete "Step and Pool" FW at the St. Andrews Lock and Dam consisting of 25 concrete pools (1.5 m wide) with 15.2 cm drops. 51% of the fish were captured in the FW during a 4 day period in late September (total monitoring period 17 Jun-12 Oct, 1994).	Perillo 2006 Kynard et al. 2003
							0.34-2.14					• 6,900 fish, i.e., 26.3% of all non-anadromous species successfully passed a concrete "Step and Pool" FW at a 3.2 m high dam on the Schuylkill River in Philadelphia (tidal influence) consisting of 14 concrete pools (3.1 x 2.4 m). The fishway was video monitored 24/7 from 1 Apr-1 Jul in 2004-2006.	Aadland 2010
							<0.6 at the bottom; ~2 m at the surface of boulder weirs					• All 4 wild caught fish made multiple trips up an experimental FW (~17 m long, 1-m wide spiral flume, alternating inside and outside baffles, ~35 cm water depth, water temperature during tests: 8.5-25ºC); all passes were made at water temperatures >17ºC.	
												• Up to 820 fish/day (median ~200 fish/d) passed a pool-and-riffle FW (~73 m long, including a 20 m-long culvert connecting the uppermost pool with a reservoir through the embankment; 2.5% slope, 0.27 m high steps, <0.85 m3/s discharge) on the Otter Tail River (Red River headwaters). Fish passed between 26 Apr and 20 Jul, 2004 when the FW was monitored twice weekly from 6 Apr to 11 Aug.; passage of fish >600mm length did not peak until late July.	

1 – This includes spawning and summer and/or fall dispersal migrations; historically, the Floodway Control Structure has been in operation mainly between April and July

2 - Water temperature in the Red River was estimated for the timing of the migration using a combination of historical water temperature data and the spawning temperature ranges for each species

3 - Fork length of individuals most likely to use the fishway

4 - Measured and calculated from swimming performance tests in experimental flumes

5 - Calculated using the equation: Ground Speed = Critical Velocity – Water Velocity (from MNR 1981); assuming a 100 m fishway is to ascended within a 10 minute transit time (i.e., Ground Speed = 0.17 m/s);

Table 1 (Continued)
Summary of Biological Parameters for Key Fish Species Relevant for the Design of a Fishway at the Floodway Inlet Control Structure
(Prepared by North/South Consultants Inc.)

Common Name	Scientific Name	Season of main movement[1]	Red River Temp (ºC)[2]	Fish length (range, cm) [3]	Swimming Performance			Fishway design criteria				Comment	Reference
					Critical velocity (m/s), measured[4]	Max allowable velocity (m/s), calculated[5]	Velocities in fishway successfully ascended (m/s)	Burst speed (m/s)	Minimum pool length (cm)	Minimum pool depth (cm)	Maximum gradient (%) or drop height (cm)		
Goldeye	*Hiodon alosoides*	May - July; late Aug - mid Oct	10-30	15-40	0.6	0.43		?	?	?	?	• Calculated using regression equation from Jones et al. (1974) determined for two fish with a mean length of 22.5 cm tested at 12 ºC. • There is no information on the burst speed of this species.	
				11-23			Unknown					• 7255, i.e, 78.5% of all fish of all species (mean total length= 32 cm of the few fish measured) captured within a 58 m long "Step and Pool" FW at the St. Andrews Lock and Dam consisting of 24 concrete pools (1.5 m wide) with 15.2 cm drops. 80% of the fish used the FW from 17 Jun-22 Aug, and 16% of all fish passed on 21 Sep, the first day the FW entrance was passable after several days of too low water levels (total monitoring period 17 Jun-12 Oct, 1994).	Willis 1994 Schwalme et al. 1985
							<0.6 at the bottom; ~2 m at the surface of boulder weirs					• Although frequently caught downstream, goldeye did not use two Denil FWs (10 and 20% slope) and a vertical slot FW that were passed by other boreal species (e.g., pike, white sucker, burbot); this may have been partially due to the weir being passable to fish during periods of high water flow.	Aadland 2010
												• Goldeye passed a pool-and-riffle FW (~73 m long, including a 20 m-long culvert connecting the uppermost pool with a reservoir through the embankment; 2.5% slope, 0.27 m high steps, <0.85 m3/s discharge) on the Otter Tail River (Red River headwaters). Fish passed between 26 Apr (cf) and 29 Jun (cf), when the FW was monitored twice weekly from 23 Mar to 11 Aug.	

Table 1 (Continued)
Summary of Biological Parameters for Key Fish Species Relevant for the Design of a Fishway at the Floodway Inlet Control Structure
(Prepared by North/South Consultants Inc.)

Common Name	Scientific Name	Season of main movement[1]	Red River Temp (ºC)[2]	Fish length (range, cm)[3]	Swimming Performance				Fishway design criteria			Comment	Reference
					Critical velocity (m/s), measured[4]	Max allowable velocity (m/s), calculated[5]	Velocities in fishway successfully ascended (m/s)	Burst speed (m/s)	Minimum pool length (cm)	Minimum pool depth (cm)	Maximum gradient (%) or drop height (cm)		
Lake Sturgeon	*Acipenser fulvescens*	late May - mid June	11-18	50-200	0.97	0.80		1.8	400	150	4%; 20 cm	• Critical velocity and burst speed for fish >100 cm at a water temperature of 14ºC; burst speed were maintained for < 30 seconds; fish of 23-55 cm length had critical velocities of 0.36-0.43 cm/s and burst speeds of 0.9 m/s.	Scruton et al. 1998
					0.97							• Critical velocity of fish of 120 cm total length at a water temperature of 14ºC; Maximum velocity for a 120 cm fish to pass a 20 m long FW (with uniform flow): ~1.3 m/s. Large fish (106-132 cm) were unable to swim at speeds >1.8 m/s. Designs that require fish to jump from step to step are not conducive to pass sturgeon	Peake et al. 1995, 1997
					0.39							• Critical swimming speed of fish with a mean total length of 15.7 cm at 15 ºC.	Webb 1986
							0.34-2.14					• The motivation of 9-10 year old (86-113 cm total length), captive fish (“less fit than wild fish”) to voluntarily move up an experimental FW (~17 m long, 1-m wide spiral flume, alternating inside and outside baffles, ~35 cm water depth, 8-21ºC) differed strongly among individuals. Several fish moved up the fishway once or several times in multiple bouts of move-pause-move behavior. Water temperatures of 10.5-17ºC in the spring did not affect passage performance, but performance was poorer at temperatures <10-12ºC in the fall.	Kynard et al. 2003
												• Extrapolation of information from other sturgeon species (e.g., shovelnose sturgeon, shortnose sturgeon, white sturgeon) should be is possible because of the common sturgeon body design and empirical data indicating very similar swimming performance of green sturgeon, pallid sturgeon, shovelnose sturgeon, and lake sturgeon.	Cheong et al. 2006, Table 1
							0.51-2.42					• Adult White Sturgeon (135-198 cm length) swam at speeds of 2.5 m/s of up to 20m past baffles in a flume (24.4 m long, 2.1 m wide, 1.4 m deep). Swimming burst were followed by longer rest periods oriented into the current on the bottom	Webber et al. 2007

Table 1 (Continued)
Summary of Biological Parameters for Key Fish Species Relevant for the Design of a Fishway at the Floodway Inlet Control Structure
(Prepared by North/South Consultants Inc.)

Common Name	Scientific Name	Season of main movement[1]	Red River Temp (ºC)[2]	Fish length (range, cm)[3]	Swimming Performance: Critical velocity (m/s), measured[4]	Swimming Performance: Max allowable velocity (m/s), calculated[5]	Swimming Performance: Velocities in fishway successfully ascended (m/s)	Swimming Performance: Burst speed (m/s)	Fishway design criteria: Minimum pool length (cm)	Fishway design criteria: Minimum pool depth (cm)	Fishway design criteria: Maximum gradient (%) or drop height (cm)	Comment	Reference
Northern Pike	*Esox lucius*	April - May Late Aug - mid Oct	4-18	25-110		-			250	60	?		
					0.19-0.47							• Calculated for fish of 12-62 cm fork length using regression equation from Jones et al. (1974) determined at a water temperature of 12ºC.	
								2.8-3.4				• Burst speeds for fish with a mean fork length of 41.2 cm at water temperatures between 8-12ºC; burst speed maintained for <0.2 second.	Frith & Blake 1995 (cited in Wolter & Arlinghaus 2003)
													Peake 2001, 2008
							Unknown					• The willingness of fish (40-104 cm fork length) to enter 25 or 50-m raceways with water velocities of 0..35-1.2 m/s 8 cm off the bottom was correlated with fish length and water temperature, but not with current speed. The proportion of fish passing the raceway depended on current speed such that the proportion was lower at 1.2 m/s than at any of the other 8 speeds of <1.0 m/s used.	Willis 1994
							<0.24-2.05					• No pike were found among the 9,244 fish captured within a 58 m long "Step and Pool" FW at the St. Andrews Lock and Dam between 17 Jun and 12 Oct, 1994. The FW consisted of 25 concrete pools (1.5 m wide) with 15.2 cm drops.	Bunt et al. 2001
							0.7-1.7						Katopodis et al. 1991
							0.23-0.68					• None of the 11,810 fish captured from 30 Mar-17 Jul in two Denil FWs on the Grand River, ON were pike, while the species was present downstream of the weir	Schwalme et al. 1985
							0.52-1.13					• Assessment of two Denil FWs on the Fairford River, MB and on Cowan Lake, SK	Schwalme et al. 1985
												• Assessment of a vertical slot FW on the Lesser Slave River, AB; indicated are the 75% limits of median daily velocities (also for Denil FWs).	Gaboury et al. 1995
												• Assessment of two Denil FWs (10 and 20% slope) on the Lesser Slave River, AB	Gaboury et al. 1995
							<0.6 at the bottom; ~2 m at the surface of boulder weirs					• Pike were able to migrate upstream over a hydraulically diverse riffle with a slope of 10:1 to 20:1 and <0.4 m water surface elevation drop per riffle.	Aadland 2010
												• Pike were observed ascending a newly constructed Pool and Riffle FW on the Little Saskatchewan River in Rapid City, MB in 1993, and 56 (4.5%) of the 1241 fish caught near the FW exit from 15-28 April, 1994 were pike.	
												• Very few (<5 annually) pike passed a pool-and-riffle FW (~73 m long, including a 20 m-long culvert connecting the uppermost pool with a reservoir through the embankment; 2.5% slope, 0.27 m high steps, <0.85 m3/s discharge) on the Otter Tail River (Red River headwaters); the FW was monitored twice weekly from late March to early August.	

Table 1 (Continued)
Summary of Biological Parameters for Key Fish Species Relevant for the Design of a Fishway at the Floodway Inlet Control Structure
(Prepared by North/South Consultants Inc.)

Common Name	Scientific Name	Season of main movement[1]	Red River Temp (ºC)[2]	Fish length (range, cm)[3]	Swimming Performance: Critical velocity (m/s), measured[4]	Swimming Performance: Max allowable velocity (m/s), calculated[5]	Swimming Performance: Velocities in fishway successfully ascended (m/s)	Swimming Performance: Burst speed (m/s)	Fishway design criteria: Minimum pool length (cm)	Fishway design criteria: Minimum pool depth (cm)	Fishway design criteria: Maximum gradient (%) or drop height (cm)	Comment	Reference
Walleye	*Sander vitreus*	April - mid Oct	4-30	25-70	0.38-0.84				200	100	?	• Calculated for fish of 12-62 cm fork length using regression equation from Jones et al. (1974) determined at a water temperature of 19 ºC.	
					0.43-1.14			1.6-2.6				• Critical velocity and burst speed for fish of 18-67 cm fork length at water temperatures from 6-21ºC. The authors propose to use maximum sustained speeds (not prolonged speeds, i.e., U_{crit}) to set water velocity criteria for fishways. In this case, a 35 cm walleye could pass a fishway (culvert) of any length at 10ºC if the current speed was <0.42 m/s.	Peake et al. 2000
						0.63						• U_{crit} values from Jones et al. (1974)	Peake 2008
												• The willingness of fish (15-61 cm fork length) to enter 25 or 50-m raceways with water velocities of 0.35-1.2 m/s 8 cm off the bottom was correlated with fish length and water temperature, but not with current speed. The proportion of fish passing the raceway depended on current speed such that the proportion was lower at 1.2 m/s than at any of the other 8 speeds of <1.0 m/s used.	Haro et al. 2004
												• Wild fish caught at spawning time voluntarily ascended a 24 m long raceway without structural elements, and flow was turbulent without macroeddies (i.e., minimal opportunities for fish to take advantage of hydraulic structure). Median maximum distances swam against average current speeds of 1.7 (at 12.6 ºC water temperature), 2.7 (15.7 ºC), and 3.3 (10.3ºC) m/s were approximately 14, 8, and 3 m, respectively; many fish swam at speeds>10 body lengths/s.	Castro-Santos 2004; Castro-Santos 2005
							0.7-1.7; 0.34-2.14					Fish length (mean ~310 mm), temperature, and holding time below the raceway entrance had little effect on attempt rate or distance of ascent. Fish avoided the walls of the flume, swimming more than 20 cm away from either wall and ~20cm off the bottom. Optimal swimming speeds in prolonged mode and sprint mode were calculated as 2.4 and 7.7 body length/s, respectively.	Katopodis et al. 1991; Kynard et al. 2003
												• Assessment of two Denil fishways on the Fairford River, MB and on Cowan Lake, SK	Willis 1994
			22				Unknown					• All 3 tested, wild caught fish made one or multiple trips up an experimental FW (~19 and 38 m long, 1-m wide spiral flume, alternating inside and outside baffles, ~35 cm water depth, water temperature during spring and fall tests: 8.5-25ºC); all passes were made at water temperatures >17ºC.	Gaboury et al. 1995
												• 3 fish, i.e, only 0.03% of all fish of all species (total length range: 28-34 cm) captured within a 58 m long "Step and Pool" fishway at the St. Andrews Lock and Dam consisting of 25 concrete pools (1.5 m wide) with 15.2 cm drops. The fish were captured in the fishway at different times over the monitoring period 17 Jun-12 Oct, 1994).	Gaboury et al. 1995; Schwalme et al. 1985
							<0.6 at the bottom; ~2 m at the surface of boulder weirs					• Although walleye were observed ascending a newly constructed Pool and Riffle FW on the Little Saskatchewan River in Rapid City, MB in 1993, none of the 1241 fish cauught near the FW exit from 15-28 April, 1994 were walleye; alternative spawning habitat was present below the dam.	Bunt et al. 2000
													Aadland 2010
													Fernet 1984; Dexter & Ledet 1997 (cited in Bunt et al. 2000, p. 483L); Schmutz et al. 1995; Bunt et al. 2001; Perillo 2006; Becker 2008

Table 1 (Continued)
Summary of Biological Parameters for Key Fish Species Relevant for the Design of a Fishway at the Floodway Inlet Control Structure
(Prepared by North/South Consultants Inc.)

					Swimming Performance				Fishway design criteria				
Common Name	**Scientific Name**	**Season of main movement**[1]	**Red River Temp (°C)**[2]	**Fish length (range, cm)**[3]	**Critical velocity (m/s), measured**[4]	**Max allowable velocity (m/s), calculated**[5]	**Velocities in fishway successfully ascended (m/s)**	**Burst speed (m/s)**	**Minimum pool length (cm)**	**Minimum pool depth (cm)**	**Maximum gradient (%) or drop height (cm)**	**Comment**	**Reference**
												• Fish were able to migrate upstream over a hydraulically diverse riffle with a slope of 10:1 to 20:1 and <0.4 m water surface elevation drop per riffle	Aadland 2010
												• Although frequently caught downstream, walleye did not use two Denil FWs (10 and 20% slope) and a vertical slot fishway that were passed by other boreal species (e.g., pike, white sucker, burbot); this may have been partially due to the weir being passable to fish during periods of high water flow.	Fernet 1984; Dexter & Ledet 1997 (cited in Bunt et al. 2000, p. 483L); Schmutz et al. 1995; Bunt et al. 2001; Perillo 2006; Becker 2008
												• Attraction efficiency of 23 radio-tagged fish into a Denil FW on the Grand River in Dunnville, ON was 21% and none of the five fish that entered ascended more than 35% of the FW length, making a total of 17 attempts.	
												• Few walleye passed a pool-and-riffle FW (~73 m long, including a 20 m-long culvert connecting the uppermost pool with a reservoir through the embankment; 2.5% slope, 0.27 m high steps, <0.85 m3/s discharge) on the Otter Tail River (Red River headwaters); the FW was monitored twice weekly from late March to early August.	
												• Generally, walleye (and the closely related European pike-perch, *Sander lucioperca*) seem not to use fishways easily. Bunt et al. (2001) have speculated that hydraulic conditions (e.g., turbulence, entrained air, back currents and whirlpools) in fishway resting areas modify walleye behavior as to delay or prevent successful upstream passage.	

APPENDIX B

DETAILED COST ESTIMATE
1 IN 100 YEAR DESIGN

Inlet Control Structure Fishway
Preliminary Design - Detailed Cost Estimate
1:100 year Design

ITEM	Quantity	Unit	Unit Cost	Cost
DIRECT COSTS				
Mobilization and Demobilization	1	lump sum	$200,000	**$200,000**
Fishway Entrance and Channel				
Excavation	15,000	cubic metre	$6	$90,000
Fill Placement	30,000	cubic metre	$5	$150,000
Channel Rockfill	10,000	cubic metre	$75	$750,000
Riffle Rockfill / Boulders	2,500	cubic metre	$100	$250,000
Rockfill - Erosion Protection	4,000	cubic metre	$75	$300,000
Geomembrane liner	2,000	square metre	$20	$40,000
Wick Drains	1	lump sum	$500,000	$500,000
			Subtotal	**$2,080,000**
Transition Structure				
Excavation / Fill Placement - **Included within Fishway Chute Excavation**	0	cubic metre	$0	$0
Transition Structure Concrete & Profile fish chute (Supply, formwork, placement and rebar)	132	cubic metre	$1,300	$171,600
Valve Chamber Roof Structure	1	lump sum	$7,900	$7,900
Inlet Fishway Chute (I.e. weir, divider plates, water chamber under concrete chute)	1	lump sum	$12,500	$12,500
Miscellaneous Structural (I.e. Handrails, Access Ladders,Valve Room Door & frame)	1	lump sum	$20,000	$20,000
Miscellaneous Mechanical (I.e. Fitting, Flanges, Butterfly valves)	1	lump sum	$115,000	$115,000
Stoplogs for emergency closure	1	lump sum	$100,000	$100,000
1219 mm Slide Gate on downstream side (Supply and Installation)	1	lump sum	$45,000	$45,000
			Subtotal	**$427,000**
Conduit through the Dyke / Chute				
1200 mm Steel Pipe with Coating (Supply and Installation)	45	lineal metre	$3,000	$135,000
1524 mm - 1200 mm Transition Half Pipe with Coating	1	lump sum	$20,000	$20,000
1200 mm Steel Half Pipe with Coating / anchoring system	55	lineal metre	$1,500	$82,500
Fill (Compacted Clay)	7,000	cubic metre	$5	$35,000
Bentonite Seal	400	cubic metre	$150	$60,000
Excavation	7,500	cubic metre	$10	$75,000
Road Sub-base Granular Fill	500	cubic metre	$60	$30,000
Asphalt	100	cubic metre	$250	$25,000
1219 mm Slide Gate on upstream side (Supply and Installation)	1	lump sum	$45,000	$45,000
South End Primary Slide Gate Structure (Concrete & Steel Superstructure)		lump sum	$38,000	$38,000
			Subtotal	**$545,500**
Recovery Pool and Fishway Exit Channel				
Excavation	45,000	cubic metre	$6	$270,000
Rockfill	2,000	cubic metre	$75	$150,000
			Subtotal	**$420,000**
Deflector Berm				
Rockfill	5,000	cubic metre	$75	$375,000
			Subtotal	**$375,000**
Pumping Station & Water Supply Line				
300 HP Pumps (Supply and Installation)	2	lump sum	$260,000	$520,000
Water Supply Line [24" HDPE pipe] (Supply and Installation) - Double Wall through East Dike	210	lineal metre	$700	$147,000
Excavation - **Included withFishway Exit Channel Excavation**	0	cubic metre	$0	$0
Rockfill - Channel and Access Road	1,000	cubic metre	$75	$75,000
Pumping Station Concrete (Supply, formwork, and placement) & Rebar	122	cubic metre	$1,560	$190,320
Roof Structure (Steel Beams, Steel Checker Plate, Hatch Covers)	1	lump sum	$60,000	$60,000
Fish Screen & Trashracks Structure - Assembled Panels (Supply and Installation)	1	lump sum	$103,000	$103,000
Pumping Station Electrical (Boxes, Frames, Connections)	1	lump sum	$17,000	$17,000
Miscellaneous Structural (I.e. Handrails, Locator Poles, Access Ladders, Access Road Gate)	1	lump sum	$32,000	$32,000
Miscellaneous Mechanical (I.e. Fitting, Flanges, Sump Pump)	1	lump sum	$166,000	$166,000
			Subtotal	**$1,310,320**
Electrical System and Housing Pad				
Fill Placement (assume Rockfill)	2,000	cubic metre	$75	$150,000
Electrical building and Concrete Slab	1	lump sum	$18,000	$18,000
Underground Power and Control Feeders	1	lump sum	$58,000	$58,000
Soft Sarters, Lighting, Controls	1	lump sum	$74,000	$74,000
Miscellaneous Electrical (Ie. PVC pipes under road for Hydro feeders)	1	lump sum	$6,500	$6,500
Hydro Service	1	lump sum	$56,000	$56,000
			Subtotal	**$362,500**
Pumping Station Access Road				
Excavation	1,500	cubic metre	$6	$9,000
Granular	2,000	cubic metre	$75	$150,000
			Subtotal	**$159,000**
Public Safety and Integration to Duff Roblin Park				
Fencing (Supply and Installation)	500	lineal metre	$75	$37,500
Signage	1	lump sum	$5,000	$5,000
Miscellaneous	1	lump sum	$5,000	$5,000
			Subtotal	**$47,500**
Construction Access & Care-of-Water				
Temporary Construction Access Roads	1	lump sum	$300,000	$300,000
Cofferdam (Installation and Removal)	1	lump sum	$500,000	$500,000
			Subtotal	**$800,000**
Construction Activities and Site Restoration				
Geotechnical Instrumentation and Monitoring	1	lump sum	$50,000	$50,000
Temporary Erosion & Sediment Control Measures	1	lump sum	$50,000	$50,000
			Subtotal	**$100,000**
TOTAL DIRECT PROJECT COSTS				**$6,827,000**
INDIRECT COSTS				
Contingency on Construction Costs			15.0%	$946,050
Detailed Engineering			5.0%	$388,653
Construction Supervision			10.0%	$777,305
Permitting/Consultation/Environmental			4.0%	$273,080
Compensation Measures for HADD		lump sum	$250,000	$250,000
Fish Passage Monitoring Program		lump sum	$150,000	$150,000
TOTAL INDIRECT PROJECT COSTS				**$2,785,000**
TOTAL PROJECT COST				**$9,612,000**

APPENDIX C

DETAILED COST ESTIMATE
1 IN 700 YEAR DESIGN

Inlet Control Structure Fishway
Preliminary Design - Detailed Cost Estimate
1:700 year Design

ITEM	Quantity	Unit	Unit Cost	Cost
DIRECT COSTS				
Mobilization and Demobilization	1	lump sum	$200,000	**$200,000**
Fishway Entrance and Channel				
Excavation	21,000	cubic metre	$6	$126,000
Fill Placement	48,000	cubic metre	$5	$240,000
Channel Rockfill	14,000	cubic metre	$75	$1,050,000
Riffle Rockfill / Boulders	3,750	cubic metre	$100	$375,000
Rockfill - Erosion Protection	4,000	cubic metre	$75	$300,000
Geomembrane liner	2,800	square metre	$20	$56,000
Wick Drains	1	lump sum	$1,000,000	$1,000,000
			Subtotal	**$3,147,000**
Transition Structure				
Excavation / Fill Placement - **Included within Fishway Chute Excavation**	0	cubic metre	$0	$0
Transition Structure Concrete & Profile fish chute (Supply, formwork, placement and rebar)	100	cubic metre	$1,300	$130,000
Valve Chamber Roof Structure	1	lump sum	$7,900	$7,900
Inlet Fishway Chute (I.e. weir, divider plates, water chamber under concrete chute)	1	lump sum	$12,500	$12,500
Miscellaneous Structural (I.e. Handrails, Access Ladders,Valve Room Door & frame)	1	lump sum	$20,000	$20,000
Miscellaneous Mechanical (I.e. Fitting, Flanges, Butterfly valves)	1	lump sum	$115,000	$115,000
Stoplogs for emergency closure	1	lump sum	$100,000	$100,000
1219 mm Slide Gate on downstream side (Supply and Installation)	1	lump sum	$45,000	$45,000
			Subtotal	**$385,400**
Conduit through the Dyke / Chute				
1200 mm Steel Pipe with Coating (Supply and Installation)	25	lineal metre	$3,000	$75,000
1524 mm - 1200 mm Transition Half Pipe with Coating	1	lump sum	$20,000	$20,000
1200 mm Steel Half Pipe with Coating / anchoring system	70	lineal metre	$1,500	$105,000
Fill (Compacted Clay)	7,000	cubic metre	$5	$35,000
Bentonite Seal	300	cubic metre	$150	$45,000
Excavation	5,500	cubic metre	$10	$55,000
Road Sub-base Granular Fill	500	cubic metre	$60	$30,000
Asphalt	100	cubic metre	$250	$25,000
1219 mm Slide Gate on upstream side (Supply and Installation)	1	lump sum	$45,000	$45,000
South End Primary Slide Gate Structure (Concrete & Steel Superstructure)		lump sum	$38,000	$38,000
			Subtotal	**$473,000**
Recovery Pool and Fishway Exit Channel				
Excavation	60,000	cubic metre	$6	$360,000
Rockfill	2,000	cubic metre	$75	$150,000
			Subtotal	**$510,000**
Deflector Berm				
Rockfill	5,000	cubic metre	$75	$375,000
			Subtotal	**$375,000**
Pumping Station & Water Supply Line				
300 HP Pumps (Supply and Installation)	2	lump sum	$260,000	$520,000
Water Supply Line [24" HDPE pipe] (Supply and Installation) - Double Wall through East Dike	240	lineal metre	$700	$168,000
Excavation - **Included withFishway Exit Channel Excavation**	0	cubic metre	$0	$0
Rockfill - Channel and Access Road	1,000	cubic metre	$75	$75,000
Pumping Station Concrete (Supply, formwork, and placement) & Rebar	122	cubic metre	$1,560	$190,320
Roof Structure (Steel Beams, Steel Checker Plate, Hatch Covers)	1	lump sum	$60,000	$60,000
Fish Screen & Trashracks Structure - Assembled Panels (Supply and Installation)	1	lump sum	$103,000	$103,000
Pumping Station Electrical (Boxes, Frames, Connections)	1	lump sum	$17,000	$17,000
Miscellaneous Structural (I.e. Handrails, Locator Poles, Access Ladders, Access Road Gate)	1	lump sum	$32,000	$32,000
Miscellaneous Mechanical (I.e. Fitting, Flanges, Sump Pump)	1	lump sum	$166,000	$166,000
			Subtotal	**$1,331,320**
Electrical System and Housing Pad				
Fill Placement (assume Rockfill)	2,000	cubic metre	$75	$150,000
Electrical building and Concrete Slab	1	lump sum	$18,000	$18,000
Underground Power and Control Feeders	1	lump sum	$58,000	$58,000
Soft Sarters, Lighting, Controls	1	lump sum	$74,000	$74,000
Miscellaneous Electrical (Ie. PVC pipes under road for Hydro feeders)	1	lump sum	$6,500	$6,500
Hydro Service	1	lump sum	$56,000	$56,000
			Subtotal	**$362,500**
Pumping Station Access Road				
Excavation	1,500	cubic metre	$6	$9,000
Rockfill / Granular	1,500	cubic metre	$75	$112,500
			Subtotal	**$121,500**
Public Safety and Integration to Duff Roblin Park				
Fencing (Supply and Installation)	500	lineal metre	$75	$37,500
Signage	1	lump sum	$5,000	$5,000
Miscellaneous	1	lump sum	$5,000	$5,000
			Subtotal	**$47,500**
Construction Access & Care-of-Water				
Temporary Construction Access Roads	1	lump sum	$300,000	$300,000
Cofferdam (Installation and Removal)	1	lump sum	$500,000	$500,000
			Subtotal	**$800,000**
Construction Activities and Site Restoration				
Geotechnical Instrumentation and Monitoring	1	lump sum	$50,000	$50,000
Temporary Erosion & Sediment Control Measures	1	lump sum	$50,000	$50,000
			Subtotal	**$100,000**
TOTAL DIRECT PROJECT COSTS				**$7,853,000**
INDIRECT COSTS				
Contingency on Construction Costs			15.0%	$1,099,950
Detailed Engineering			5.0%	$447,648
Construction Supervision			10.0%	$895,295
Permitting/Consultation/Environmental			4.0%	$314,120
Compensation Measures for HADD		lump sum	$250,000	$250,000
Fish Passage Monitoring Program		lump sum	$150,000	$150,000
TOTAL INDIRECT PROJECT COSTS				**$3,157,000**
TOTAL PROJECT COST				**$11,010,000**