TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

5.0 PHYSICAL ENVIRONMENT

5.1 INTRODUCTION

The assessment of the physical environment involves evaluation of the effects of the Project on the Water Regime, Groundwater, Erosion and Sedimentation, Drainage, Ice Processes, Climate, and Physiography, Geology and Soils. The effects of the Project on each of these areas are summarized within this report.

5.2 APPROACH AND METHODOLOGY

5.2.1 Categories of Impact Assessment

The categories of impact assessment used were based on both the *Guidelines for the Preparation of an Environmental Impact Statement for the Red River Floodway Expansion Project* and areas that were identified of particular interest during the public consultation process. The categories of the physical environment that were considered in the impact assessment include:

- water regime;
- groundwater;
- erosion and **sedimentation**;
- drainage;
- ice processes;
- surface water quality;
- climate, noise and air quality; and
- physiography, geology and soils.

5.2.2 Approach to Impact Assessment

A complete discussion of the assessment approach is provided in Chapter 2. Aspects particular to the Physical Environment Assessment are discussed in this sub-section.

The assessment approach involves assessing the effects of the proposed Floodway Expansion Project (the Project) as compared to the baseline of the Existing Floodway. It does not include an explicit assessment of the effects of the Existing Floodway, although, where relevant, effects of the Existing Floodway are described in baseline conditions or considered in cumulative effects. The *Guidelines for the Preparation of an Environmental Impact Statement for the Red River Floodway Expansion Project* requires that the following components of the physical environment be described:

General:

- general climate conditions with sufficient data to predict the effect of the Project on climate and the potential effects of climate on the Project over time;

- local air quality potentially affected by the Project;
- ambient noise levels in the Project area; and
- local and regional soil, land use and geology.

Hydrology and Hydrogeology:

- local and regional hydrogeology;
- existing range of flows and water levels in the context of the operation of the existing flood control system;
- ice conditions, including changes during the winter and variability from year to year;
- existing shoreline environment and the rate of shoreline erosion and recession based on long term monitoring programs; and
- nature and extent of existing sediment deposition and shoreline debris.

During the public consultation process, the public identified certain aspects of the physical environment as being of particular interest. This section has been structured to this information. The discussion of the hydrology and hydrogeology components has been divided into specific topics (i.e., water regime, groundwater, ice processes) to enable easy reference to these particular topics of interest.

This section has been structured to provide an evaluation of the Project effects on each of the above aspects of the physical environment. Each section follows the same basic outline and begins with a brief description of baseline conditions. The environmental effects during each phase (i.e., construction, inactive, spring operation, extreme event, summer operation) of the proposed Floodway Expansion Project are stated.

These effects, after consideration of mitigation measures and overlapping or cumulative effects from other projects, are then judged as to their significance to the physical environment.

5.2.3 Geographic Boundaries

The study area for the physical environment, in general considered the Floodway Study Region, is described in Section 2.1 and Figure 2-1. For specific environmental effects, the study area was frequently defined to correspond to the geographic extent of that particular effect.

5.2.4 Source of Effects

The potential sources of effects on the physical environment include:

- channel widening and deepening;
- disposal of excavation materials;
- dewatering of the groundwater at the bridges or aqueduct into the Floodway during construction;
- revegetation of the disturbed portion of the Expanded Floodway Channel; and
- operation of the Project.

5.2.5 Assessment of Scientific Uncertainties

The environmental assessment discussed in the main report used various methods such as collection of data, analysis of past effects and trends, cumulative effects, and the use of computer models to determine effects. The results of these analyses were then used to estimate the effects of the Project and draw judgments on residual effects and their significance for each of the issues discussed.

One of the key challenges in any scientific analysis is to estimate the areas of uncertainty and whether the uncertainty could change the conclusions of the assessment. If the uncertainty is great enough to change the assessment, further analysis and/or data collection is required.

The major issues in the physical environment assessment were reviewed in order to test the uncertainty determination. The steps used are as follows:

1) Determine potential areas of uncertainty in the scientific analysis.

2) Determine whether this type of uncertainty changes the Existing Floodway effects assessment and the Expanded Floodway effects assessment in the same manner and magnitude. If the change in the effect due to uncertainty for the existing environment and for the Project is in the same direction and magnitude, then there is no potential to change the significance or non-significance determination.

3) If the uncertainty only affects the Project or affects the Project differently than the Existing Floodway, then a determination must be made as to whether the magnitude of the uncertainty is large enough to potentially change the determination of significance or non-significance.

5.3 WATER REGIME

5.3.1 Approach and Methodology

5.3.1.1 Effects Assessment

The methods used to estimate the water flows and water levels in the Red River and the Floodway during inactive and spring operation of the Floodway are discussed in this sub-section. To estimate the base flow in the Floodway during non-operational conditions, a temporary weir was placed in the Floodway low-flow channel in January 2004 to measure these flows over the winter (KGS 2004b). Changes in the base flow into the Floodway were estimated using computer-based groundwater models, which calculate discharges to the Floodway.

The water levels and flows for existing and future conditions were estimated using various recognized computer-based hydraulic models. These hydraulic models have been calibrated for various historic flood events up to, and most importantly, the Flood of 1997. As discussed later, the expansion of the Floodway Channel is not expected to change flows and water levels relative to those that would occur in the Existing Floodway for lower magnitude floods. The flows and water levels in the Expanded Floodway are expected to be different than flows and water levels in the Existing Floodway for floods that are at or above the order of magnitude of the 1997 flood.

In order to estimate and illustrate the effects, four large flood scenarios were assessed. The large floods include the 100-year flood event (similar to 1997), a 120-year return period event, a 225-year return period event, and a 700-year return period event. These four scenarios and the associated peak Red River discharge at James Avenue under natural conditions are shown in Table 5.3-1.

Table 5.3-1
Large Floods Used to Assess Effects of Floodway Expansion Project

Return Frequency	Natural Conditon Flow at James Avenue		Comment on Magnitude
	Cms	Cfs	
1 in 100 year	4,600	163,000	Similar to 1997 flood
1 in 120 year	4,900	173,000	Larger than 1997 flood
1 in 225 year	5,900	208,000	Similar to 1826 flood, and maximum capacity of Existing Floodway
1 in 700 year	7,700	272,000	Larger than any flood recorded historically and selected as the Design Flood based on cost-benefit analysis

Natural flow conditions at James Avenue refers to the peak flow which would occur without the Floodway, the Portage Diversion, or the Shellmouth Dam on the upper Assiniboine. Since this natural condition at James Avenue can be made up of various flows from the Assiniboine and Red Rivers, specific assumptions were made for the flow on the Assiniboine River. A detailed description of the peak flows in each segment of the river upstream of the Inlet, downstream of the Inlet, in the Floodway Channel, downstream of the Floodway Outlet, and in the Assiniboine River, is shown in Appendix 5A. In order to determine how the Floodway Inlet gate structure would be operated during each scenario and how the flows would be split between the Red River and the Existing Floodway and the Project, the Manitoba Water Resources Branch simulated each flood using the MIKE 11 hydrodynamic river model. MIKE 11 is a linear 1-dimensional mathematical model and was developed by the Danish Hydraulics Institute (DHI) and is used around the world for prediction of flood routing and water levels in river basins. Water levels upstream of the Inlet and throughout Winnipeg were calculated by the MIKE 11 model. The results from this model were then provided to the lead engineering consultants (KGS/Acres/UMA 2004a), who performed additional hydraulic analysis using the Hydrologic Engineering Center is River Analysis System (HEC-RAS) Model. This model was developed by the U.S. Army Corp of Engineers. The HEC-RAS model was used to calculate water levels in the Red River downstream of Winnipeg and the Floodway for the given flows. Water levels along the rivers and in the Floodway were calculated for both the Existing

Floodway and for the Project. In the following sections, water levels for key locations shown on Figure 5.3-1 will be compared to illustrate the effects of the Project.

When calibrating an hydraulic model, data collected in the field is used to validate that the hydraulic model predictions are reasonably correct for that scenario. The model is then used to simulate future and different scenarios with larger floods. There is inherent uncertainty in these predictions. For the same flow, hydraulic models could predict levels throughout the system ½ foot higher or ½ foot lower, for example. This uncertainty would be the same in manner and magnitude for the Existing Floodway and proposed Expanded Floodway Project. If the models predict levels ½ foot higher than actual for the Existing Floodway, they also will predict ½ foot higher than actual for the Expanded Floodway. Therefore, the analysis of difference in water levels upstream within the City and downstream for the various flood scenarios would be essentially the same. This uncertainty would not change the determination of significance of water levels as predicted by the models.

Another uncertainty in hydraulic simulations is whether the Floodway will be maintained in order to keep vegetative growth to the same level as estimated in the design. Growth of willows and other brush in the Floodway due to lack of maintenance could lower the capacity of the Floodway. This lack of maintenance is equally likely with or without the Expanded Floodway. Therefore, although lack of maintenance could lead to decreased capacity and therefore, potentially higher than predicted water levels within and especially upstream of the City of Winnipeg, it is a factor applicable to the Existing Floodway and the Project. As a result assessments of these effects on water levels would not change. The maintenance plan is discussed in Section 4.15.

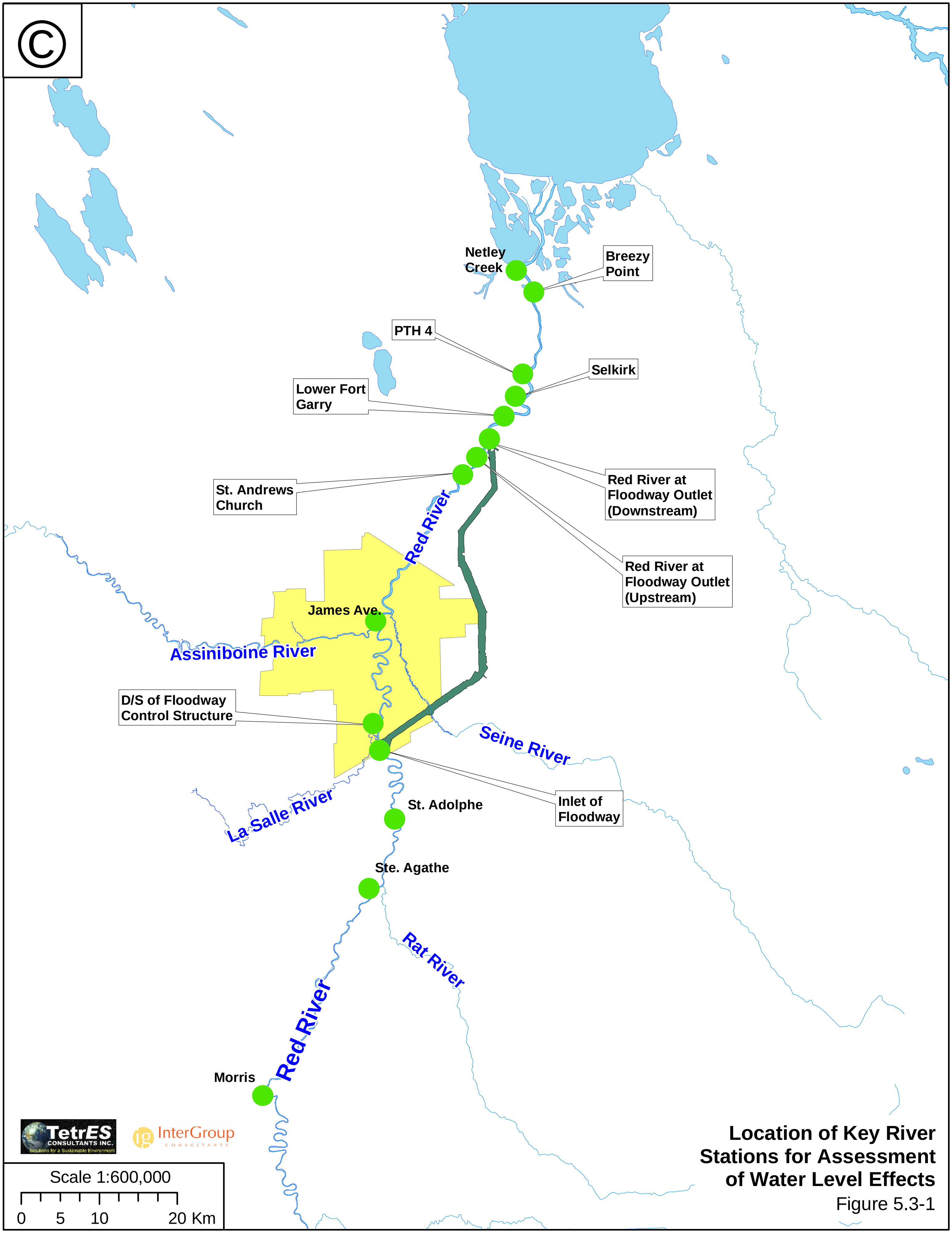
5.3.1.2 Sources of Effects

The increased capacity of the Expanded Floodway will affect the water levels in the Red River when the Floodway is active. Dewatering of groundwater at bridges and the City of Winnipeg Aqueduct during construction has the potential to affect water flows in the channel.

5.3.2 Existing Environment

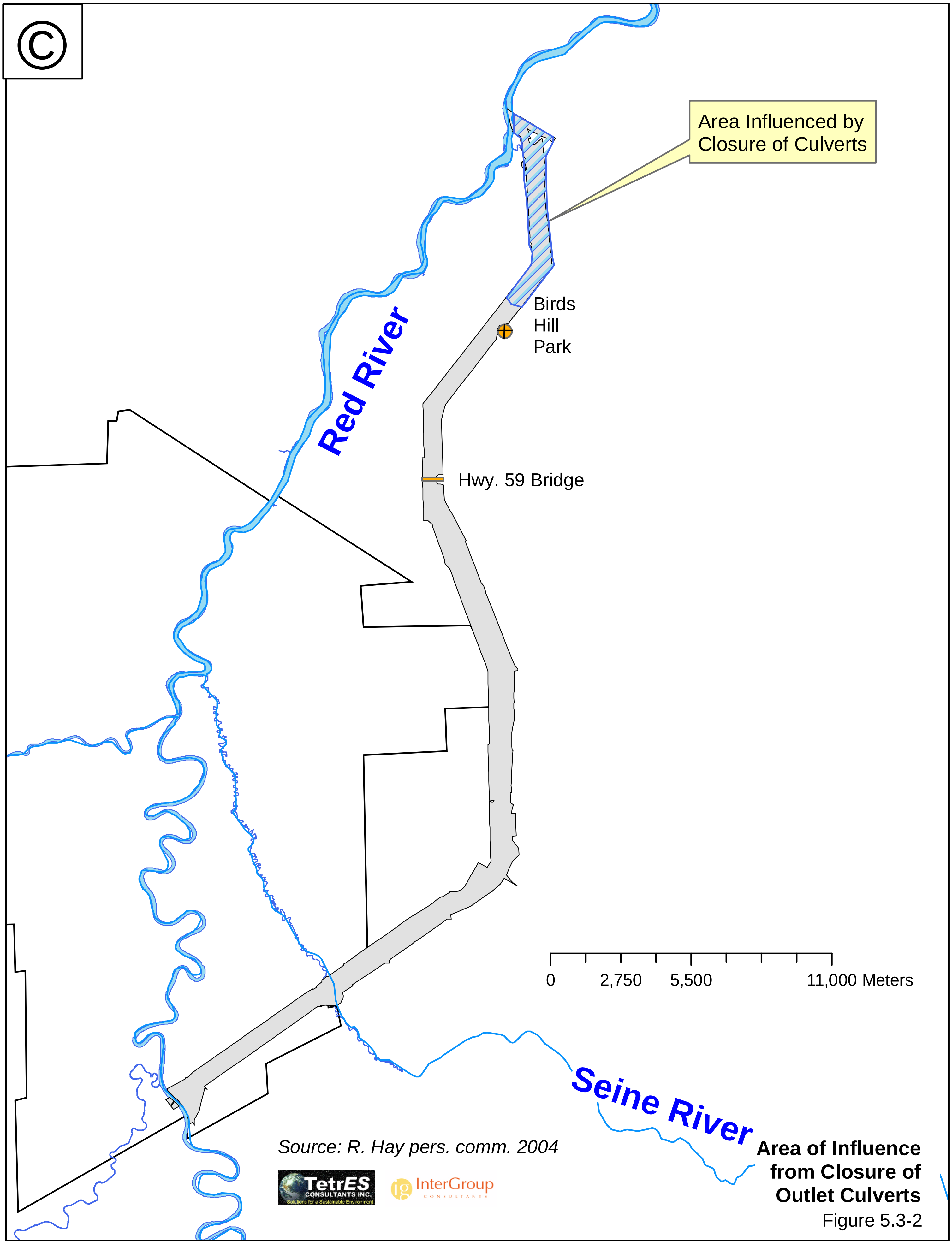
5.3.2.1 Inactive Operation

KGS estimated the magnitude of groundwater flow in late February at about 0.013 m^3/s (1,700 Igpm) (KGS 2004a). The depth of water in the low-flow channel of the Floodway is variable and ranges from 1.0 m (3 feet) to 2.0 m (6 feet). Rainfall events that occur during the inactive operations increase the flows in the channel, however, these flows are well below the capacity of the channel. At the Outlet to the Floodway water levels are controlled by the Outlet weir elevation and two low-flow central culverts (1.07 m diameter each) located below the weir elevation. These culverts have gates that were operated according to an agreement with Ducks Unlimited to maintain water in the lower (northern) reach of the Floodway Channel. Water levels were maintained at the higher level from late May to mid- to late October. The extent of this backwater effect from the impoundment was 7.2 km (4.5 miles; Hay pers. comm. 2004b). upstream from the Outlet weir (see Figure 5.3-2).



Location of Key River Stations for Assessment of Water Level Effects

Figure 5.3-1



Area of Influence from Closure of Outlet Culverts

Figure 5.3-2

5.3.2.2 Floodway Spring Operation

Three major flood control works were constructed to protect Winnipeg from flooding; the Floodway, the Portage Diversion and the Shellmouth Reservoir (International Red River Basin Task Force December 1997). The Portage Diversion carries flood flow from the Assiniboine River to Lake Manitoba and the Shellmouth reservoir is used to store floodwater. These flood control works on the Assiniboine River reduce water levels during a flood along the Assiniboine River, in Winnipeg, downstream on the Red River in Selkirk and the surrounding region. Additionally, many towns outside the City of Winnipeg are protected from flooding by ring dykes. Following the 1997 flood, further flood protection was added including raising of ring dykes and individual property flood proofing the Red River Valley and the addition of the Grand Point Diversion and dykes. The Floodway is currently operated according to a "state of nature" discharge curve developed using conditions in Winnipeg following the 1950 flood and a set of operating rules updated after the 1997 flood (Red River Floodway Operation Review Committee 1999). These rules were accepted by Manitoba on and Canada in 2000. An updated "state-of-nature" discharge-rating curve has been developed (Acres 2004c) based on current computer based hydraulic analysis and this is used to assess the existing or baseline operation. This "state-of-nature" rating curve is used to calculate the "natural" elevation at the Inlet which is maintained by operation of the Inlet Control Structure in Rule 1. The operating rules are discussed below.

- operating 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, until the water surface elevation at the James Avenue gauge reaches el. 24.5 ft., or the river level anywhere along the Red River within the City of Winnipeg reaches 2 ft. below the Flood Protection Level of el. 27.8 ft.
- operating rule 2:
  - once the river levels within Winnipeg reach the limits described in Rule 1, the level in Winnipeg should be held constant while river levels south of the Control Structure continue to rise. Furthermore, if forecasts indicate that river levels south of Winnipeg will rise more than 2 ft. above natural, the City must proceed with emergency raising of the dykes and temporary protection measures on the sewer systems 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's entrance be allowed to rise to a level that infringes on the allowable freeboard on the Floodway West Embankment (Winnipeg side) and the West Dyke.
- operating rule 3:
  - for extreme floods, where the water level at the Floodway Channel's entrance reaches the maximum level that can be held by the Floodway West Embankment and the West Dyke, the river level must not be permitted to exceed that level. All additional flows must be passed through Winnipeg.

An illustration of the Floodway operating rules based on this up-to-date curve is shown in Figure 5.3-3. This figure shows how the water level at the Floodway Inlet changes during each operational rule. As shown in this figure, as long as the water elevation at the James Avenue gauge is below 24.5 ft and the river level within the City limits is 2 ft below the flood protection level of 27.8 ft, the Floodway is operated to maintain “natural” water levels on the Red River at the Existing Floodway entrance. This is shown as “Rule 1” on Figure 5.3-3. When the elevations exceed the limits of Rule 1, the River levels within the City are held at a constant elevation by raising the water levels at the Existing Floodway Inlet and allowing more water to pass through the Floodway. This is shown as “Rule 2” on Figure 5.3-3. When the water level at the Floodway Inlet reaches the maximum level that can be held by the Floodway West Embankment and the West Dyke, the river level cannot exceed that level and all additional flows must be allowed to pass through the City of Winnipeg. Thus the water levels at the Existing Floodway Inlet remain constant at the maximum level. This is illustrated as “Rule 3” on Figure 5.3-3.

It should be noted that the current existing condition is different from 1997 conditions and the previous Flood Protection Study (KGS 2001). The Rule 1 curve is based on a newly-calculated “natural” rating curve. Rule 2 is lower at floods greater than 1997 due to improvements made at the Inlet.

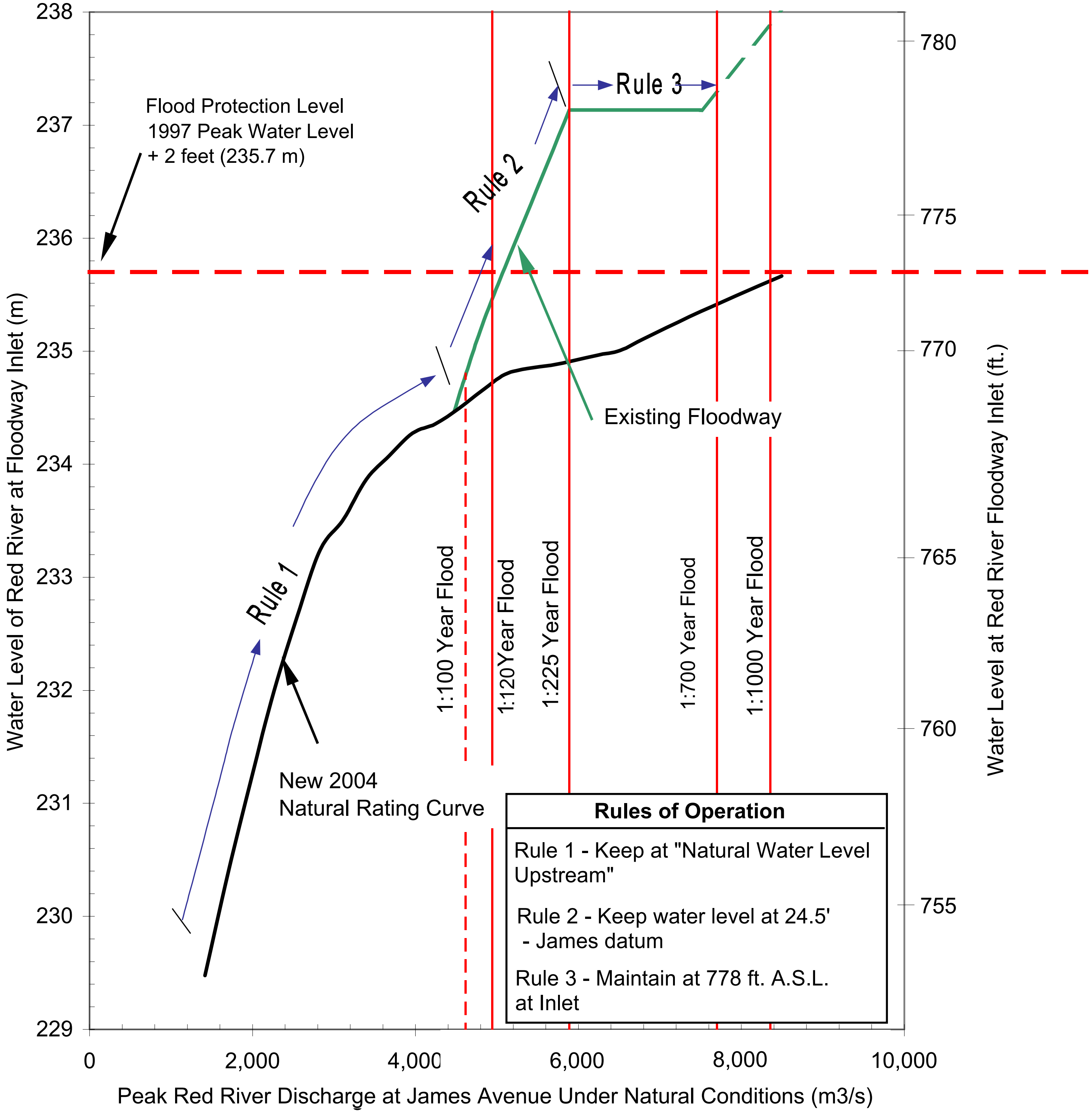
5.3.2.3 Emergency Summer Operation

In 1993, higher than normal summer water levels occurred in July in combination with heavy thunderstorms and significant basement flooding occurred within Winnipeg. When the river is high the combined sewers are unable to provide relief from large rainstorms. Flood Pumping Stations are activated to lift the combined sewage up into the river. In 1993, the City of Winnipeg Flood Pumping Stations, which were designed for less intense spring rain showers, were overwhelmed increasing extensive basement flooding damage due to sewer backups. The total damages of the 1993 storms were estimated at $100 million.

In 2002 and 2004, the Floodway gates were operated to lower water levels within the City of Winnipeg during the summer. The Minister of Water Stewardship ordered the operation of the gates based on the combination of high water levels within Winnipeg and the threat of thunderstorms. In 2004, the water level at James Avenue was 15-16 ft when the Minister ordered the emergency operation of the gates on June 10, 2004. Water levels dropped to between 10 to 11 ft above James Avenue datum by June 11, 2004. Water levels at the Inlet were raised above natural levels to 756-757 ft (230.4 to 230.7 m). Flooding of low-lying areas occurred, including market gardens, and the Minister has committed to full compensation of those affected by flooding above “natural” water levels (caused by emergency operation of the gates).

5.3.3 Effects and Mitigation

The effects assessment evaluated the variation from the baseline water regime during each phase of the Project. The cumulative effects of the Existing Floodway has been integrated into effects analysis. Other future projects that have the potential to result in cumulative effects include upstream storage such as the Shellmouth Reservoir Upgrades drainage upstream including Devil’s Lake drainage, and the Winnipeg dyking system.



Source: KGS/Acres/UMA 2004a

Application of Floodway Operation Rules for Existing Floodway

Figure 5.3-3

rules
ms\01\0211\09

5.3.3.1 Construction

During, the construction phase of the project there may be partial effects on the water regime in spring as the Floodway capacity is increased. The full effects of the Project are discussed in Section 5.3.3.3. It is planned that construction will not occur during the spring operating season in April and May, and summer operation of the Existing Floodway will not occur during construction unless emergency conditions occur. Summer operation has typically occurred when there is a combination of high water levels within Winnipeg and a risk of thunderstorms pose a risk to basement flooding. If these conditions occur during construction, the decision to implement emergency summer operations will cause a delay in construction. For this reason it is unlikely that summer operations will occur during construction. This may increase the risk of basement flooding in Winnipeg, however, the cost of increased risk of basement flooding in Winnipeg over 5 years is low compared to the flood protection benefits of the Project (discussed in Section 8.4). Accordingly, the likelihood of flooding of low-lying areas upstream of the Inlet will be reduced.

5.3.3.2 Operation - Inactive

It is anticipated there will be no permanent, noticeable changes to water levels and flows due to the Project when it is not in operation. Predominantly, the channel will be widened, not deepened (cf. Project Description) so it is not anticipated that any more groundwater will discharge into the channel (cf. Section 5.4 for a discussion of groundwater effects). The base flows in the Expanded Floodway Channel are expected to remain at about 0.13 m^3/s (5cfs).

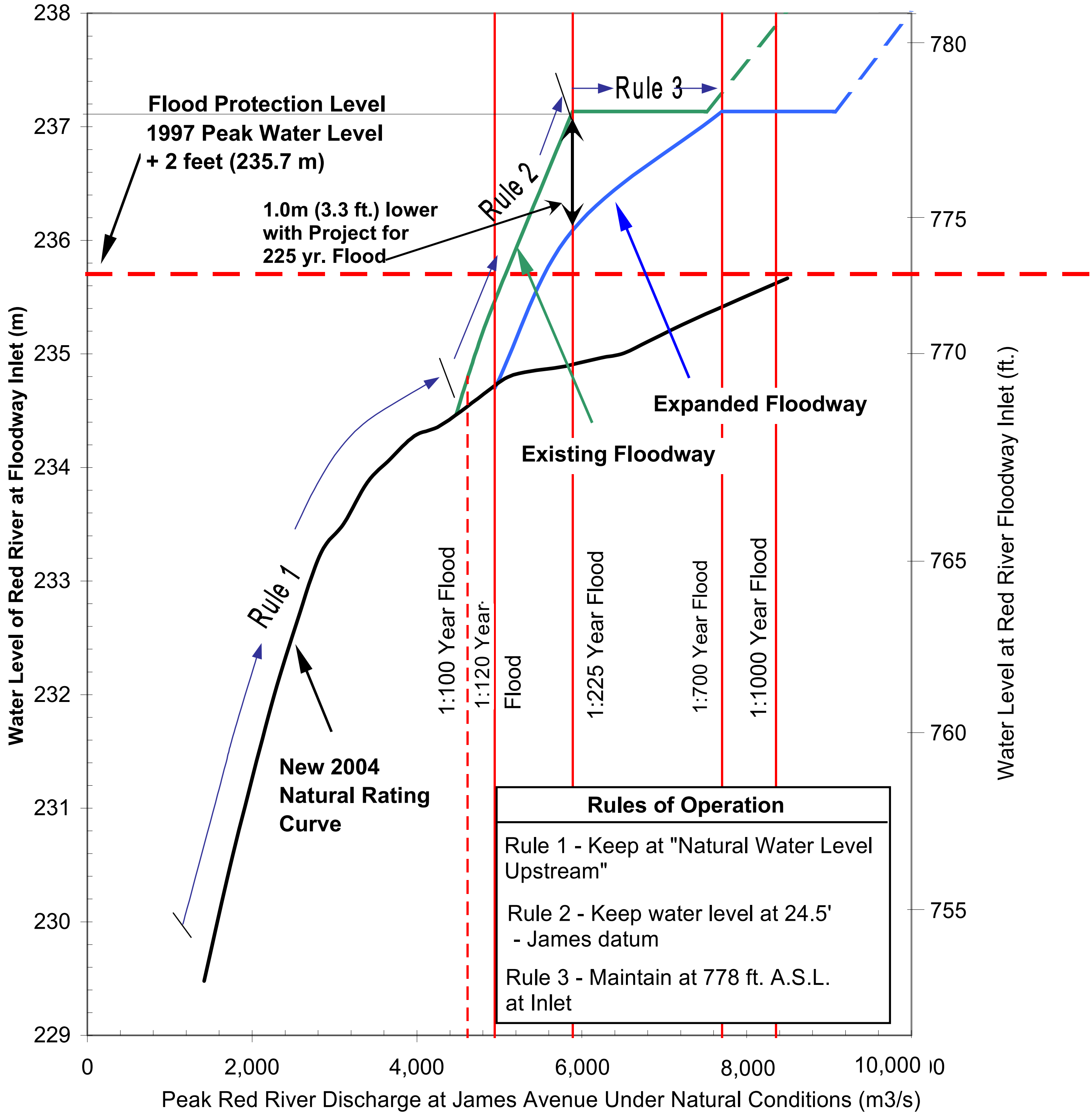
The Expanded Floodway will have a low-flow channel designed to eliminate ponding and will be armoured to prevent erosion. The Outlet structure will have a culvert at the elevation of the pilot channel base (KGS/Acres/UMA 2004c), and the culvert will not be closed to impound the water as is currently done. Therefore, water levels will remain within the Low Flow Channel. The agreement with Ducks Unlimited was terminated as of April 26, 2004 (Hay *pers. comm.* 2004), to allow for this new mode of operation for the Project.

5.3.3.3 Operation - Active

The Project will protect Winnipeg from floods that are higher than the 1997 flood by providing a substantial increase in the flow capacity of the Floodway Channel. The flow capacity of the existing channel is currently 2,550 m^3/s (90,000 cfs [although this capacity is not considered reliable due to the need to submerge bridges crossing the Channel and inadequate freeboard in the West Dyke]); with the Project this capacity will increase to 3,960 m^3/s (140,000 cfs) and the freeboard at the West Dyke will be 1.7 m (6 ft) in critical sections.

The rules of operation for the Project will remain the same as for the Existing Floodway. The application of the rules of operation for the Project are illustrated and compared to the Existing Floodway in Figure 5.3-4.

For floods less than the 100-year flood, the water levels at the Inlet will remain the same as for the Existing Floodway as defined by Rule 1. The Project will allow more flow will be diverted through the Floodway Channel and less through Winnipeg (Figure 5.3-5) at the same water level at no inlet.

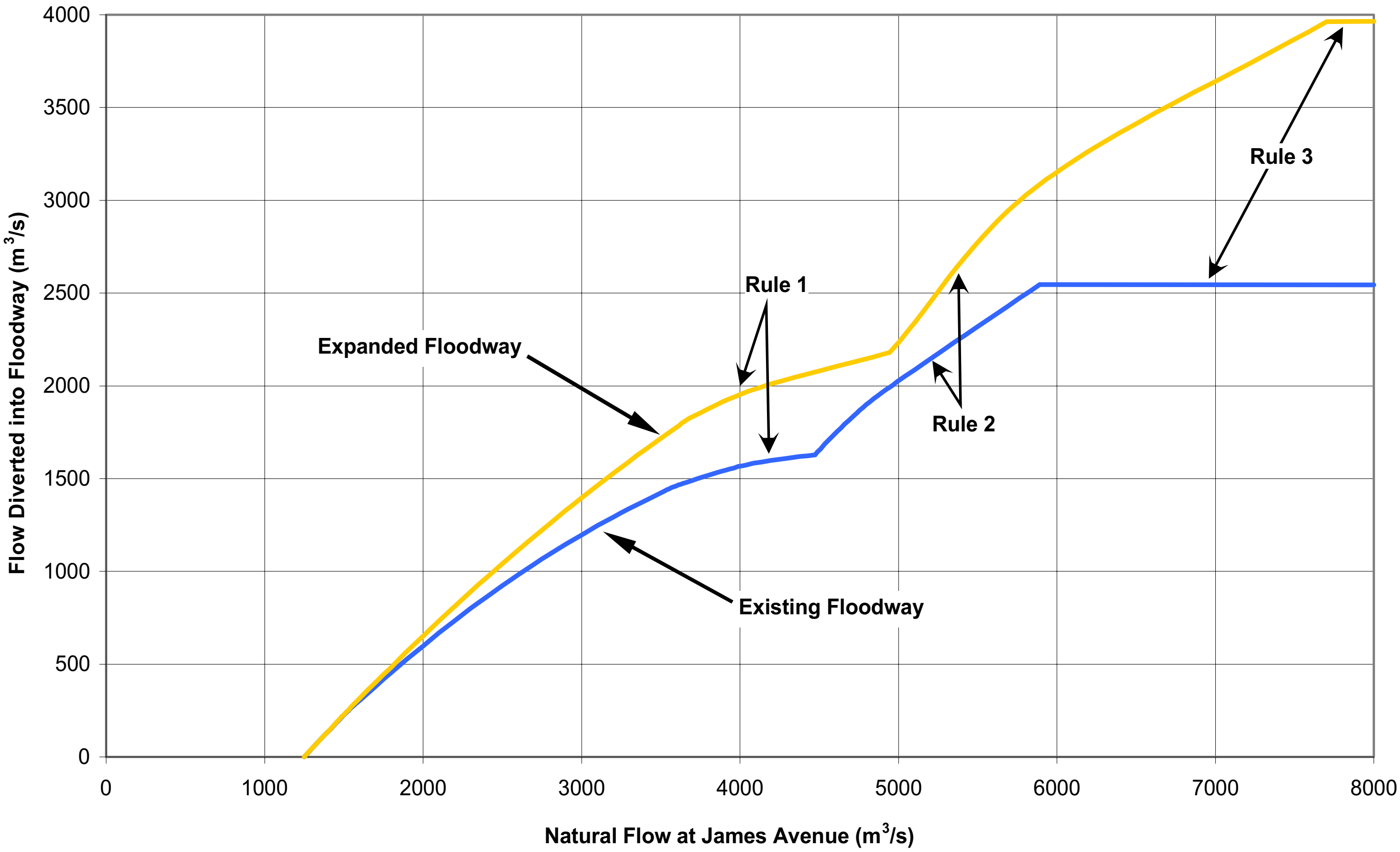


Source: KGS/Acres/UMA 2004a

Application of Floodway Operation Rules for Existing and Expanded Floodway

Figure 5.3-4

rules2
ms\01\0211\09



Source: KGS/ACRES/UMA 2004a

Relationship Between Natural Flows at James Avenue and Flows Diverted into the Floodway
Figure 5.3-5

relate
ms\01\0211\09

Therefore, water levels in Winnipeg will be up to 0.3 m (1 ft) lower during the high range of this Rule 1 operation. The Expanded Floodway Channel will receive more flow before Rule 2 (maintaining 24.5 James, and rising above natural upstream) is enacted. At the point where Rule 3 (maintain 778 ft at inlet) is enacted the Expanded Floodway Channel of 3,960 m^3/s will reach full capacity.

The pre- and post-expansion profiles upstream and downstream of the Floodway during spring operation were determined for a 100-year flood, a 1:120 year flood, a 1:225 year flood and a flood that is at the design capacity (i.e., 1:700 year flood) of the Project. Table 5.3-2 shows the difference between the pre- and post-expansion levels at key locations for each of these flood conditions (cf. Figure 5.3-1). An expanded Table is available in Appendix 5C. Tables 5.3-3 and 5.3-4 show the maximum increase and decrease in water levels from the Project at the locations where there is the greatest effect on water levels.

In the event of a 100-year return frequency flood (1997-type flood), it is anticipated that the water levels at the Inlet would be 0.3 m (0.96 ft) lower, tapering to no effect on water levels at Ste. Agathe (cf. Table 5.3-2). Water levels in Winnipeg would be expected to be about 0.3 m (1 ft) lower and water levels downstream of the Outlet would be a maximum of 0.04 m (0.16 ft) higher during this type of event.

If a 1:120 year flood occurs, it is anticipated the Project would not have any effect on the water levels from Morris to Ste. Agathe. Water levels at St. Adolphe would be approximately 0.3 m (1 ft) lower than the existing condition and the water levels at the Inlet would be approximately 0.75 m (2.5 ft) lower. Water levels on the Red River downstream of the Floodway Inlet within Winnipeg would be approximately the same during this magnitude of flood event. Downstream of the Floodway Outlet water levels would be about 0.02 to 0.08 m (1-3 in) higher.

Table 5.3-2
Differences in Maximum Water Elevations Following Floodway Expansion

Location	Magnitude of Flood Event			
	1 in 100 Year Flood	1 in 120 Year Flood	1 in 225 Year Flood	1 in 700 Year Flood
Morris	0	0	0	0
Ste. Agathe	0	0	-0.50 m (-1.63 ft)	0
St. Adolphe	-0.14 m (-0.46 ft)	-0.32 m (-1.06 ft)	-0.88 m (-2.91 ft)	0
Inlet of Floodway	-0.29 m (-0.96 ft)	-0.75 m (-2.46 ft)	-1.06 m (-3.50 ft)	0
James Ave.	-0.36 m (-1.17 ft)	+0.08 m (+0.28 ft)	+0.01 m (+0.03 ft)	-1.60 m (-5.26 ft)
St. Andrews Church	-0.05 m (-0.16 ft)	+0.11 m (+0.36 ft)	+0.05 m (+0.16 ft)	-0.24 m (-0.79 ft)
Red River at Floodway Outlet	+0.05 m (+0.16 ft)	+0.12 m (+0.39 ft)	+0.06 m (+0.20 ft)	+0.27 m (+0.89 ft)
Lower Fort Garry	+0.02 m (+0.07 ft)	+0.08 m (+0.26 ft)	+0.04 m (+0.13 ft)	+0.13 m (+0.43 ft)
Selkirk	+0.02 m (+0.07 ft)	+0.08 m (+0.26 ft)	+0.04 m (+0.13 ft)	+0.13 m (+0.43 ft)
PTH 4	+0.02 m (+0.07 ft)	+0.07 m (+0.23 ft)	+0.04 m (+0.13 ft)	+0.10 m (+0.33 ft)
Breezy Point	0	+0.02 m (+0.07 ft)	+0.01 m (+0.03 ft)	+0.05 m (+0.16 ft)

Notes: "-" indicates a decrease in the maximum water level
"+" indicates an increase in the maximum water level

Source: Acres Manitoba Limited 2004a

Table 5.3-3
Location and Magnitude of Largest Water Level Increases
Due to the Floodway Expansion Project

Flood Scenario	Location of Largest Increase	Project Increase in Water Level
1 in 100-Year Flood	Red River at Floodway Outlet	+0.05 m (+0.16 ft)
1 in 120 Year Flood	Red River at Floodway Outlet	+0.12 m (+0.39 ft)
1 in 225 Year Flood	Red River at Floodway Outlet	+0.06 m (+0.20 ft)
1 in 700 Year Flood	Red River at Floodway Outlet	+0.27 m (+0.89 ft)

Table 5.3-4
Location and Magnitude of Largest Water Level Decreases
Due to the Floodway Expansion Project

Flood Scenario	Location of Largest Decrease	Projected Decrease in Water Level
1 in 100-year Flood	James Avenue	-0.36 m (-1.17 ft)
1 in 120 Year Flood	Floodway Inlet	-0.75 m (-2.46 ft)
1 in 225 Year Flood	St. Adolphe	-0.89 m (-2.91 ft)
	Floodway Inlet	-1.06 m (-3.50 ft)
1 in 700 Year Flood	James Avenue	-1.60 m (-5.26 ft)

For a 1:225 year flood, it is anticipated the Project would not have any effect on the water levels from Morris to the U.S. border. It will, however, reduce water levels for communities immediately upstream of the Floodway (i.e., Grande Pointe, St. Adolphe, Niverville) from approximately 0.9 m (3 ft; cf. Table 5.3-2) over current dyke elevations to elevations that are approximately at the top of the dyke. In Winnipeg water levels would be about the same; however, the risk of failure of flood protection infrastructure will be greatly reduced because of the Project, the freeboard on the West Dyke would be considerably more (1.7 m) and no bridges crossing the Floodway Channel will be submerged. The water levels at the Outlet would be a maximum of 0.06 m (0.2 ft) higher due to reduced ponding in Richot, upstream of Winnipeg.

During an extreme 1:700 year event, no effects on water levels upstream (i.e., Morris to the Floodway Inlet) are anticipated. In Winnipeg it is anticipated that river water levels would be 1.5 m (5 ft) lower (cf. Table 5.3-2) and major flooding would be avoided. It is anticipated that water levels at the Floodway Outlet will be approximately 0.27 m (0.9 ft) higher (cf. Table 5.3-2), but will remain within the banks of the Red River. The water levels from Lockport to Lake Winnipeg would be about 0.03 to 0.12 m (1–5 in) higher with the Project. These downstream water levels will be higher since water is being conveyed in the Expanded Floodway Channel instead of being partially stored in the Winnipeg floodplain.

For floods larger than the 1 in 700-year flood, the water level upstream of the Floodway Inlet would be maintained at 237.13 m (778 ft) ASL and water levels in Winnipeg would rise above 26.5 ft at James Avenue as additional flow is passed through Winnipeg. If the primary dykes in Winnipeg cannot be raised, flooding will occur in Winnipeg, however, for floods greater than the 1 in 700 year flood, the flooding would be less extensive in Winnipeg with the Project. The incremental flood levels with the Project downstream of the Floodway Outlet should be no greater than the incremental difference for the 1 in 700-year flood. For an extreme event (7,900 m^3/s at the inlet), the capacity of the Inlet Structure may be exceeded and require the need for removal of part of the West Dyke to allow passage of the flood. At this level, flooding will have occurred on the north side of the West Dyke; and the location will be selected as to cause no additional flooding.

As is shown on Table 5.3-2, the Project will result in lower or equal water levels for all locations with the exception of the downstream of the Outlet. Downstream of the Outlet, it is expected there will be a small effect of higher water levels of less than 0.27 m (0.9 ft) for a 700-year flood, but these will remain within the banks at that location. In areas further downstream, the incremental effect will be less than 0.13 m (0.43 ft). Additional sandbags will be provided to properties of affected by this incremental downstream flooding caused by the Project as a form of mitigation.

The West Dyke will be raised to increase the freeboard up to 1.7 m (5.8 ft). This will have no effect on water levels or flow patterns of the Inlet. This 1.7 m (5.8 ft) freeboard is required to meet an extreme condition Dam Safety Standard of the combination of a 1 in 700-year flood and a 1 in 100-year windstorm. This very high design standard was chosen since the consequence of failure could be catastrophic since Winnipeg would not be fully evacuated. River dykes which are not subject to wind action, and community ring dykes, and single residence dykes have only a 0.6 m (2 ft) freeboard. Communities in the valley and single residences will be evacuated during a major flood to protect against loss of life if they are overtopped by extreme events.

The Seine River Syphon will be maintained as part of the Floodway Expansion, and will have the same capacity (140 cfs). Enhanced low level flows are being investigated by MFEA.

The operation of the Shellmouth Dam and Portage Diversion is not expected to change with expansion of the Floodway. There is a proposal to add gates to the spillway at the Shellmouth Dam. This will increase the potential for water supply from the reservoir in the Assiniboine River. The operation of the Project and the effect of the Project on water levels is not expected to change due to this expansion.

If the Devil's Lake diversion project is constructed, it's operation would be expected to result in increased water flows by about 2.5 m^3/s (100 cfs). This development is a concern for water quality in Manitoba but is insignificant in terms of effect on water levels in Manitoba.

The proposed City of Winnipeg Flood Protection Infrastructure Improvements are scheduled to occur during or after completion of the Project. As proposed, these improvements will have no adverse cumulative effect on water levels within the flood region.

The Floodway Expansion Project will result in larger flows being passed through the Floodway Channel and water levels in the City of Winnipeg will be 0.3 m (one foot) lower, so the Expanded Floodway is less likely to operate under Rule 2. Therefore, the ability to adhere to natural water levels is more likely to happen without the Project than with the Project.

The major effect on water levels occurs within the City of Winnipeg where there are very large decreases in water levels. The major decreases are for events greater than 1 in 225 year floods. This corresponds with the primary purpose of the Project.

The Project is also expected to have a positive benefit upstream of the Floodway due to less frequent operation above natural water levels. In the event the Project must be operated above natural water levels, compensation for upstream flooding will be awarded in accordance with the *Red River Floodway Act*.

5.3.4 Residual Effects and Significance

The residual effects of the Project on water levels are shown in Table 5.3-5. The Project is designed to reduce water levels within Winnipeg for very large and infrequent flood events (greater than 1 in 100 years). It will also have an effect on water levels upstream of the City (lowering) and downstream of the City (both lowering and raising) during these same infrequent floods. The determination of significance in this section is based solely upon the impact to the physical environment. The assessment of how these infrequent floods impact the people, communities and infrastructure, adversely and beneficially is discussed in Chapter 8 – Socio-Economic Environment. In order to understand how the Project can have no significant residual effect on the physical environment it should be compared to other water resource projects such as a permanent high level dam or a continuous water diversion. The effects of the Project on water levels are large in some locations (the City of Winnipeg) for very infrequent events, however so infrequent as to be not significant.

The effects and mitigation sub-section of this Physical Environment chapter provides the information for developing assessments in Chapter 6 (Aquatic Environment), Chapter 7 (Terrestrial Environment), Chapter 8 (Socio-Economic Environment) and Chapter 9 (Heritage Resources).

Table 5.3-5
Summary of Residual Effects and Significance on Water Levels Related to the Floodway Expansion Project

Description of Effect	Mitigation	Residual Effects and Significance
Construction		
The probability of using the Floodway for summer operation will decrease. Water levels may be higher in Winnipeg and lower upstream, although the likelihood of this change in operation is difficult to predict.	None	The effect is of moderate magnitude, short duration, and of low frequency. **Not significant**
Operation - Inactive		
None	None	No permanent, noticeable changes to water levels and flows when the Expanded Floodway is inactive are anticipated. **Not significant**
Operation – Active		
Change in water levels due to active operation of the Expanded Floodway will vary depending on the magnitude of the flood and the geographic location. For the more frequent floods (less than 1 in 100 year), there is no effect on water levels to the region other than a decrease of up to 0.3 m (1 foot) within Winnipeg. For larger floods (greater than 1 in 100-year return frequency). For each area, the magnitude of the effect for varies: • upstream of Winnipeg moderate benefit; • in Winnipeg large benefit; • downstream to St. Andrews Church moderate benefit; • Lockport to Lake Winnipeg small adverse effect.	Additional sandbags will be provided to properties affected by incremental downstream flooding caused by the Project.	For all areas, the physical environment related effects are: • of short duration (1-2 months); • very infrequent; • fully reversible; • of regional extent; and • not significant

5.3.5 Monitoring and Follow-Up

After major floods (of similar magnitude as those used to assess effects in this section), it is expected that the Province of Manitoba will engage the Manitoba Water Commission or other similar agency to independently study effects of the flood and action taken during the flood. The Agency is expected to have a mandate to determine the extent of unnatural upstream and downstream flooding, to determine whether the Project had any significant effect on water levels, and to recommend appropriate compensation for incremental damage downstream due to this effect. To the extent that flood mitigation was not fully effective during a flood event, MFEA is committed to ensuring that flood compensation will be provided to those adversely affected by incremental flooding caused by the Project.

5.4 GROUNDWATER

5.4.1 Approach and Methodology

5.4.1.1 Effects Assessment

A groundwater investigation was conducted to collect baseline information. The investigation included a review of available data from the Water Branch;

- a drilling, testing and monitoring program with wells installed in the bedrock;
- till and clay **aquifer** pump testing;
- water quality sampling; and
- groundwater baseflow mapping.

A regional well inventory was prepared including both private domestic and municipal well systems (KGS 2004a); this involved identification of a total of 287 wells, interviews with households/owners of 200 of these wells and collection and analysis of water samples from 25 of these wells for analysis. The household well survey and monitoring well construction program was conducted (SNC/Wardrop 2004a), and the information gained from this program was incorporated into the baseline data. The locations of the groundwater wells used to collection baseline information (i.e., through interviews, borehole logs and sample collection) are shown in Appendix 5C.

Groundwater models were generated for the regional Upper Carbonate Bedrock aquifer (KGS 2004b) the saline intrusion area located within the St. Germain/Vermette area and for the Bird's Hill aquifer (SNC/Wardrop 2004d). The model for the saline intrusion was generated using GMS v4.0 with MODFLOW 2000 while MODFLOW 2000 was used to generate the model for the Bird's Hill Aquifer. Three different simulations were modeled to determine the effects on the saline/freshwater interface: a simulation of the effects of the Floodway Channel design: simulation of blowout conditions, and simulation of a 1:700 year Red River Valley flood event.

A two-dimensional cross sectional model was developed using Visual Modflow to evaluate the effects of the Expanded Floodway on surface water intrusion and the potential effects of Floodway widening on groundwater levels (KGS 2004d). A steady state simulation using spring water table levels and dry Floodway conditions was modelled. The model simulated the flow directions and predicted the extent of groundwater discharge and surface water infiltration for dry Floodway conditions and during a large flood (1997-magnitude). The models also evaluated the predicted effects of Floodway widening in these areas.

The modelling was completed at four locations: Spring Hill; Oasis Road; Dunning Road, and the CPR Keewatin Bridge. The purpose of the modelling at each location is shown in Table 5.4-1.

Table 5.4-1
Location and Purposes of Models

Study Area Location	Purpose of Model
Springhill	Study effects on Birds Hill sand and gravel surficial aquifer and the bedrock aquifer.
Oasis Road	Study effects of Floodway widening relative to the Birds Hill aquifer.
Dunning Road	Represent unconfined water table conditions in the northern portion of the Floodway where the Floodway base is in carbonate till.
CPR Keewatin Bridge	Simulate confined water table conditions in an area where the Floodway is based in a thin clay layer overlying a relatively thin carbonate till above bedrock.

Source: KGS 2004d

5.4.1.2 Sources of Effects

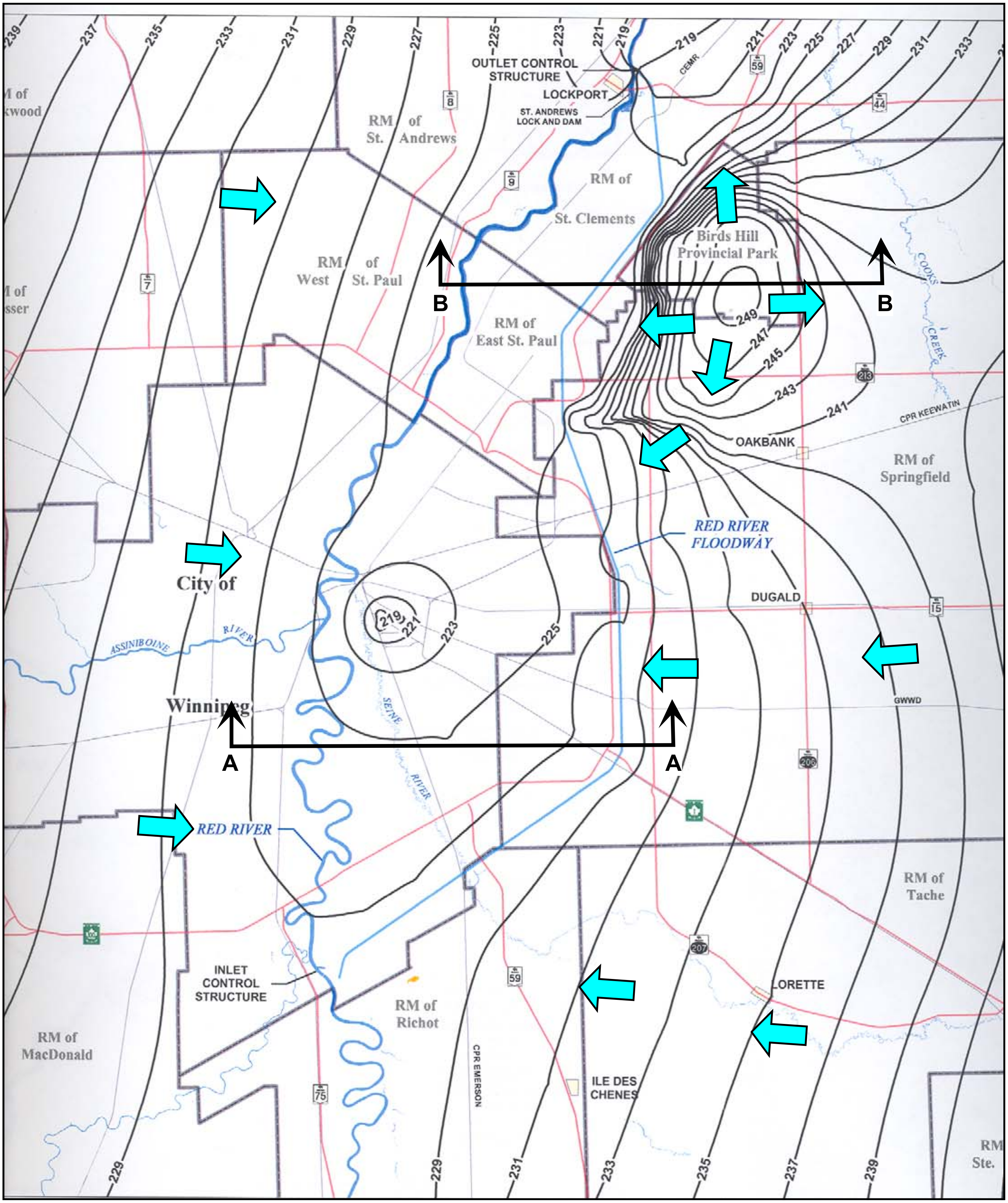
The main potential source of effect on groundwater is any deepening of the Floodway Channel. Other potential sources of effect include temporary construction dewatering around bridge piers and the Winnipeg Aqueduct and widening of the Floodway Channel. There is also a potential for Red River water carried in the Floodway during flood events to seep through the Floodway Channel bottom and sides into the underlying bedrock aquifer.

5.4.2 Existing Environment

5.4.2.1 Groundwater Levels and Flows

The typical regional groundwater bedrock **piezometric** surface is shown in Figure 5.4-1. The typical stratigraphy is clay and till **overburden** over dolomitic and limestone bedrock. A regional stratigraphic cross-section is shown in Figure 5.4-2. Both the Red River and the Floodway are contained within the clay/till overburden. The regional stratigraphic section shows a recharge area at Bird's Hill into a groundwater aquifer that flows west and discharges into the Red River. Figure 5.4-3 shows a cross-section of the Birds Hill aquifer. The **unconfined aquifer** is located in a sand and gravel deposit above the bedrock. The ground surface elevation of the sand and gravel aquifer is higher than the surrounding area with the highest elevation point being approximately 270 m ASL. This aquifer is recharged through the sand and gravel, with the water then flowing down into the bedrock. Figure 5.4-1 shows the contour map of the bedrock groundwater surface throughout the regional area. This figure shows that on the eastern side of the Floodway the bedrock groundwater contours are from south to north with groundwater flowing from east to west. On the western side of the Floodway, the contours occur around the Red River with the flow typically being into the Red River and to the north.

Baseline information on groundwater was collected through the inventory of wells, sampling and analyzing water from private wells, installation of monitoring wells, evaluating the influence of the Red

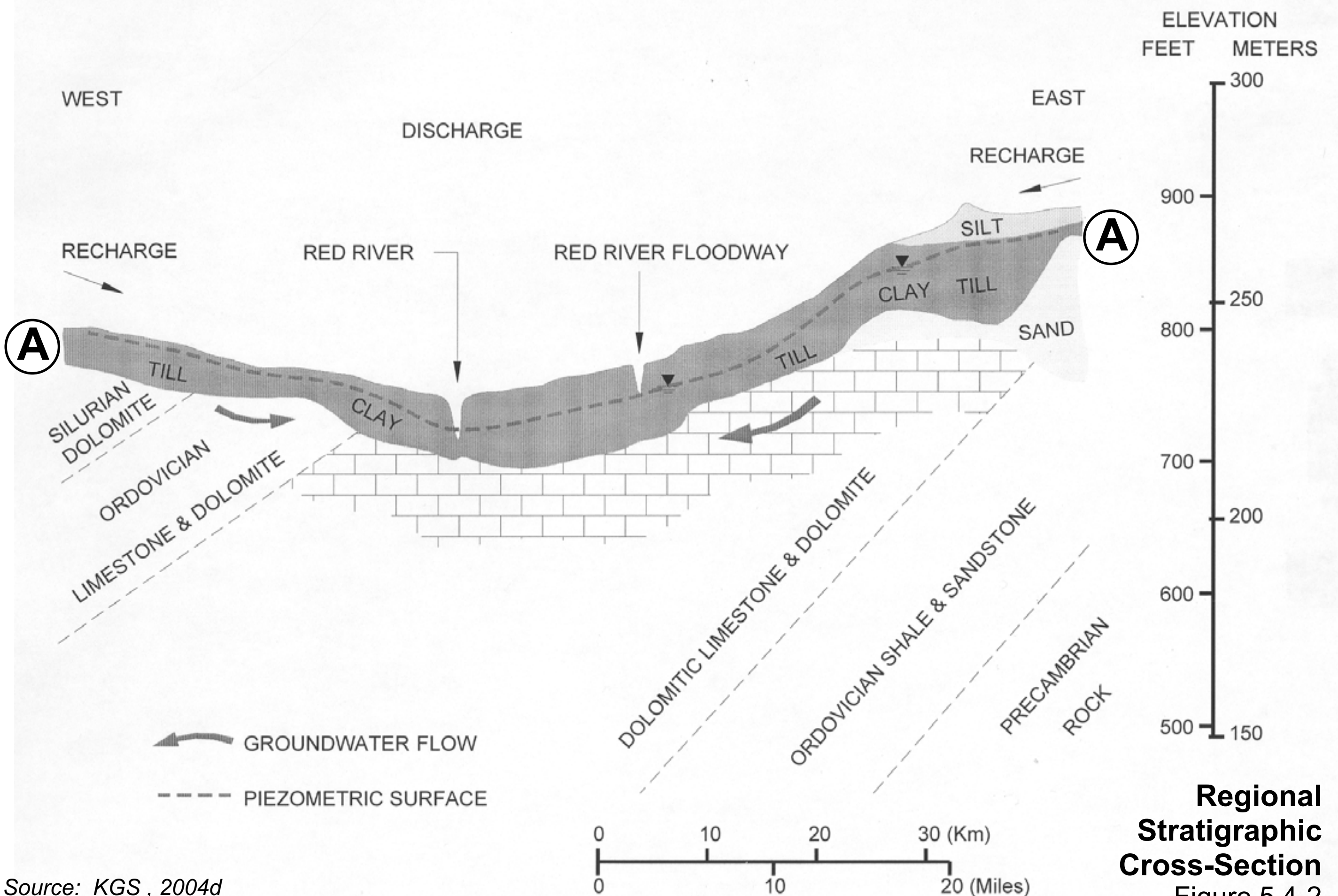


Source: KGS 2004b

➡	Groundwater Flow Direction
—229—	Piezometric elevation (MASL)

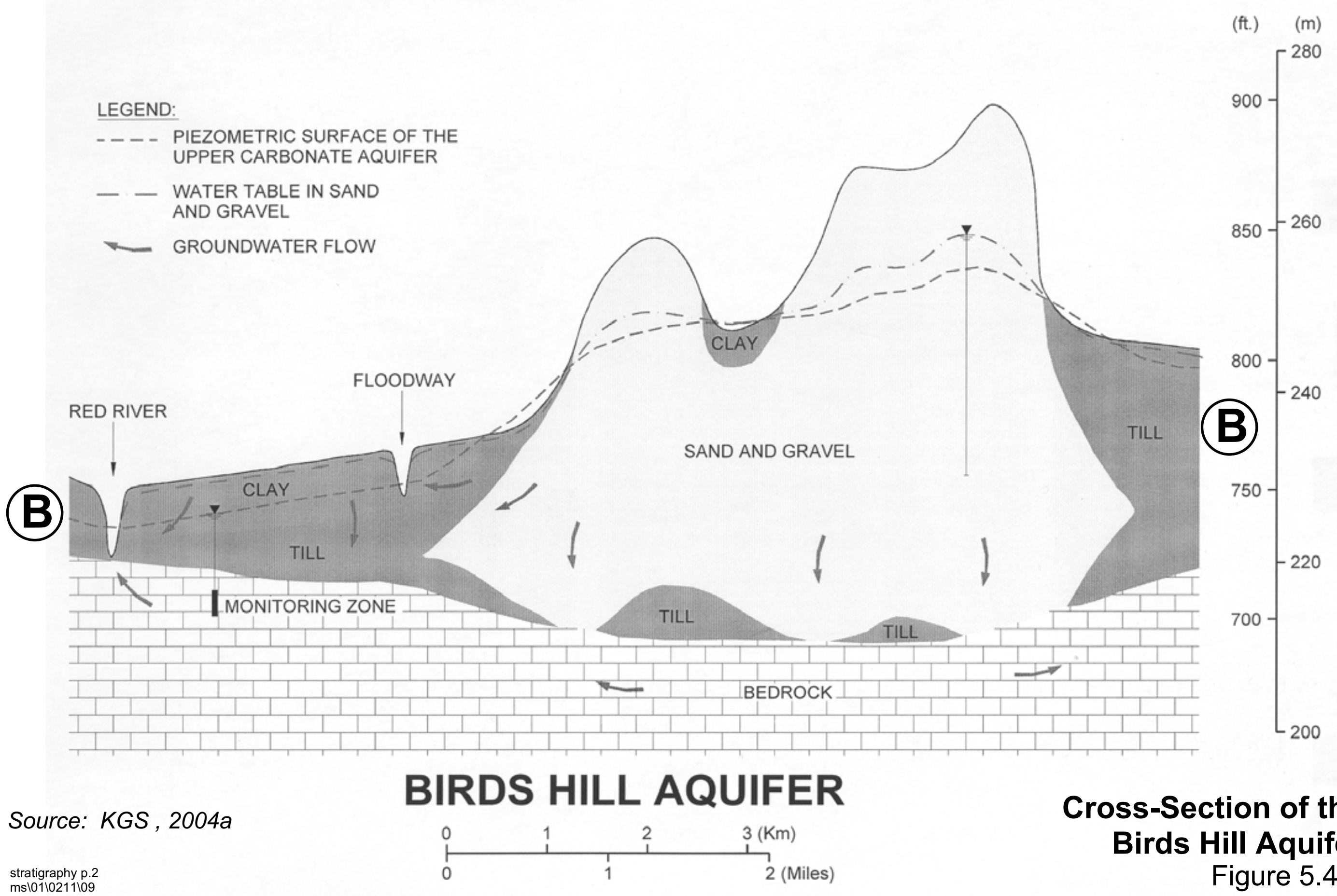
gwatflow
ms\01\0211\09

Regional Groundwater Elevation and Flow
Figure 5.4-1



Source: KGS , 2004d

Regional Stratigraphic Cross-Section
Figure 5.4-2



Source: KGS , 2004a

Cross-Section of the Birds Hill Aquifer
Figure 5.4-3

stratigraphy p.2
ms\01\0211\09

River on the Upper Carbonate aquifer, and evaluating the base flow in the Floodway Channel. KGS considered historical readings of the piezometric surface around the Floodway from provincial monitoring well data (KGS 2004a). The historical data showed the following:

- after 1964, declines in water levels could be seen in many of the piezometers, in some cases these declines took place over several years (Note: construction of the Existing Floodway occurred from 1962-1968);
- the hydrographs showed yearly spring recharge events with annual cycles of 1 to 3 m; and
- there are annual declines in wells near the City of Winnipeg during the summer months when consumptive uses increase.

5.4.2.2 Groundwater Quality

An assessment of baseline groundwater quality was conducted by KGS (2004a) and Wardrop (2004a) during their groundwater investigations (2004a). This included an evaluation of both the bedrock water quality and the till water quality. A summary of the baseline water quality data is shown in Table 5.4-2.

KGS notes that the Red River and the Existing Floodway quality have an effect on the groundwater quality. Some areas where this effect was identified include:

- specific conductance well data at the Floodway Inlet decreases during the spring from 1,000 – 1,500 µS/cm to 300 to 500 µS/cm at the same time as high river flow conditions occur in March, April or May;
- an increase in nitrate concentrations in spring from 1 to 5 mg/L show an increase in nutrient concentration from runoff; and
- a decrease in conductivity occurs at the Selkirk bridge during the spring from approximately 1,000 µS/cm to 200 to 600 µS/cm.

Approximately two-thirds of the Existing Floodway Channel is excavated in low permeability lacustrine clay, while the bottom of the remaining third is till (KGS June 2004b). There is the potential for Red River water carried through the Floodway to seep through the till sides and channel bottom into the underlying bedrock aquifer.

5.4.2.3 Saline Freshwater Interface

A **saline freshwater mixing zone** exists in the vicinity of the Red River at the south end of the City of Winnipeg (Wardrop-SNC 2004b). This poor quality saline water is located to the west of the Red River while freshwater is located in the carbonate aquifer on the east side of the river. Dewatering during construction of the Existing Floodway in the 1960's resulted in the encroachment of this saline front into the freshwater aquifer, resulting in intrusion of poorer quality saline groundwater into some domestic wells (Wardrop-SNC 2004b). This was a temporary effect and the saline-freshwater interface has returned to its historic location.

Table 5.4-2
Baseline Groundwater Quality

Parameter	Canadian Environmental Quality Guidelines[1]	Manitoba Water Quality Standards, Objectives and Guidelines[2]	Carbonate Bedrock Aquifer	Till Water Quality
Dissolved Solids	≤ 500 mg/L[3]	≤ 500 mg/L[3]	Generally high in dissolved solids (>500 mg/L), lower dissolved solids found in carbonate bedrock at Bird's Hill	Up to 3,200 mg/L
Sulphate	≤ 500 mg/L[3]	≤ 250 mg/L[3]	Sulphate concentration above 500 mg/L at one bedrock well located at Dunning Road	Maximum value of 1,530 mg/L near Highway 1
Chloride	≤ 250 mg/L[3]	≤ 200 mg/L[3]	140 to 146 mg/L between St. Mary's and St. Anne's Road and decreasing further north to less than 25 mg/L at Bird's Hill, maximum value of 213 mg/L near the Floodway Inlet Gate	Maximum value of 224 mg/L near St. Mary's Road
Sodium	≤ 200 mg/L[3]	45 mg/L[4]	Variable from 26 to 263 mg/L	Maximum value of 199 mg/L at Dugald Road
Nitrate	45 mg/L[4]	≤ 0.3 mg/L[3]	Generally below 0.05 mg/L	
Iron	≤ 0.3 mg/L[3]	≤ 0.05 mg/L[3]	Exceeded the aesthetic objective of the CCME in most wells	
Manganese	≤ 0.05 mg/L[3]	≤0.05 mg/L[3]	Exceeded the aesthetic objective in two wells near Spring Hill, did not exceed the aesthetic in any other well	
Strontium	NV[5]	NV	Noticeably lower in the Bird's Hill area and north of Spring Hill	
Specific conductance	NV[5]	NV[5]	Ranges from 400 – 2,000 µS/cm	Ranges from 500 to 3,500 µS/cm

Sources:

1. CCME 1999
2. Manitoba Conservation 2002
3. Aesthetic Objective
4. Maximum Acceptable Concentration
5. NV = no value
6. KGS 2004a

5.4.2.4 Surface Water Intrusion

A modeling study has predicted the potential for water from the Existing Floodway to infiltrate the groundwater (KGS 2004d, e).

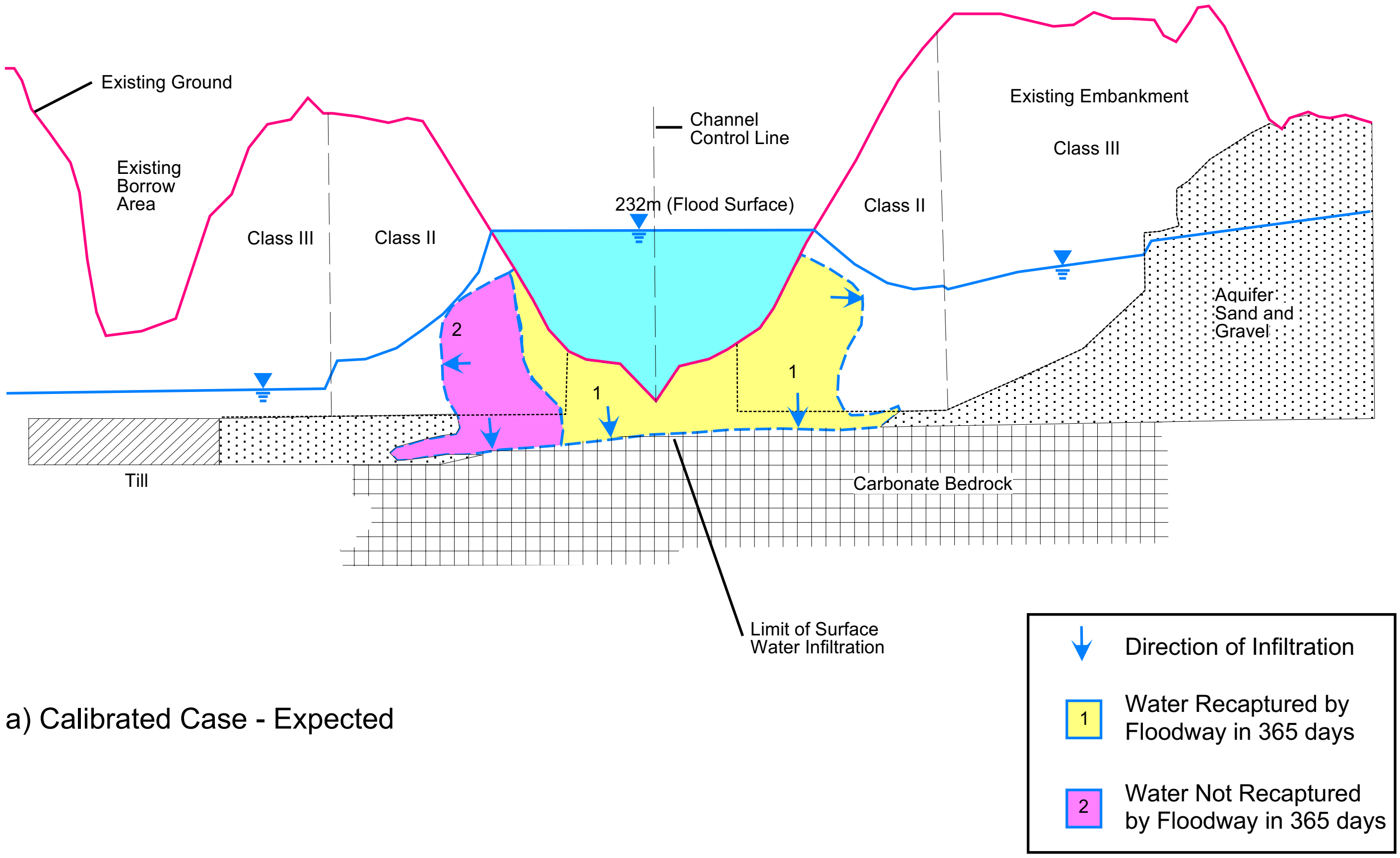
The southern two-thirds of the channel are based in very low permeability clay, and the northern third of the channel is based in till which has a higher permeability than the clay. Under “dry” (non-operating) Floodway conditions, groundwater flow is upward from the bedrock aquifer through the till with discharge into the Channel, and no surface water infiltration or recharge occurs downward into the till. The discharge in the areas near Dunning Road and CPR Keewatin are examples of these conditions under dry Floodway conditions. Some surface water discharges into the Channel from municipal drains. On occasion, a limited amount of potentially contaminated runoff may discharge into the Floodway Channel from the surface drains and influence the water quality in the low-flow Channel. This runoff will not infiltrate the till under normal groundwater discharge conditions.

During a flood event, when Red River water is diverted into the Channel, the local groundwater flow direction can reverse if the flood stage elevation is above piezometric surface elevation of the aquifer. In the southern (upstream) two-thirds of the Channel based in clays, there would be negligible infiltration. In the northern third of the Channel based in tills, there would be more potential for flow into the till.

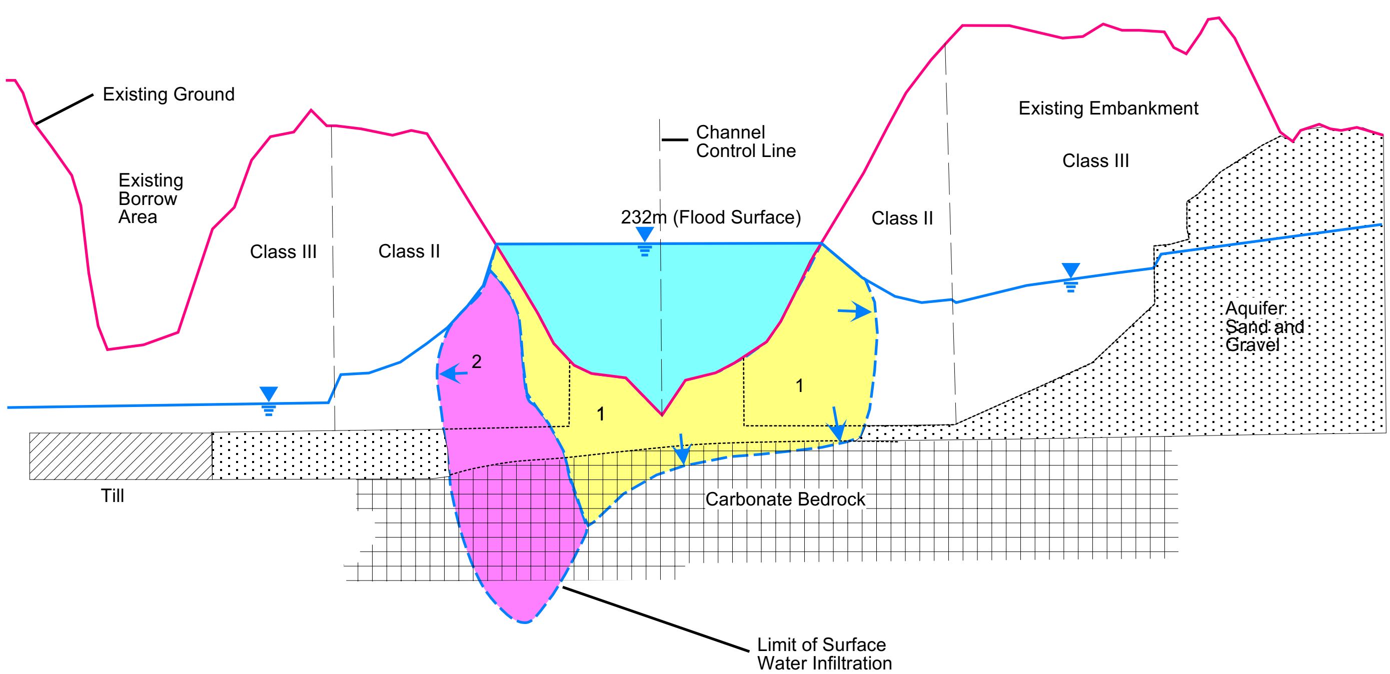
Models of surface water intrusion during a 1997-magnitude type flood were prepared at three locations including Spring Hill, Dunning Road, and CPR Keewatin. These models predicted that during a flood of this magnitude, infiltration of surface water at the Spring Hill location was entirely within the Floodway Right-of-way limits (KGS 2004d; cf. Figure 5.4-4). Infiltration into the east bank of the Floodway extended only 17 m into pervious sand and gravel from the peak wetted channel perimeter. On the west side, the surface water infiltrated a maximum horizontal distance of approximately 30 m. Groundwater that had infiltrated into the east flowed back to the Floodway but had not completely reached the Floodway within a year. The model showed that although the water that infiltrated the west side did flow back into the Floodway after the flood event, a portion of the water did not reach the Floodway within one year. There is a potential for this water to move further west during subsequent floods; however, the volume is expected to be low and the travel time slow (KGS 2004d).

The model of surface water intrusion for the Dunning Road site showed minimal infiltration into the east and west banks of the Floodway with water infiltrating into the channel bottom to a depth of less than 1 m. The model showed the Floodway captured all infiltrated water within one year (KGS 2004d).

The 1997 flood simulation for the CPR Keewatin section predicted surface water in this area would infiltrate 2 m vertically into the till for 20 days, directly below the low-flow channel, and then approximately 3 m into bedrock. The predicted horizontal infiltration is expected to be minimal, and infiltration into the till below the main channel was predicted to be less than 1 m. All infiltration is predicted to remain within the Floodway Right-of-way and the infiltrated water would be recaptured within one year.



a) Calibrated Case - Expected



b) Sensitivity Analysis - not representative

Source: KGS 2004d

Existing Surface Water Intrusion at Spring Hill
Figure 5.4-4

intrusion2
ms\01\0211\092

In order to assess the uncertainties that may occur in groundwater, modeling sensitivity analysis was performed. Although not considered representative, the hydraulic conductivity was increased 100 times in the overburden and 10 times in the bedrock. Under these unrepresentative conditions some surface water from the Floodway could move west towards the Right-of-way. The travel time to the Right-of-way was between 0.5 year at the CPR Keewatin Bridge, 1 year at Dunning Road and 10 years at Spring Hill.

There is public concern that contaminant passing through the Floodway Channel could contaminate the groundwater wells. This is not a likely path of contamination due to the large distance water must travel through till or the carbonate aquifer. Infiltration from surface water to groundwater is a natural phenomena. In addition, septic fields throughout the area percolate contaminated water towards the groundwater when operating properly. The aquifer can act as a filter to treat the water. The greatest risk to well owners is overland flooding which flows down into the well thus contaminating the well. Improperly designed or overloaded septic fields can bring contaminated water to the surface where there is potential to contaminate well heads during local flooding.

Although MFEA does not have jurisdiction over any wastewater and land drainage discharged to the Floodway, it is expected that any wastewater discharges would be required to comply with the applicable Manitoba Conservation regulations.

5.4.3 Effects and Mitigation

The cumulative effect of the Existing Floodway are considered while assessing potential project effects.

5.4.3.1 MFEA's Groundwater Mitigation Policy

The Manitoba Floodway Expansion Authority's policy on dealing with effects to groundwater as a direct result of the Project have been discussed and presented to the public as:

- throughout the pre-design, final design and construction stages, groundwater will be monitored. The monitoring may extend beyond construction, if necessary;
- the preferred approach for dealing with a groundwater effect is to prevent the effect. For example, MFEA is lessening the depth of Floodway Expansion to reduce the potential for effects.
- if a potential effect cannot be avoided through the project design, mitigation of the effect would be pursued. The Floodway Expansion project includes a budget item specifically for mitigation of groundwater effects. Protocols will be established for investigating and responding to complaints on groundwater issues to ensure they are related to Floodway Expansion. Examples of mitigation include lowering pumps in individual wells, deepening existing wells, installing new wells for temporary impacts, providing delivered water. Affected property owners are to be involved in determining mitigation, and MFEA is open to their suggestions on mitigation alternatives; and
- MFEA goal is to prevent any direct effects to well owners. However, if there is an effect that can't be prevented, then the authority will work with the affected property owner to determine the best course of remedial action. As a last resort, compensation as a form of mitigation will be provided.

The effects of other future projects are also considered. The Project effects are expected to be limited and mitigable with respect to groundwater levels and quality (as discussed later). Independent of the Project effects of increased development in the R.M. of East St. Paul are expected to increase demand on the regional aquifer in this area and may lead to lowering of groundwater elevations. The magnitude of this future effect is uncertain. The effect of increased development on groundwater levels is expected to confound monitoring of effects caused by the Project. Monitoring programs will need to be developed to identify the effects of other development separately from any potential Floodway effect. The predicted continued development of the R.M. indicates that effects on groundwater quality will be of concern. Any surface water that infiltrates into groundwater would be “filtered” by the surficial deposits prior to reaching the aquifer and would not be expected to change the groundwater quality. However, overland flooding may bring water contaminated from improperly operated septic fields which may contaminate wells. If this occurs during or after construction of the Project, the public may link the Project to these events although they would not be connected.

5.4.3.2 Construction

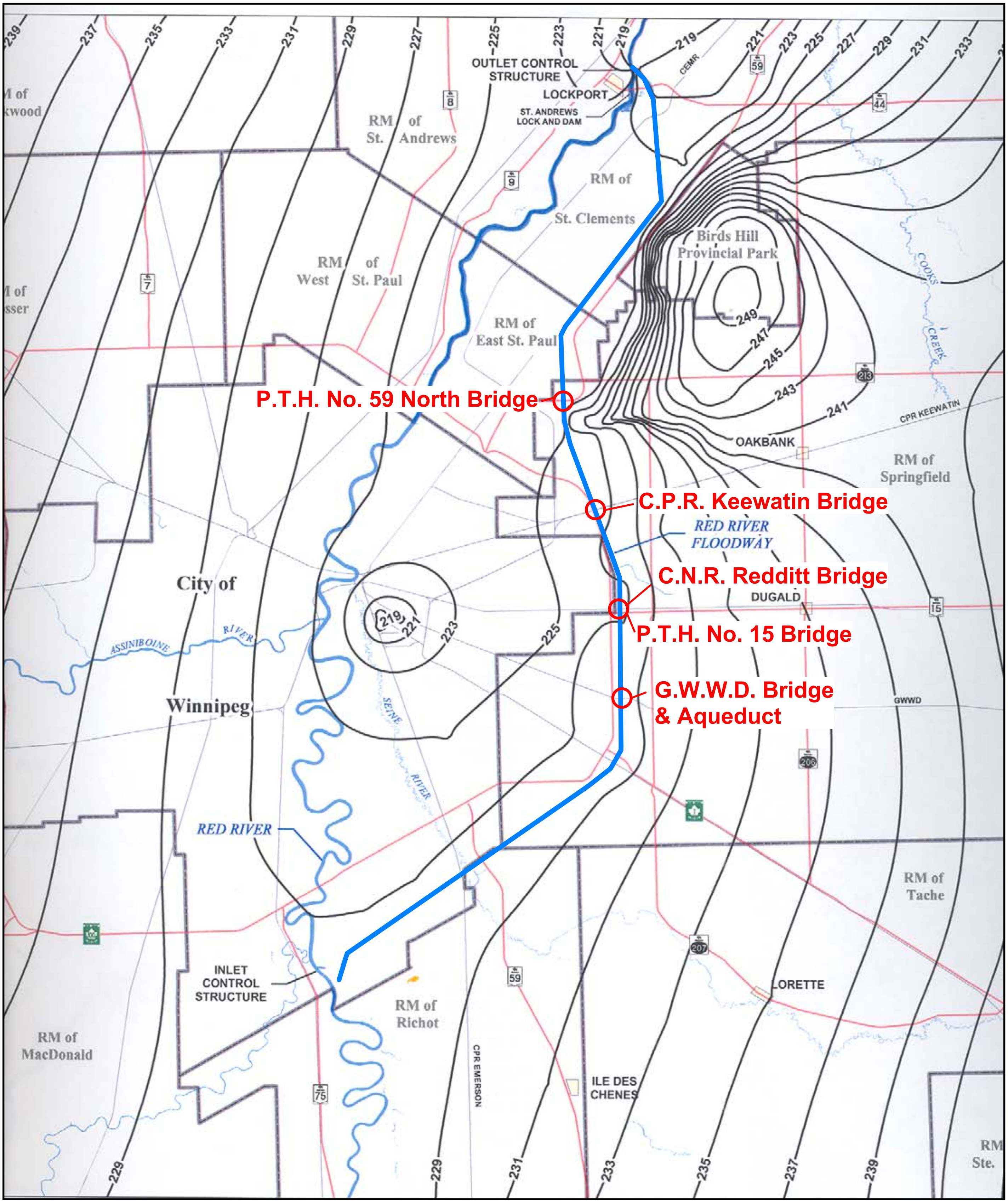
Potential effects on groundwater associated with the construction phase are related to dewatering at construction sites.

5.4.3.2.1 Construction Dewatering Sites

<u>Bridges</u>

Dewatering will be required to provide safe and dry working conditions during the construction phase. The Project will require construction of new rail and highway bridges at all Floodway crossings, and these will include driven steel H or precast concrete piles. Dewatering during construction will be required at some bridge construction sites to install pile caps (Figure 5.4-5). It is anticipated that dewatering will be required where the piezometric level in the bedrock could result in inflow up the annulus of the driven piles. The predicted drawdown for each bridge that requires dewatering against the distance from the pumping well is shown in Figure 5.4-6. The pumping rates required to achieve the required drawdown at each location have been calculated.

At the Highway 59 North bridge, a pumping rate of 0.033 m^3/s (70 US gpm) in the bedrock aquifer is estimated to create a 3 m drawdown a distance of 30 m from the pumping well after 10 days (KGS 2004e). It is predicted this will result in a drawdown of 1.5 m in the bedrock aquifer at the Floodway Right-of-way (KGS 2004e). The nearest residential groundwater wells are located adjacent to the Floodway Right-of-way and are finished in the sand and gravel aquifer deposit. The predicted drawdown in the bedrock aquifer underlying these wells is expected to be 1 m (KGS June 2004b). The drawdown in the piezometric bedrock aquifer is expected to result in a smaller drawdown response in the overlying sand and gravel deposit (KGS June 2004b). Pumping tests will be needed to verify the response of the sand and gravel aquifer to the bedrock aquifer drawdown. The potential mitigation measures that may be used to minimize impacts to residential wells include grouting to limit pumping requirements and recharge of pumped water back into the bedrock aquifer to create a **hydraulic barrier** (KGS 2004e).



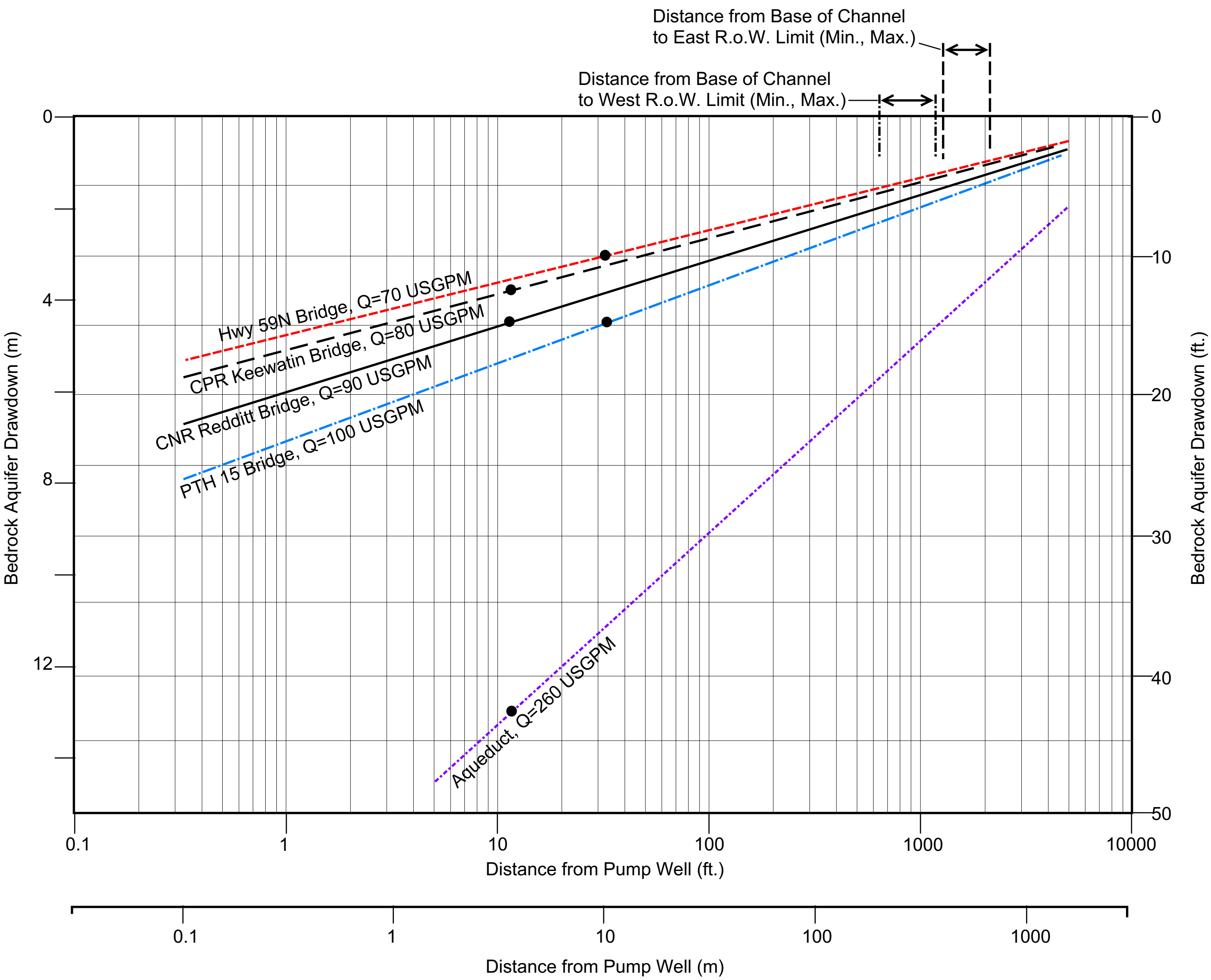
Source: KGS 2004e

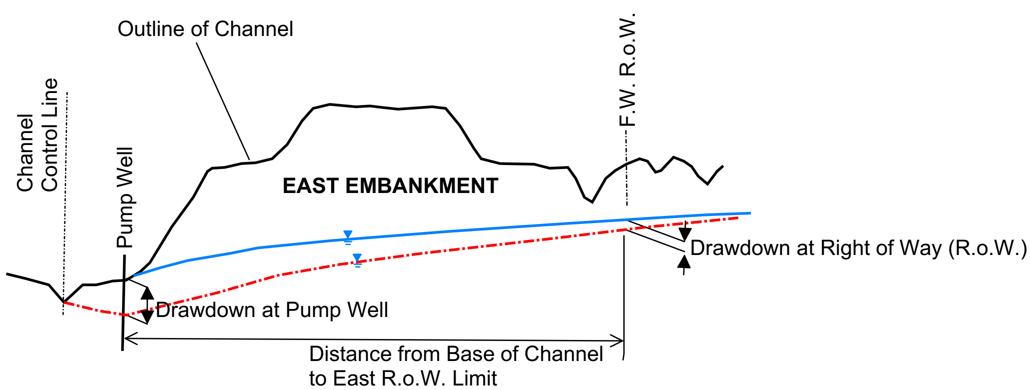
229 — Piezometric elevation (MASL)

Locations Where Dewatering Will Likely Occur During the Construction Phase

Figure 5.4-5

dewater2
ms\01\0211\09





TYPICAL DRAWDOWN ILLUSTRATION

● Drawdown Required, at Specified Distance from Pumping Well

Distance Drawdown Curves for Construction Dewatering Scenarios

Figure 5.4-6

drawdn
ms\01\0211\09

Source: KGS, 2004e

The estimated pumping rate for the Highway 15 bridge dewatering is 0.047 m^3/s (100 US gpm; KGS 2004e). This is expected to result in a maximum predicted drawdown cone of 2.5 m at the west Floodway Right-of-way. It is predicted that the nearest residential groundwater wells could experience 1.5 m or less of drawdown. At CNR Reditt Bridge and CPR Keewatin Bridge the effects on groundwater wells will be of less magnitude.

Mitigation measures for the bridge construction dewatering program may include the following (KGS June 2004b):

- grouting of bedrock to reduce bedrock transmissivity locally and minimize required pumping rates;
- sequentially dewatering one pier at a time to allow for limited groundwater drawdown;
- monitor the aquifer response and minimizing the pumping rates during the program based on the monitoring results. Drawdown increases with greater pumping rates, so lower pumping rates would be expected to result in less drawdown;
- use of recharge wells to create a hydraulic barrier;
- supply an alternate source of water.

The exact mitigation measures that will be used at each crossing will be determined during final design; and thus, the effect of these mitigation measures is also uncertain at this time. However, the groundwater impacts associated with bridge dewatering are expected to be local, temporary and of short-term duration, and therefore insignificant.

Winnipeg Aqueduct

The Existing Floodway Channel bottom is at an elevation of 224 m at the aqueduct crossing. The bedrock piezometric level is approximately 227 m at this location. The aqueduct must be reconstructed at this location to accommodate channel widening and set at a lower depth to meet current design standards for protection against blowout and heave (KGS 2004e). The pipes at the aqueduct channel crossing will be installed on hard till at an approximate invert elevation of 215 m. Excavation of the soil for installation of the pipe could cause uplift of the soils and pipe and excavation blowout and failure. Temporary dewatering of the area will be required during construction to provide a drawdown cone of 12 m at the pipe. It is estimated that an effective pumping rate of 260 US gpm will be required to create this drawdown. The predicted drawdown at the nearest Floodway Right-of-way, located approximately 280 m west of the channel, is anticipated to be less than 5 m. The drawdown at the nearest residential wells is anticipated to be less than 4 m. Drawdown in the residential wells would be temporary with water levels returning to normal shortly after pumping stops (KGS 2004e).

The construction dewatering at the aqueduct location would be carried out during the late summer and early fall for a period of one to two months.

Pumping tests will be required at this location to determine the actual aquifer transmissivity (KGS 2004e). The results of the pumping tests will be used to determine mitigation measures. Mitigation measures that are being considered at this site include (KGS 2004e):

- bedrock grouting to lower transmissivity;
- use of groundwater recharge to minimize drawdown beyond the Right-of-way;
- limited controlled pumping for construction dewatering;
- if necessary supply an alternate source of water.

Additionally, field visits to residential wells may be required to identify wells that may experience supply problems as a result of the dewatering. Monitoring of these wells may be required during the dewatering programs, and temporary alternate water supplies may be required at these wells during the construction-dewatering program. The pumping rates may also be reduced based on the results of the monitoring program.

MFEA or their representatives will consult with the property owner with regard to the mitigation measure. It is expected that with the implementation of appropriate mitigation measures as discussed, any effects associated with construction dewatering will be temporary and site specific, and therefore not significant. The proposed dewatering of groundwater for construction is not expected to have any effect on groundwater quality.

5.4.3.2.2 Saline Freshwater Interface

The construction of the Floodway Expansion is not anticipated to have an effect on the saline-freshwater interface in the Upper Carbonate bedrock aquifer.

In order to test whether there was any potential for an effect on the saline-freshwater aquifer interface, three severe scenarios were modeled (SNC/Wardrop 2004c). The first simulation was the maximum potential deepening scenario (.i.e, 2 m deepening throughout the channel, which has now been revised to a no deepening except for 0.6 metres in localized areas). Secondly, a very unlikely catastrophic blowout at the Winnipeg Aqueduct Crossing, and finally a three-month long, 1 in 700 year design flood passing through the Floodway channel. For each of these severe events there was little or no effect on the saline-freshwater aquifer boundary in the region. Therefore there should be no adverse effects on groundwater quality due to a shift in the saline-freshwater aquifer interface.

5.4.3.2.3 Management of Hazardous Materials

Hazardous materials such as hydrocarbons and herbicides will be used during the construction phase. Herbicide may be used to eliminate or control non-natural vegetation in the Floodway. Herbicide selection will avoid the extensive use of those known to be harmful to aquatic life, terrestrial life and humans. An analysis of the potential impacts of herbicide use on the aquatic environment is considered in Chapter 6. Any potential effects associated with the use of these materials will be mitigated through the use of appropriate construction practices as discussed in the Environmental Protection Plan (EPP; Section 4.16). The EPP will address such items as secure storage, maintaining good fueling practices and spill response clean-up. With the use of the specified mitigation measures, no significant impacts on groundwater quality are expected during the construction phase. Potential effects on groundwater quality that could occur through the use of hydrocarbons, herbicides and other chemicals during construction activity will be mitigated through the use of an Environmental Protection Plan that specifies appropriate handling measures for these materials.

5.4.3.2.4 Monitoring

Groundwater elevation and water quality monitoring will occur during construction to establish the response of the bedrock at the Birds Hill Aquifer and to identify any interconnections to the carbonate aquifer (KGS June 2004b). Baseline groundwater elevation and quality data has been collected. Groundwater monitoring programs will be required along the Floodway including the bridge and aqueduct dewatering sites. A monitoring plan will be developed during detailed design prior to construction.

5.4.3.3 Operation - Inactive

5.4.3.3.1 Groundwater Elevations

The Project is based on widening of the channel with only minor local deepening of not more than 0.6 m in selected areas if required (KGS/Acres/UMA 2004b). Modelling was conducted to determine the potential effects of the Channel widening on water levels. This modelling was conducted at three representative locations: Oasis Road; Dunning Road, and at CPR Keewatin where the greatest effect would be expected. The results of the modelling at Oasis Road are discussed in Section 5.4.3.2.2. The model simulation showed that widening of the Floodway at Dunning Road based in till would have a very small effect on groundwater levels within the Floodway Right-of-way. The widening is anticipated to decrease the groundwater elevation by less than 0.5 m. The model did not show any noticeable change in groundwater levels in the bedrock in the nearest provincial well (G05OJ002). A model was used to simulate the effects of Floodway Channel widening at the CPR Keewatin section. The model predicted a potential water table drawdown of less than 0.5 m within the Floodway Right-of-way and no discernable water table drawdown in the nearest provincial well (G05OJ014). Although excavation may lower water levels in the immediate vicinity of the excavations of Dunning Road and CPR Keewatin, it is anticipated that this effect will not be noticeable. However, if unanticipated groundwater problems do arise these problems will be mitigated as discussed in Section 5.4.3.3.2. Lowering of water levels during the inactive phase is anticipated to be of long-term duration but of small magnitude and in a localized area and is, therefore, insignificant.

Since the 1990's, water has been temporarily ponded in the northern reach of the Floodway approximately between Birds Hill and the Outlet, during the early summer (May, June) and then drained down in winter. After the construction of the Floodway Expansion Project, it is intended that the operating regime will return to pre-1990's levels; that is, the Floodway will be operated such that water will not be retained in the northern reach of the Floodway. Wells in the area have not reacted to this past operation and no significant effect is expected from the change in operation.

Potential impacts to groundwater have been mitigated through Floodway design (i.e., minimize channel deepening, control dewatering.)

A cost allowance has been provided for remediation of domestic wells that experience proven impacts as a result of the Floodway widening (KGS 2004e). The mitigation measures will be based on site-specific evaluations of well construction and performance and may include (KGS 2004e):

- pump and well replacement;
- pump replacement and well deepening; or
- pump replacement and lowering.

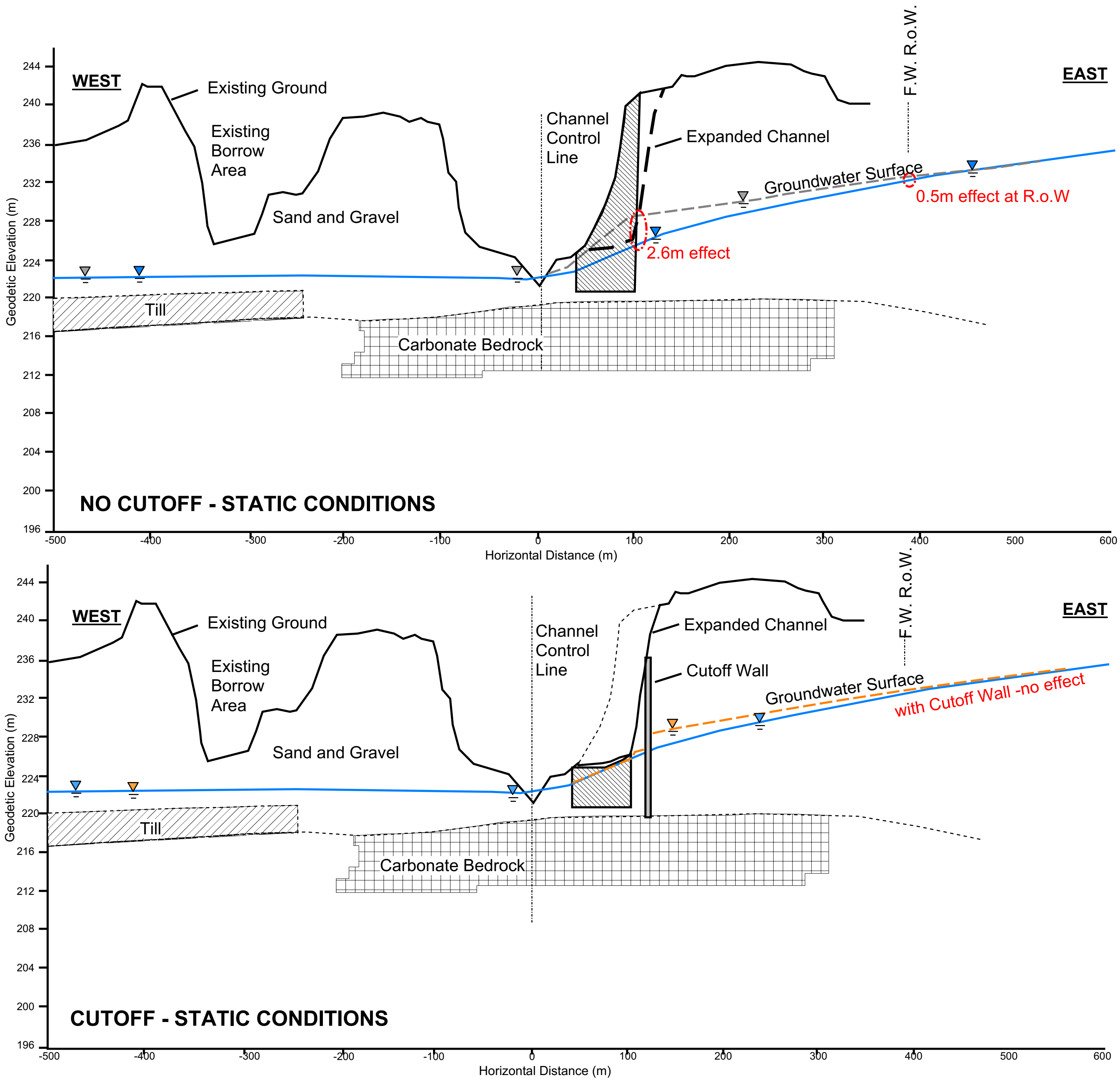
5.4.3.3.2 Birds Hill/Oakbank Aquifer

The Project will only involve widening of the channel and will not involve deepening of the Floodway Channel. The **Birds Hill/Oakbank Aquifer** is near the surface, and there is a potential for the excavation to encroach on to the aquifer. The aquifer is a drinking water source for the town of Birds Hill, and thus, is sensitive to potential effects. The Project is anticipated to involve channel widening of approximately 60 m at Oasis Road. A model simulation was run assuming worst-case conditions to evaluate the potential effects of this widening on the Birds Hill Aquifer. The model showed the slope of the new channel base could intersect the water table, creating a seepage face (KGS 2004d) depending on the nature of the overburden soils (silts and clays versus a granular connection to the aquifer). This would result in a drop in the water table of approximately 2.6 m. This drawdown would lessen in the sand and gravel aquifer east of the Floodway Right-of-way at Oasis Road. The estimated drawdown at this location assuming a granular connection is anticipated to be 0.5 m within 3 months and 0.6 m within 1 year. A subsurface cutoff wall is being considered as a potential mitigation measure. Thus, a second model that included a cutoff wall in the east bank was developed for this area. This model showed that with the use of a cutoff wall there was no noticeable decline in water table levels at the observation points. The results of both model simulations are shown in Figure 5.4-7 (KGS 2004d). Protection of this aquifer may require the use of a low-permeability cutoff wall as a mitigation measure. With the use of appropriate mitigation measures, potential effects on the Birds Hill/Oakbank aquifer are anticipated to be preventable, and thus insignificant.

5.4.3.3.3 Groundwater Supply

The Project will not involve deepening of the channel except in localized areas; therefore, no long term effects on groundwater supply are expected.

The potential effect on groundwater flow to industrial water supplies in east Winnipeg was estimated by assuming the Channel would be deepened by 1.5 m (KGS 2004e). The preliminary design does not involve deepening of the Floodway, so it is anticipated that there will not be any effects on industrial groundwater supply (KGS 2004e).



Source: KGS, 2004e

cutwall
ms\01\0211\09

Oasis Road STA 34+470
Predictive Modeling Floodway Expansion and Cutoff Wall
Figure 5.4-7

5.4.3.3.4 Regional Bedrock Aquifer Impacts

The Project will not involve deepening of the Channel except in localized areas, but will involve widening the channel. The anticipated flows in the regional aquifer pre and post-expansion are not expected to change.

5.4.3.3.5 Groundwater Quality

Saline water is present in the upper carbonate aquifer west of the Red River with the interface between saline water and fresh water located at the Red River (KGS 2004e).

The preliminary design does not include deepening the Floodway Channel, and simulation results of the saline aquifer show the position of the saline front would remain unchanged even if deepening were to occur (SNC/Wardrop 2004d). The Floodway widening in this location would be within clay deposits that receive little to no base flow, and no increase in base flow is expected (KGS 2004d).

No significant effect on saline aquifer intrusion is expected to occur as a result of widening the Floodway.

Groundwater east of the industrial wells located in St. Boniface is low in salinity; higher salinity groundwater is located to the south and southwest. The effect of decreasing the freshwater input to east Winnipeg was evaluated. The evaluation found that no changes to salinity in provincial monitoring wells occurred either as a result of the original Floodway construction of the decrease in pumping rates in the industrial wells that occurred during the late 1980's (KGS 2004d). The preliminary design of the Expanded Floodway does not include Floodway deepening, so it is anticipated there will be no changes to the groundwater quality of the regional bedrock aquifer.

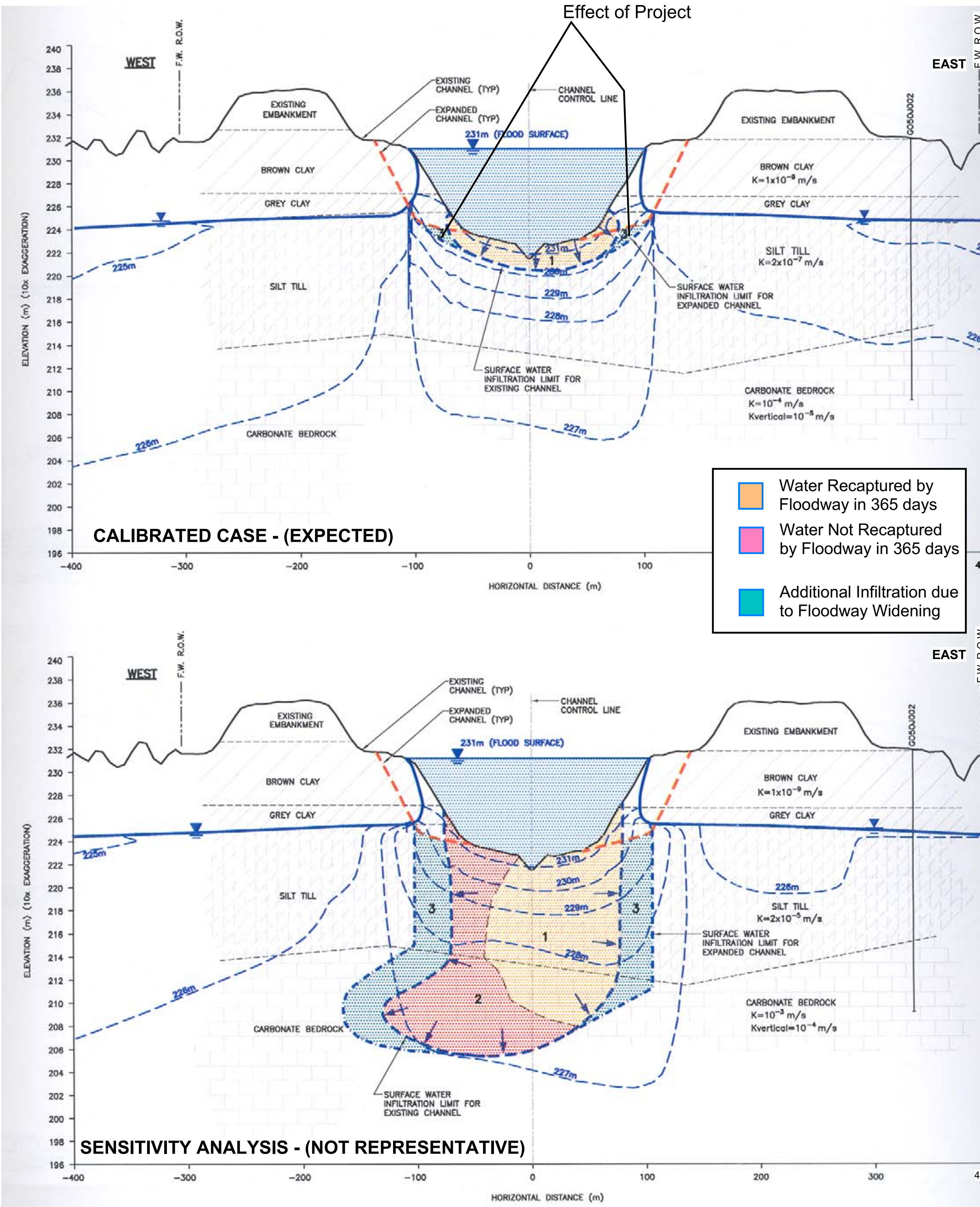
5.4.3.4 Operation – Active

5.4.3.4.1 Groundwater Levels and Quality

The effect of widening the channel on infiltration of surface water into groundwater was also assessed. The effect of Floodway widening on infiltration at Dunning Road is also shown on Figure 5.4-8). The calibrated model results are most representative of actual conditions, although a sensitivity analysis was also performed. The only change from existing conditions is that water infiltrates into the till along the slightly wider channel bottom proportional to the extent of widening. This zone is still directly adjacent to the channel, and there is no additional vertical infiltration from existing conditions.

At CPR Keewatin Bridge and Springhill similar effects are expected. Results are shown in Appendix P of the Preliminary Engineering study (KGS 2004d). These Project effects are of low magnitude, local and not significant.

As noted in Section 5.4.3.2.5, a saline aquifer is located in the southwest portion of the province. The interface between the saline and freshwater Upper Carbonate aquifers is located near the Floodway in the vicinity of St. Norbert and Grande Point. The interface between the two aquifers is located approximately underneath the Red River. A model was used to simulate the effects on the saline



Source: KGS, 2004d
Final GW Report, Fig. 8

infilt
ms\01\0211\09

Effect of Widening on Surface Water Infiltration at Dunning Road
Figure 5.4-8

freshwater interface during a 1:700 year flood event. The simulation predicts there would be no appreciable increase in heads during these conditions (SNC/Wardrop 2004d). It also predicts there would be a pressure effect from the hydraulic loading of the Floodway during the 1:700 year flood, however, this is expected to have a positive effect on the saline freshwater interface by pushing the boundary to the west.

During an extreme flood event, there is a potential for floodwaters to enter wells if the floodwater overflows the wells. For wells that are located within the Floodway protection area, the Project will result in increased flood protection and thus will have a positive effect on protecting surface water quality.

The Floodway Expansion will not involve deepening, except in localized areas, so there is no potential groundwater quality concern associated with floodwater coming into contact with bedrock. The Project will involve widening of the channel and this may expose more till in the channel bottom locally (cf. Figure 5.4-8). However, due to the low permeability of the overburden till materials, the rate of groundwater movement is slow and no effects on groundwater quality are anticipated.

5.4.4 Residual Effects and Significance

The residual effects of the Project on groundwater are shown in Table 5.4-3. With mitigation the predicted effects on groundwater are not expected to be significant.

Table 5.4-3
Summary of Residual Effects and Significance on Groundwater Related to the Floodway Expansion Project

Description of Effect	Mitigation	Residual Effects and Significance
Construction		
Drawdown in the residential groundwater wells near the Highway 59 N bridge construction dewatering is expected to occur as a result of construction for dewatering. This adverse effect is expected less than 1 m drawdown at the RM of East St. Paul wells.	This effect would be monitored, and mitigation measures could include grouting or recharge of pumped water back into the bedrock aquifer to create a hydraulic barrier to reduce the adverse effect.	The effect would last for approximately 6 months during construction dewatering, would be short term, only occur during construction, and would be reversible. The effect would be limited to a local area. **Not significant**
Residential groundwater wells near the Highway 15 bridge, CNR Reditt and CPR Keewatin could experience a drawdown of 1.5 m or less.	Mitigation measures such as; • grouting of bedrock; • dewatering one pier at a time; • lower pumping rates; • supply alternate source of water.	This effect is expected to be adverse, local, temporary and of short-term duration. **Not significant**

Description of Effect	Mitigation	Residual Effects and Significance
Drawdowns of 4 m in residential groundwater wells, located near the aqueduct crossing during construction dewatering is expected.	This effect would be monitored and mitigation measures could include grouting or recharge of pumped water back into the bedrock aquifer to create a hydraulic barrier. Field visits may be required to identify wells that may be affected, and temporary alternate water supplies may be required. Monitoring of wells will also be required during this program, and pumping rates may be reduced based on the results of the monitoring program. The various options would be discussed with the affected parties.	This adverse effect would be local, temporary and of short term duration. **Not significant**
Potential effects on groundwater quality that could occur through the use of hydrocarbons, herbicides and other chemicals during construction.	Effects will be mitigated through the use of an Environmental Protection Plan. The plan will address; storage, good fuelling practice and spill response and cleanup. It must be flexible to cover wide range of potential events.	With mitigation measures effects on groundwater should be small and local. **Not significant**
Operation - Inactive		
Potential water table drawdown of less than 0.5 m within the Floodway Right-of-way at the CPR Keewatin and Dunning Road location is anticipated. No discernable change in water levels at the nearest provincial wells is predicted.	No mitigation required.	This small adverse effect is expected to be of long-term duration in a local area and is not expected to be reversible. **Not significant**
Drop in the water table elevation at Birds Hill/Oakbank of 2.6 m tapering to 0.6 m at Oasis Road is expected. If a groundwater interconnection is exposed to the channel due to widening	A mitigation measure being considered if necessary is the use of a subsurface cutoff wall to reduce the effect of the Right-of-way to neglible.	The residual small adverse effect is long-term duration in a local area and would be irreversible. **Not significant**
Operation - Active		
The zone of surface water infiltration is expected to widen in proportion to the Floodway widening in the northern third of the Floodway. No additional vertical intrusion is expected.	No mitigation required.	The effect is temporary, local and of small magnitude, and may be reversible. **Not significant**

5.4.5 Monitoring and Follow-up

Extensive groundwater level monitoring during construction is required as part of the mitigation of construction impacts. Monitoring of groundwater quality on the western side of the Floodway should be done following a large flood to verify the movement and any effect of surface water intrusion. The EPP should be developed and enforced to mitigate any potential for hazardous chemical spills during construction.

5.5 EROSION AND SEDIMENTATION

5.5.1 Approach and Methodology

5.5.1.1 Effects Assessment

An assessment was conducted to determine the risk of erosion during construction (KGS/Acres/UMA 2004b).

Mathematical modeling was used to determine the anticipated velocities and shear stresses that could occur during construction and operation of the Project. Estimated shear stresses were determined using hydraulic models under a variety of flow conditions. The estimated shear stresses were compared to the critical erosion shear stresses for each type of soil material. Areas where the estimated velocities exceeded the critical velocities were considered at risk for erosion. These were compared to the shear stresses that typically occur when the Existing Floodway is in operation.

To estimate the effects during construction various scenarios of excavation during the expansion were considered. A HEC-6 model (from the Hydrologic Engineering Center of the U.S. Army Corp of Engineers) was used to estimate erosion and transport of sediment under these varying conditions. Two types of scenarios were considered:

- a spring flood occurring during construction; and
- a major rainstorm occurring during construction.

These scenarios were further divided into those events that have a higher probability of occurring (i.e., events that are likely to occur during construction) and those events that have a lower probability of occurring (i.e., a contingency event such as a large flood during construction). The effects expected from higher probability events should be mitigated to conform to appropriate guidelines. Potential sediment loading effects from contingency events were determined; however, mitigation measures to prevent significant effects from these unlikely events are not proposed.

During the construction of the Expanded Floodway is when erosion and sedimentation are at their greatest potential. There are areas of scientific uncertainty in predicting the erosion and sediment impacts downstream. These involve:

- the range of potential flood events that could occur during the construction of the Floodway;

- the range of potential rainstorm events that could occur during the construction of the Floodway;
- the flow in the Red River, which has an impact on dilutions of any sediment discharged to the Red River;
- the sediment concentrations in the Red River, which are highly variable and uncertain at any time during the spring or summer;
- the rate at which revegetation will occur due to various weather conditions occurring during construction; and
- uncertainty in the coefficients used in the models that predict erodibility of the channel.

Since it was understood that this potential for erosion would not occur without the Floodway, addressing these uncertainties is very important in determining the significance of effects. Additional analysis was done looking at a range of potential flood events, rainfall events, and potential sediment concentrations in the Red River. In addition, various construction techniques and erosion control techniques will be developed and adapted as the construction occurs. We are proposing that the Environmental Protection Plans include monitoring of the proposed erosion control activities as well as monitoring the effects downstream in the Red River. Uncertainties have been analyzed and considered in the determination of significance, and will be in the further development of mitigation and monitoring program in the EPP.

In order to assess existing conditions and assess potential effects of the Project on erosion downstream of the Floodway Channel Outlet Control, various techniques were used:

- discussions with local Rural Municipalities;
- review of historic aerial photographs;
- development of computer based Computational Fluid Dynamic (CFD) analysis with the FLOW-3D model developed by Flow Science of Los Alamos, New Mexico;
- development of a physical model of the proposed Outlet Structure at the Hydraulics Research and Testing Facility (HRTF) of the University of Manitoba.

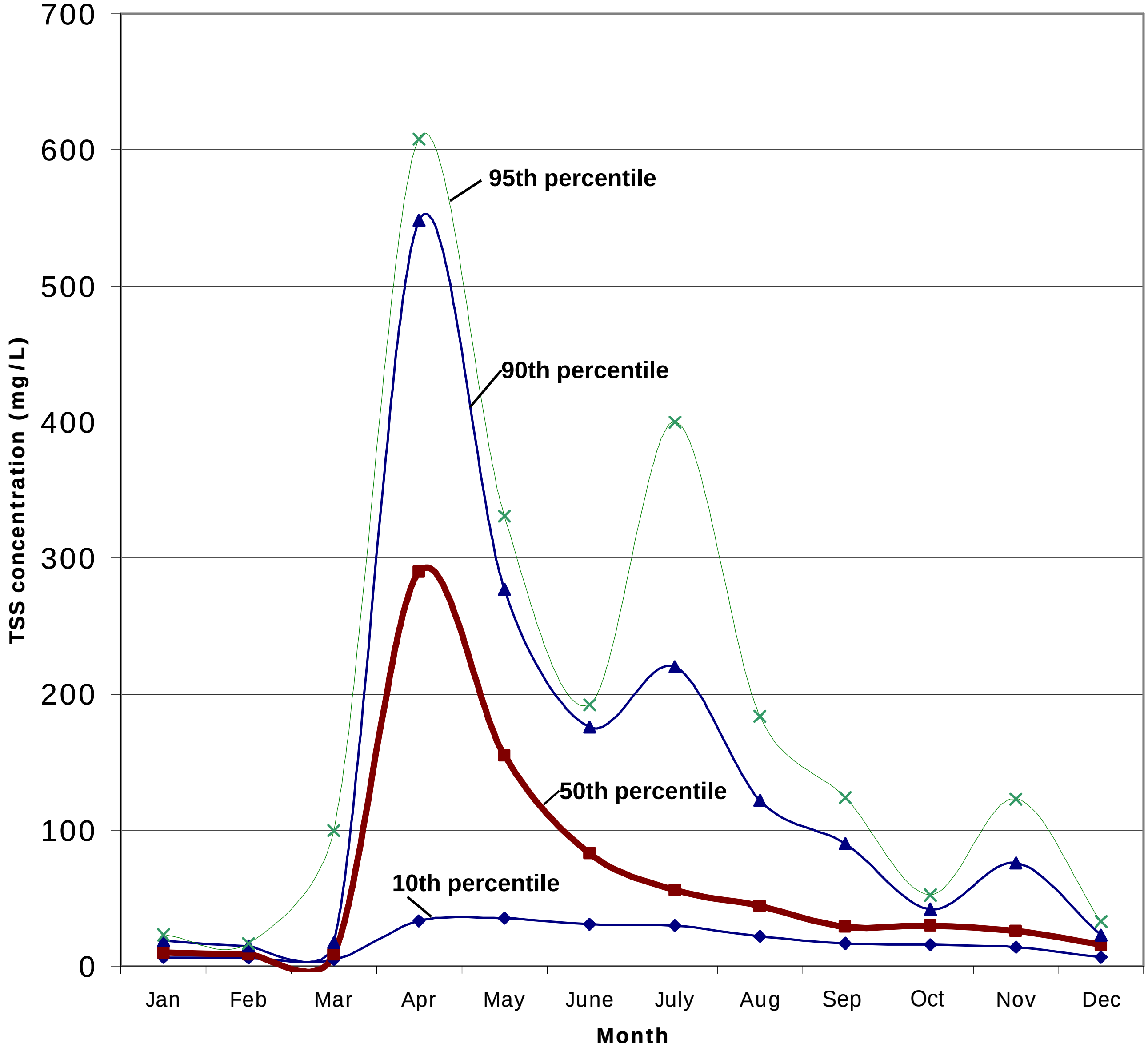
5.5.1.2 Sources of Effects

The typical sources of effects are:

- the removal of soil during the construction of the Floodway Expansion, creating the potential for temporary erosion and sedimentation during construction; erosion of the low-flow channel during use of the Floodway or during the inactive phase when it transports local runoff;
- potential for erosion of the spoil piles and channel sideslopes from rain fall/runoff;
- erosion at the Outlet Control Structure during construction and operation;
- erosion at the Inlet Control Structure in the Red River; and
- increase in sediment carried downstream to Lake Winnipeg due to reduced flooding and sedimentation in Winnipeg.

5.5.2 Existing Environment

The typical monthly baseline sediment conditions at the Red River at Selkirk based on data from the years 1970 to 2003 are shown in Figure 5.5-1. This figure shows that the **total suspended solids** (TSS) at this location range widely throughout the year with the concentrations varying from less than 25 mg/L during the winter months to 600 mg/L during the spring. The highest TSS concentrations tend to occur in April; then the concentrations taper off during the summer and fall. A wide range of expected



Seasonal Concentrations of Total Suspended Solids in the Red River at Selkirk (as Surrogate for Lockport Concentrations)

Figure 5.5-1

Source: Water Quality Management Section 2004

tssconc
ms\01\0211\09

concentrations of TSS are expected in spring and summer due to the wide variation of runoff and river flow conditions occurring from year to year in the Red River Basin. The average annual load of sediment transported to Lake Winnipeg under existing conditions is about 1.8 million tonnes. These data show that high concentrations of TSS in the Red River are expected to occur frequently during periods when the Existing Floodway is expected to be operated. This is a natural phenomena in the Red River during floods.

In the Existing Floodway, there has been localized erosion of the Low-Flow Channel where the base of the channel is lacustrine clay; and there has been very little deposition of sediment in the Existing Floodway (KGS/Acres/UMA June 2004). The existing Low-Flow Channel has eroded since construction in the 1960's. This erosion has been in the order of 1.0 to 1.5 meters in some locations, and this has created pools within the Floodway Low-Flow Channel (see Figure 5.5-2). Erosion would be expected to continue in the future without remedial action to the Low Flow Channel.

Historically there has been erosion on the downstream embankments immediately adjacent to the Inlet structure during major floods, and this erosion was repaired following the flooding in 1997.

There are concerns about erosion downstream of the Existing Floodway Outlet. Discussions were held with the R.M. of St. Andrews and the R.M. of St. Clements to understand these concerns (KGS/Acres/UMA – Appendix D of Engineering Report). Recognizing that erosion along riverbanks is both a natural and artificial phenomena, the various potential causes of erosion were identified. These causes are:

- wind induced wave action;
- wave action from boat traffic;
- river velocity induced erosion; and
- wave action from operation of the Floodway Outlet Structure.

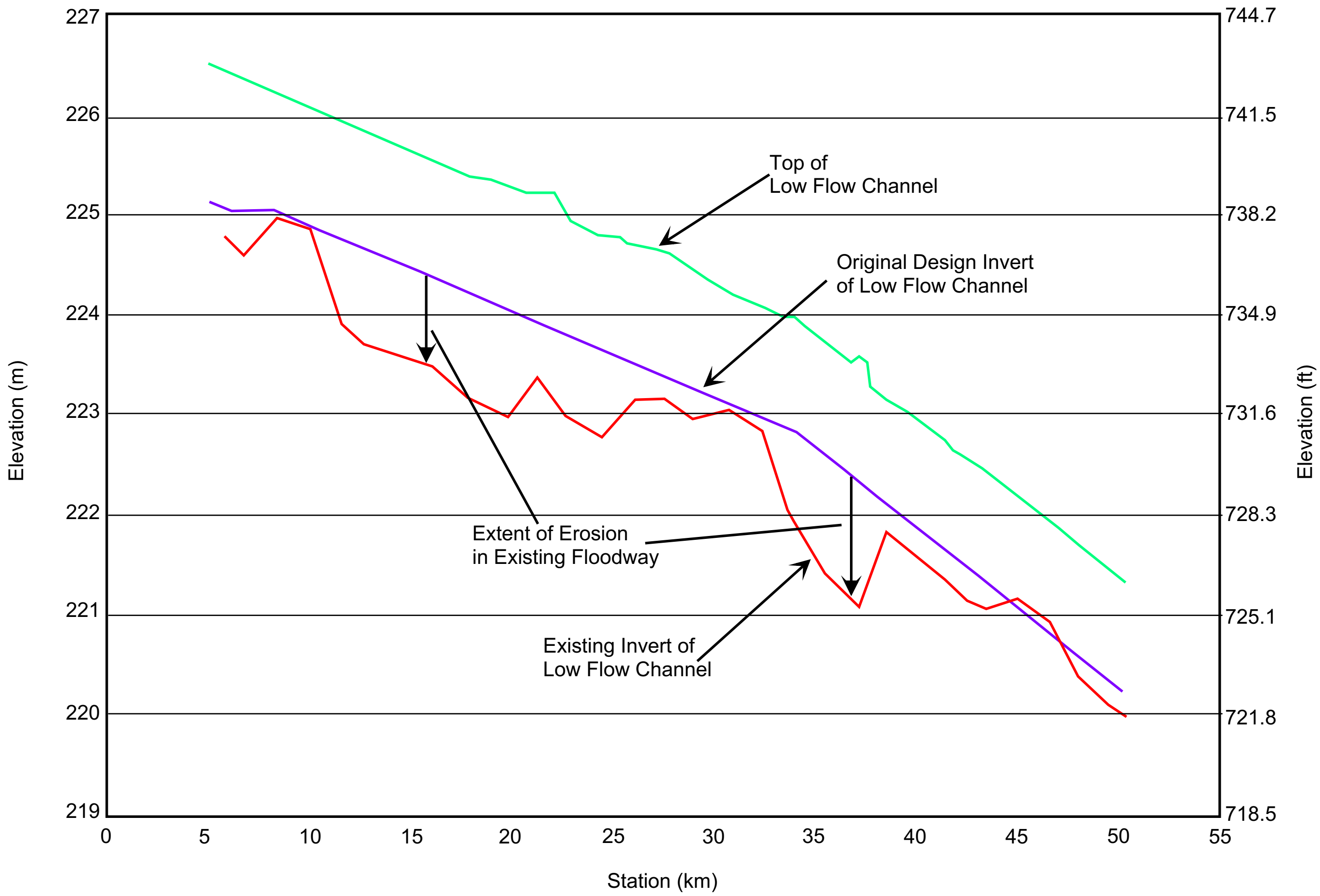
Observations during the 1997 flood and FLOW-3D modelling analysis indicated that wave action and slightly increased river velocities on the west bank of the Red River, for 1,200 m downstream of the existing erosion protection, could cause increased erosion during major flooding.

5.5.3 Effects and Mitigation

The effects of the Existing Floodway on erosion in the Red River downstream of the outfall were considered in the assessment of Project effects. Other existing conditions are integrated into the baseline information collected. Other projects that have the potential to increase the cumulative effects of erosion and sedimentation include enhanced summer operation of the Floodway during construction, dredging, additional City of Winnipeg flood protection infrastructure, recreational use of the Floodway and other infrastructure.

5.5.3.1 Construction

Soils will be exposed during the construction stage of the Floodway Expansion, creating the potential for temporary erosion and sedimentation to occur in the Floodway Channel and on disposal piles from rainfall



Source: KGS - ACRES - UMA 2004b, Appendix B
Fig. 8-1: Proposed Invert Profile of the Low Flow Channel

Profile of Existing Low Flow Channel
Showing Erosion Since Construction
Figure 5.5-2

profile1
ms\01\0211\09

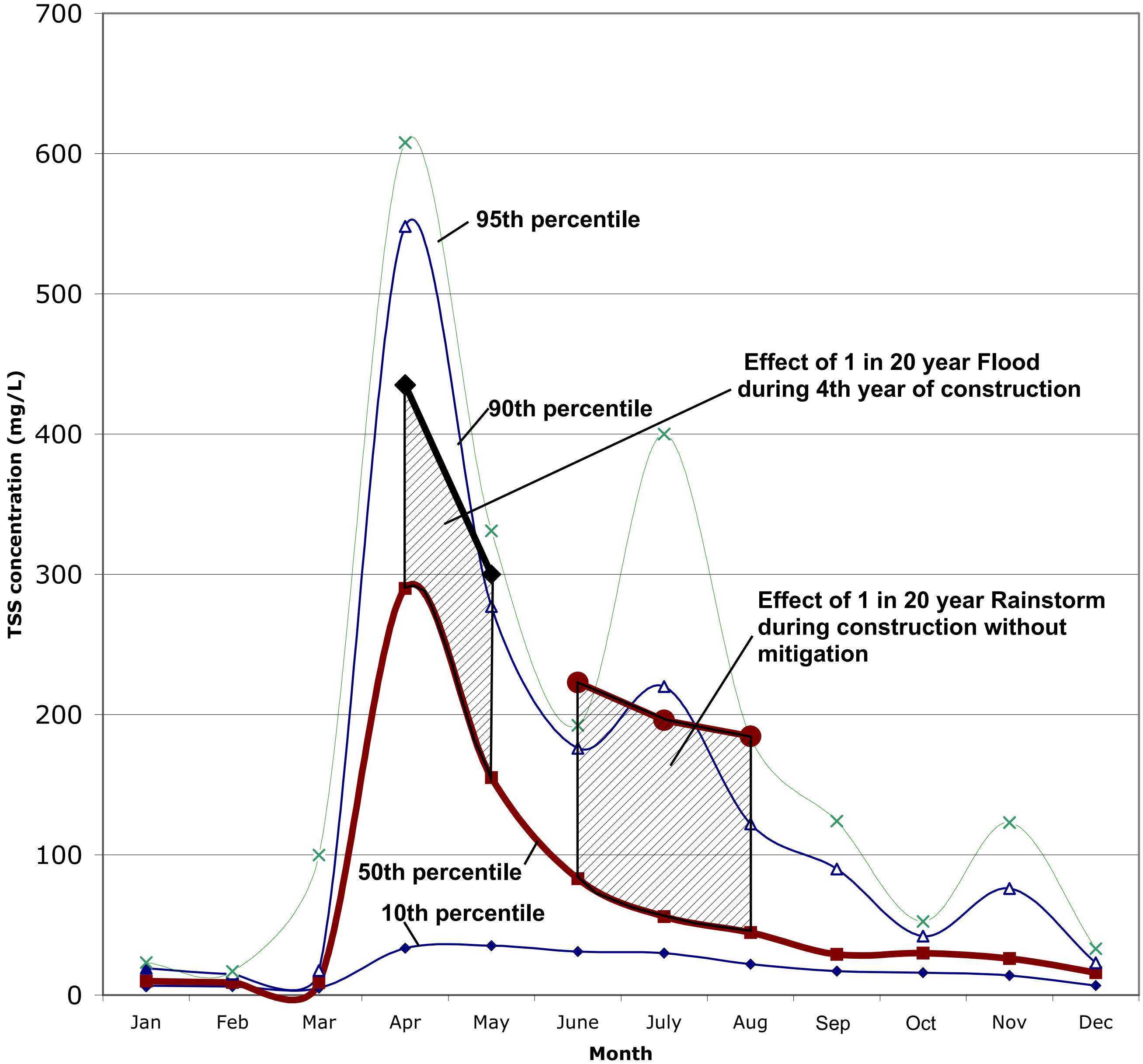
runoff while excavation is occurring. This could result in a temporary increase in sediment concentration in the Red River. This effect will be managed through the use of a sediment and erosion control plan within the Channel Excavation EPP such that any project-related increases in total suspended solids ("TSS") in the Red River will remain within the applicable provincial guidelines for normal periods of construction. Severe floods or rainstorms may cause increases above guidelines; however, these events have a low probability of occurring during construction.

Flood Event During Construction

There is also a potential for erosion and sedimentation to occur at the Floodway Outlet and Outlet Channel; however, a sediment and erosion control plan (in the EPP) and the other specified mitigation measures will be used at this location. Thus, no noticeable change in erosion or sedimentation in the Red River from rainfall runoff due to construction at the Floodway Outlet and Outlet Channel are anticipated.

There is a potential for an increase in sediment concentration in the event of a flood occurring during the excavation. The difference in sediment concentration during construction was estimated for floods of various magnitudes for construction schemes A and B using the USACE's HEC-6 sediment transport analysis software. Scheme A excavates from upstream to downstream while scheme B excavates from downstream to upstream. The results of this analysis are shown in Table 5.5-1; (KGS 2004b).

The typical baseline total suspended solids at this location are >250 mg/L (Water Quality Management Section 2004). The Manitoba Water Quality Standards, Objectives and Guidelines ("MWQSOG"; Williamson, 2002) allows for 25 mg/L induced change from background levels in one day or 5 mg/L average induced change from background levels over 30 days. For the more likely flood event of less than 1 in 20 year return periods, the increase in TSS at Lockport is less than the Manitoba Guideline (25mg/L). In a low probability scenario, such as if a 1:33 year or larger flood occurs during the construction period, the sediment concentration would exceed the stipulated objectives for the one-day period during year four in both construction schemes A and B. In the event of a 1:100 year flood the sediment concentration would also be expected to exceed the stipulated objectives (a 25 mg/L increase) during years 2 and 3 for construction scheme A. These TSS increases are still within the historical range for spring flood events. To illustrate a potential effect of an unlikely flood (1 in 20 year) during the fourth year of construction we have added the increase of 145 mg/L to the mean TSS in April and May (Figure 5.5-3). This indicates that TSS concentrations would be with the natural variation in spring.



Maximum Effects of Floods or Rainstorms During Construction on Sedimentation Concentration at Lockport

Figure 5.5-3

Source: Water Quality Management Section 2004
KGS, Acres, UMA 2004b

fldeffct
ms\01\0211\09

Table 5.5-1
Differences in Sediment Concentration in the Red River at Lockport During Construction Schemes A or B

	Construction Scheme A Difference in Sediment Concentration in the Red River at Lockport (mg/L)				Construction Scheme B Difference in Sediment Concentration in the Red River at Lockport (mg/L)			
Flood Event	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 1**	**Year 2**	**Year 3**	**Year 4**
For Likely Events								
1 in 3.3 Year	ng	ng	ng	ng	ng	ng	ng	ng
1 in 5 Year	ng	ng	ng	ng	ng	ng	ng	ng
1 in 10 Year	ng	ng	ng	ng	ng	ng	ng	ng
1 in 20 Year	ng	3.9	ng	21.2	ng	ng	ng	15.7
For Very Low Probability Events								
1 in 33 Year	ng	ng	ng	53.4	ng	ng	ng	113.1
1 in 50 Year	ng	ng	ng	58.7	ng	ng	ng	145.3
1 in 100 Year	ng	32.0	54.5	49.7	ng	ng	ng	114.0

1. Negative values represent deposition of sediment in the Floodway.
2. Adapted from KGS, March 2004
3. ng = negligible change of <1.0 mg/L

Major Rainstorm During Construction

There is a risk of erosion occurring as a result of a rainstorm during construction. For most common rainstorms there will be no noticeable effect on the Red River. The risk of a five-year event rainstorm occurring during the construction period was calculated and is expected to be 60%, while the risk of a 20-year storm occurring during construction is approximately 18.5%. An analysis was conducted to estimate the potential erosion due to these higher magnitude rainfall events. The potential for incremental increases in total suspended solids ("TSS") at various locations along the Red River due to the Floodway Expansion is shown in Table 5.5-2. These are the anticipated increases in total suspended solids that may occur due to rainfall events if no mitigation measures for preventing erosion are in place.

Table 5.5-2
Potential Incremental Increase in Total Suspended Solids at Red River from Floodway Excavation

Location	5 Year Storm		20 Year Storm	
	Runoff Volume (m^3/day)	TSS (mg/l)	Runoff Volume (m^3/day)	TSS (mg/l)
Runoff from 3,000 m Construction Zone	16,000	50,000	21,000	220,000
Runoff into Floodway[1]	2,592,000	90	7,614,000	90
Totals at Floodway Outlet	2,608,000	400	7,635,000	700
Red River at Lockport	25,920,000	90	25,920,000	90
Red River downstream of Floodway Outlet	28,528,000	120	33,555,000	230
Total increase in TSS		30		140

1. Runoff into Floodway is assumed to have same background as Red River
2. Adapted from KGS, June 2004

The effect of a large and unlikely flood or rainstorm on sediment concentrations at Lockport is shown in Figure 5.5-3. This assessment shows the effect of construction on the Red River without mitigation. In terms of the expected physical effects, this variation is not significant relative to natural variation of sediment concentrations. A sediment and erosion control program with an EPP for the Channel Expansion will be implemented to mitigate the potential for erosion of the Floodway Channel.

The West Dyke is not immediately adjacent to major rivers. An erosion control plan will be developed as part of an EPP to ensure sediment does not adversely impact downstream waterways.

The effect of increased TSS concentrations in the Red River on aquatic life is considered in Chapter 6.

Mitigation-Erosion Control Plan - Channel

A sediment and erosion control plan will be developed in order to mitigate erosion and sedimentation effects associated with the construction phase. The current Project budget has an allowance of $6.2 million or 6-7% of the Channel Project Cost for erosion control. The possible **best management practices** that may be used to minimize potential erosion (KGS/Acres/UMA 2004b) include:

- Construction timing and sequencing will be coordinated to maximize excavation while minimizing the time of exposure for newly excavated slopes to less than 30 days before planting;

- Minimize disturbance to adjacent vegetated areas and base of Floodway for buffering suspended sediment;
- Implement 'surface roughening' techniques;
- Re-vegetate exposed areas directly after finished grade is established and minimize the amount of over-winter exposed surfaces.

The general best management practices (KGS/Acres/UMA 2004b) that will be used to manage the excavation include:

- Excavation should be completed from the top down not from the inside out (cf. Figure 4.3-10). This will maximize the vegetation buffer below the excavation (Chapter 4 – Channel Excavation);
- When excavating below 1:20 year summer Floodway levels (years 2, 3 and 4) excavate from the outside in, and leave an earth plug until the end of the construction period. This will maintain excavation in the dry, and allow for containment of internal sediment during storm runoff;
- Implement slope roughening techniques on exposed side slopes to limit erosion.

These measures are anticipated to reduce erosion and sediment transport by more than 10% (KGS/Acres/UMA 2004b).

A silt fence will be maintained around the perimeter of excavated areas and a number of intermediate sediment control techniques are being considered to reduce sediment transport (Figure 5.5-4), including:

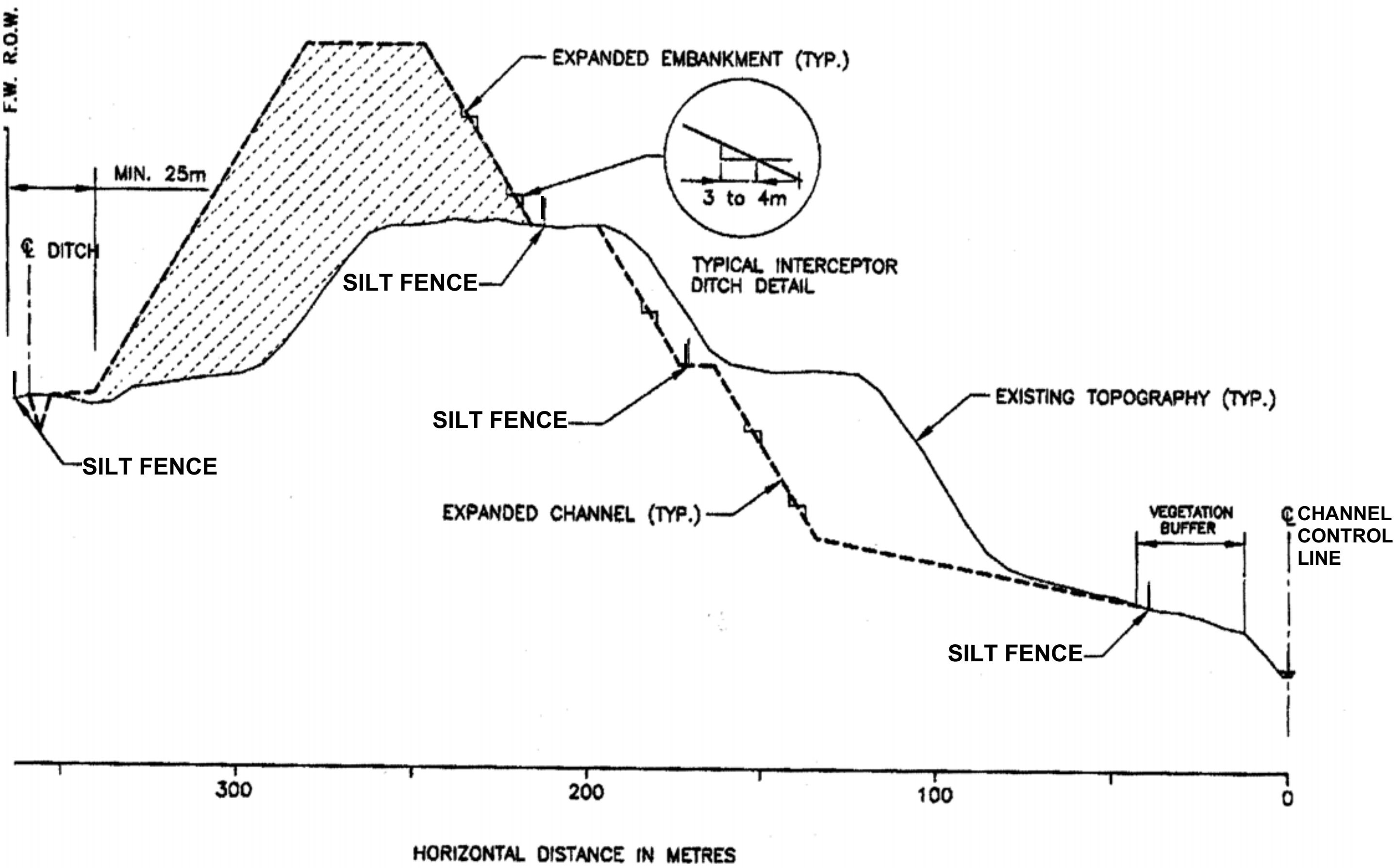
- installation of silt fencing parallel to the benched areas, allowing 3 to 4 metres of buffer between the toe of the up slope and the line of the silt fence;
- construction of flow interceptor swales at regular intervals cross-slope;
- permeable sediment barriers;
- temporary vegetation seeding.

These will be reviewed during the development of an Environmental Protection Plan (Section 4.16) and the effectiveness of techniques will be monitored and reviewed during the course of construction. The most effective measures will be maintained.

The sediment and erosion control measures that KGS recommends for preventing sedimentation at the bridges and drop structures include:

- silt fences placed along the outside edge of the work area;
- construction of an erosion resistant pad with coarse granular or small rockfill riprap.

In order to prevent erosion on the slopes of the Floodway and from the disposal piles during the construction phase, these areas will be revegetated immediately after excavation. Measures will be used to promote fast establishment of plant growth (see revegetation plan in Section 4.3.5); the survival rate will be monitored, and areas where seed does not take will be replanted.



Source: KGS, Acres, UMA 2004b - Appendix B

Sediment and Erosion Control Plans

Figure 5.5-4

sedctrl
ms\01\0211\09

Mitigation-Erosion Control Plan - Outlet

Mitigation measures that may be used to control erosion from precipitation runoff at the Floodway Outlet and Outlet channel during the construction phase may include:

- isolation of construction area from Red River;
- use of silt fences and low level weirs for filtration and sedimentation.

Outlet channel protection work will be completed before spring to avoid soil exposure in this area during spring and summer.

The potential for erosion and sedimentation if spring flooding occurs during the construction phase will be mitigated via the following measures:

- maintaining vegetation in the base of the Floodway;
- building the Project in sequential segments to minimize the amount of time the given area of soil is exposed; and
- revegetating as excavation proceeds instead of waiting until excavation is complete.

Mitigation –Erosion Control Plan –West Dyke

As erosion control plan with in the EPP for the West Dyke will be developed prior to construction. The construction is planned to occur over two years and revegatation at that time permanent erosion control will be established (Section 4.3.5).

All the mitigation measures that will be used will be outlined in further detail in the sedimentation and erosion control plan in the Environmental Protection Plan for the Project construction. With the implementation of the sediment and erosion control plan, the monitoring program and the contingency plan, it is anticipated that temporary increases in the sediment concentration in the Red River from erosion of the Channel and disposal piles will be within regulatory guidance, and the changes in erosion and sedimentation in the Red River due to construction at the Floodway Outlet and Outlet channel will not be noticeable.

Future Projects

There is a potential for erosion and sedimentation caused by the Project to result in an increased need for dredging downstream of the Floodway Outlet. An analysis of the potential additional sediment load during construction was completed and was compared to the existing Red River baseline data. The analysis found that any potential increase in sediment levels is expected to be minor. If a 20-year storm occurred during construction (without the mitigation discussed above), approximately 4,600 tonnes of sediment may be eroded in this event (KGS/UMA/Acres 2004b.) This is only 0.26% of the 1.8 million tonnes average annual discharge of sediment in the Red River. Dredging may increase sediment in the river if it is resumed during construction it may have potential to overlap with the Project effects. The effect of dredging on sediment would be assessed at the time dredging is resumed. After construction no adverse project effects are expected, so there is no overlap of projects.

Other City of Winnipeg flood protection projects such as raising dyke levels, may potentially affect sedimentation and erosion. It is expected that these types of projects would be reviewed, and any effects on erosion and sedimentation along with suitable mitigation measures would be identified during the process.

Since the unmitigated effects of the Project construction on sediment is not expected to be outside the natural variation of sediment concentrations in the Red River (even for unlikely events), and Best Management Practices for erosion control will be implemented, there will be no significant effect on sediment concentrations in the river. The proposed EPP will be submitted for approval prior to construction. Chapter 6 will discuss potential effects on aquatic habitat.

5.5.3.2 Operation - Inactive

When the Floodway is inactive it is anticipated there could be erosion from the slopes of the Floodway Channel and the disposal piles. These areas will be immediately revegetated after excavation and the disposal piles will not be any steeper than the existing piles. Thus, the amount of erosion due to the Project is expected to be negligible.

Recreational use of the Floodway has the potential to increase erosion. Future plans to designate the Floodway for various types of recreational use should be reviewed to identify the potential impacts to erosion and sedimentation. Mitigation measures should be specified and appropriate monitoring programs implemented.

Materials from the Floodway spoil piles could be used in the construction of other infrastructure. If this occurs, appropriate measures, such as revegetation, will be required to mitigate any potential increases in erosion. It is anticipated that other infrastructure projects would require review, and the effects of these projects on erosion and sedimentation and appropriate mitigation measures would be identified during this process.

5.5.3.3 Operation - Active

There is a potential for change in sedimentation and riverbank erosion when the Expanded Floodway is operating.

5.5.3.3.1 Inlet Control Structures

Improvements will be made to erosion protection on the embankments immediately upstream and downstream of the existing Inlet Control Structure to conform to current design standards and to handle extreme floods. Thus, the Floodway Expansion will reduce potential erosion in the vicinity of the Floodway Inlet when the Floodway is operating during a flood event.

5.5.3.3.2 Low Flow Channel

The low-flow channel of the Existing Floodway has been eroded. As part of the Project, these eroded areas will be in-filled to restore the original channel bed. Furthermore, erosion control measures, such as riprap etc., will be installed in eroded areas to protect it from future erosion (Figure 5.5-5). About 30 km of the channel is estimated to be rip-rapped. These measures are likely to result in reduced erosion in the Floodway Channel. For floods that are within the capacity of the Existing Floodway, the velocities within the channel will be lower, resulting in lower potential for erosion. For more severe floods, the velocities may be higher but can be accommodated by the enlarged channel configuration of the Expanded Floodway. Channel configurations for the Expanded Floodway were determined by considering the potential for erosion, and the configuration that was adopted supports velocities that are within limits that the channel bed can resist without causing erosion. For these reasons, it is anticipated that there will be no additional erosion, and there could possibly be a reduction in erosion when the Project is operating.

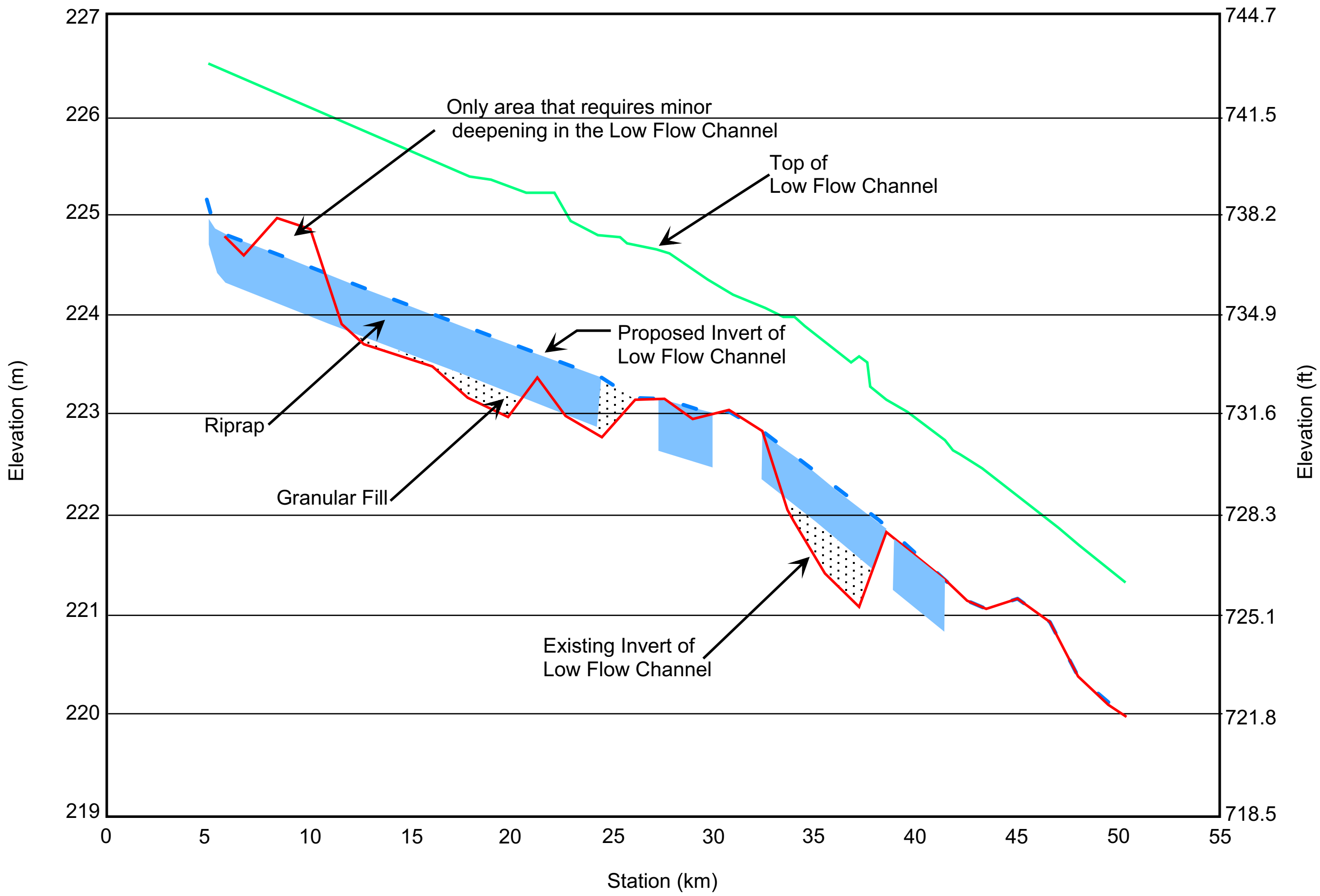
It is anticipated that during small floods, some sediment may drop out in the channel; however, this is not expected to be significant with respect to decreased capacity.

5.5.3.3.3 Effects on Lake Winnipeg

During large flood events (i.e., greater than 1 in 225 year return period), it is anticipated that sediment that would have settled on the flood plain protected by the Floodway will be carried down to Netley Marsh and Lake Winnipeg. This is anticipated to be both an infrequent event and a small percentage of the total load going into Lake Winnipeg in a flood year. The increase in load to Lake Winnipeg due to the Expansion Project, during the 1 in 700 year flood scenario, would be at most 3-4% of the total load to the Lake during the Flood. Since this is a rare event, the change in average annual load due to the Project is much smaller, calculated to be 0.1% of the total annual load of 1.8 million tonnes/year and is not significant.

5.5.3.3.4 Effects on Red River

The Project could effect sedimentation and erosion on the Red River within Winnipeg and downstream to the Outlet by reducing velocities in the River during larger floods. This lower velocity would increase sedimentation and reduce erosion relative to the Existing condition. Reduced erorion would be considered an positive effect, however increased sedimentation could, over the long term, reduce hydraulic capacity in the river. An preliminary analysis (KGS 2004a) indicates that, assuming the past 32 years of flow record is representative of the future conditions, a slight increase in sedimentation from the Project relative to Existing conditions may occur. This effect in expected to be small, local (to the section of the Red River bypassed by the Floodway), long-term and not significant.



Source: KGS - ACRES - UMA 2004b

Proposed Invert Profile of the Low Flow Channel
Figure 5.5-5

profile2
ms\01\0211\09

5.5.3.3.5 West Dyke

Erosion control along the West dike is to be improved, thus reducing potential for erosion during major floods.

5.5.3.3.6 Outlet Structure

During flood events that are less than the design capacity of the Existing Floodway (i.e., less than 1 in 200 return events), the Expanded Floodway Outlet design will dissipate energy more effectively than the existing Outlet design, thus reducing erosion. During Flood events equal to or greater than the existing design capacity, the new outlet design will reduce any increased downstream erosion due to the Existing Floodway Operation.

Modeling (Flow 3-D) was conducted to estimate the anticipated erosion at the Floodway Outlet when the Floodway is operating at the Design Flood (1 in 700 year return period event). The modeling demonstrates there is no anticipated increase in wave action or velocities on the east bank of the Red River due to the operation of the Floodway; thus, it is not necessary to add increased erosion protection on the east side of the river. The design of the Outlet structure, along with added erosion protection in the Outlet channel and along the west bank of the river, will reduce downstream wave action to levels that are substantially lower than those that occur within the Existing Floodway in most locations. There may be a slight increase in velocities on the west bank of the Red River immediately north of the Outlet; however, this increase is expected to be approximately 0.1 m/s (i.e., an increase from 1.1 m/s to 1.2 m/s). Mathematical modeling (KGS/Acres/UMA 2004c) predicts that there will be no additional velocities due to the Floodway Expansion beyond 800 metres from the Floodway Outlet. The water velocities traveling by Lower Fort Garry, Selkirk and other upstream locations will remain the same during spring operating conditions.

Several design features have been incorporated into the Expanded Floodway Outlet to mitigate potential erosion during the Project operation. Stilling blocks, chute blocks and other design features have been incorporated into the Outlet structure to reduce velocities and dissipate energy in flows entering the Red River. Other Project mitigation measures include the construction of sidewalls in the Outlet channel to prevent erosion in this area. On the west bank of the Red River, immediately north of the Outlet, the existing riprap will be repaired, and the erosion protection will be extended 1,200 m downstream of the Outlet beyond the areas that could potentially be affected by higher velocities when the Expanded Floodway is operating at design capacity. This protection will be designed so that no additional Project related erosion occurs in this area when the Floodway is operating at design capacity.

With the implementation of these mitigation measures, the impacts on erosion and sedimentation during the operations of the Project are expected to be short-term, beneficial, localized, minor and not significant.

5.5.4 Residual Effects and Significance

The residual effects of the Project on erosion and sedimentation are shown in Table 5.5-3. The effects on erosion and sedimentation will be mitigated through the implementation of a sediment and erosion control plan. With the implementation of these mitigation measures, the Project is not expected to have any significant effects on erosion and sedimentation.

Table 5.5-3
Summary of Residual Effects and Significance on Erosion and Sedimentation Related to the Floodway Expansion Project

Description of Effect	Mitigation	Residual Effects and Significance
Construction		
There is a potential for increased erosion and sedimentation at the **Floodway Outlet** during construction.	This effect will be mitigated through the implementation of a sediment and erosion control plan.	It is expected there will be a very small change in erosion or sedimentation in the Red River. This effect is expected to be short-term, reversible and local. **Not significant**
Potential for an increase in TSS concentrations in the **Red River** in the event of a **flood occurring during construction**. For likely floods there will be no noticeable effect. If a 1:33 or larger magnitude flood occurs, the sediment concentration is expected to exceed the Manitoba Objectives; however, they are expected to be within the range of concentrations historically experienced during flood events.	This effect will be mitigated by construction sequencing	This event has a low to moderate probability of occurring, would occur for the duration of the flood event (~1 month), and would be temporary. **Not significant**
Potential for incremental increases in TSS in the **Red River** due to erosion caused by **higher magnitude rainfall events**. For smaller rainfall there will be no effect on TSS in the Red River. The risk of a five-year rainstorm event occurring during construction is anticipated to be 60%, resulting in a maximum potential incremental increase in total suspended solids of 400 mg/L. The chance of a 20-year rainstorm occurring during construction is considered to be 18.5%, resulting in a maximum total suspended solids increase of 700 mg/L.	This effect will be mitigated through the use of a sediment and erosion control plan.	The magnitude of the potential effect after mitigation measures are added is expected to be less than natural variation of TTS, to be of short-term duration and reverisible. **Not significant**
Potential for sediment from West Dyke construction to effect downstream waterways.	This effect will be mitigated through the use of a sediment and erosion control plan.	The effect will be adverse, small, local and reversible. **Not significant**.
Operation - Inactive		
Erosion from the **slopes of the Floodway Channel and Disposal Piles** may occur when the Floodway is inactive.	These areas will be immediately revegetated after excavation, and the disposal piles will not be any steeper than the existing piles.	This effect is expected to be of small magnitude long-term and will occur locally throughout the Floodway Channel. It is not expected to be reversible. **Not significant**

Description of Effect	Mitigation	Residual Effects and Significance
Operation - Active		
The Project will result in the **Inlet Structure's** upstream and downstream embankments being better protected, thus reducing erosion in this location.	None	Project is expected to create a positive site-specific permanent effect. **Not significant**
Eroded areas in the existing **low flow channel** will be in-filled and further erosion control measures will be added. These measures are likely to result in reduced erosion.	None	It is anticipated there will be no additional erosion in the low flow channel, and there may be a reduction in erosion. The effect will be positive, local, minor and permanent. **Not significant**
During large flood events sediment that would have settled on the floodplain protected by the Floodway will be carried to Netley Marsh and Lake Winnipeg. The amount of sediment is anticipated to be no more than 0.1% of the total load of 1.8 million tones/year entering Lake Winnipeg.	None	The effect is regional, small in magnitude and permanent. **Not significant**
Reduction in velocity in the Red River within Winnipeg may reduce erosion and increase sedimentation	None	The effect in both beneficial and adverse but small, local and long-term. **Not significant**
Erosion control along the West Dyke will be improved	None	The effect will be small, local, and beneficial. **Not significant**
The **Outlet Structure** of the Project has been designed to mitigate potential erosion and sedimentation impacts. Erosion control features include stilling blocks, chute blocks and other design features. These measures are expected to reduce downstream wave action to levels that are substantially lower than those that occur from the Existing Floodway in most locations. There may be a slight increase in velocities on the west bank of the Red River immediately north of the Outlet; however, this is expected to be a moderate increase in velocity from 1.1 m/s to 1.2 m/s.	Potential effects will be mitigated by extending erosion control on the west bank of the Red River by 1,200 m downstream of the Floodway Outlet. Erosion Control could be either riprap or vegetation	This effect is expected to be short-term and beneficial although infrequent. **Not significant**

5.5.5 Monitoring and Follow-up

A monitoring plan will be developed and will include monitoring of sedimentation upstream and downstream of the Floodway Outlet on the Red River during construction to ensure the TSS concentrations are within the stipulated guidelines. The erosion control plan can be modified to maintain or reduce the impact on the Red River during construction.

If emergency summer Floodway operations occur during the construction period, monitoring may be required to evaluate the effects on erosion and sedimentation.

5.6 DRAINAGE

5.6.1 Approach and Methodology

5.6.1.1 Effects Assessment

Hydrology and/or hydraulic studies were reviewed or developed for each of the drains (KGS/Acres/UMA 2004c). New structures were designed to maintain or improve the capacity of each drain. Current runoff analysis formulas were used to develop the designs.

5.6.1.2 Sources of Effects

The sources of effects are:

- construction of new drop structures; and
- change in capacity.

The Project does not include any new drainage structure to the Floodway.

5.6.2 Existing Environment

The Existing Floodway did alter the drainage pattern as existing drains were consolidated and intercepted by the Floodway. There are several existing drainage structures within the Floodway Right-of-way. Rural drainage/drop structures include:

- the Grande Pointe Diversion Drop Structure;
- the Centreline/Prairie Grove Drain Drop Structure;
- North Bibeau Drain Drop Structure, Cooks Creek Diversion Drop Structure;
- Springfield Road Drain Drop Structure;
- Shkolny Drain Drop Structure; and
- Ashfield Drain Drop Structure.

Urban drainage/drop structures include the Kildare Trunk-Transcona Storm Sewer Outlet Drop Structure and the Country Villa Estates Drain Drop Structure. Drainage structures and channels outside of the Right-of-way are the responsibility of the municipal or provincial government, and therefore their adequacies were not considered in the impact assessment. Only the drainage/drop structures within the Existing Floodway Right-of-way were considered. The major drains through the west include:

- the Bolen Drain;
- the Maness Drain; and
- the Domain Drain.

5.6.3 Effects and Mitigation

5.6.3.1 Construction

The Project will involve the replacement of several of the existing drainage structures including:

- the Centreline/Prairie Grove Drain Drop Structure;
- the North Bibeau Drain Drop Structure;
- the Springfield Road Drain Drop Structure;
- the Shkolny Drain Drop Structure; and
- the Ashfield Drain Drop Structure.

Additionally, the Kildare Trunk-Transcona Storm Sewer Outlet Drop Structure will be replaced; the Cooks Creek Diversion Drop Structure will be repaired, and the Country Villa Estates Drain Drop Structure will be modified (refer to Project Description). There is a potential for the construction phase to impact on the existing drainage while each structure is repaired or replaced. A new culvert and gate structure will be located through the West Dyke (Section 4.11).

Construction of these new drainage structures is anticipated to occur in late fall and early winter when little drainage is taking place. Furthermore, the existing drop structures will remain operational while the replacement drop structures are built. With the implementation of these measures, the construction phase of the project is expected to result in minimal interruption of drainage.

The Seine River Syphon will be maintained and a back flow control structure will be developed to prevent flow from the Floodway to Grande Pointe.

The following mitigation measures will be used during the construction phase:

- the existing drop structures will remain operational while the new drop structures are built; and
- the drainage drop structures will be replaced in late fall and early winter when little drainage is taking place.

5.6.3.2 Operation - Inactive

Most of the existing Inlet structures and associated channels within the Floodway Right-of-way will be replaced or modified to accommodate the Floodway widening. At each replaced drainage structure the hydraulic capacity will be increased substantially to accommodate 1 in 100 year design flows within the local drainage system. Channel improvements will be made within the Right-of-way to accommodate increased design flows. For agricultural drop structures, transition structures will be built lower and drain channel depth increased within Right-of-way to accommodate future growth in local drainage systems. The invert of rural drainage drop structures will be built lower and drain channel depth increased within the Right-of-way to accommodate future upgrading in local drainage systems. For all drainage drop structures and channels along the Floodway and within the Right-of-way, the capacity will be maintained or increased. Furthermore, the ability to accommodate future upgrading of local drainage systems will be improved at four agricultural drainage sites. Until upgrades upstream of the structure are undertaken, the benefit will be insignificant. However, these actions are being undertaken by MFEA to accommodate future upgrades by other authorities.

There may be future upgrades to drainage structures in rural municipalities; however, the locations where improvements to these drainage structures will be made are currently unknown. The Floodway Expansion Project includes the repair and replacement of many of the existing drainage structures. The new drainage structures have been designed to accommodate future increases in drainage capacity, so no significant adverse cumulative effects on drainage are anticipated. Future projects which improve drainage upstream will combine increased capacity of the drop structures to the Floodway to improve drainage in the area.

5.6.3.2.1 Seine River Syphon

Two of four overflow pipes will be plugged, since the new Grande Pointe flood protection structure makes these unnecessary. A new trash rack at the syphon inlet ensures flows enter the syphon and do not overflow until the capacity of the syphon is exceeded. A gatewell will be located within the Floodway spoil berm to allow the remaining pipes to be closed to prevent backwater flooding into Grande Pointe. These modification will be beneficial but not significant.

5.6.3.2.2 West Dyke

The borrow materials for construction of the West Dyke will be taken from the adjacent ditches resulting in increased ditch capacity. The rehabilitation of the affected ditches will include possible steepening for drain slopes and other enhancements that will improve drainage. A new gated culvert will be added through the Dyke southwest of Labarriere Park to improve drainage to the LaSalle River. There is concern that improved drainage will impact water levels in the La Salle River, but these effects would be minor and not significant.

5.6.3.3 Operation - Active

The Expanded Floodway will have an increased capacity resulting in lower water levels during flood events. The lower water levels in the Expanded Floodway during flood events will allow the drainage structures to operate more efficiently during these periods, thus providing more capacity in the upstream drains. In the case of extreme flood events (i.e., greater than 1:250), the three downstream structures (Ashfield, Shkolny, and Country Villa Estates) will need to be closed to prevent backwater flooding. Local drainage will have to be pumped during these extreme events.

5.6.4 Residual Effects and Significance

Although many of the drop structures at the Floodway will provide increased hydraulic capacity, limitations to drainage occur upstream regardless of whether the Project proceeds or not. No significant benefit in terms of improved drainage will occur with the Project.

The residual effects of the Project on drainage are shown in Table 5.6-1.

Table 5.6-1
Summary of Residual Effects and Significance on Drainage related to the Floodway Expansion Project

Description of Effect	Mitigation	Residual Effects and Significance
Construction		
Potential adverse effects on drainage may occur while each structure is repaired or replaced.	This impact will be mitigated by timing repair and replacement to occur when there is normally little runoff, and the existing drop structures will remain in place while the replacement drop structures are built.	The magnitude of this effect is expected to be low; it would occur for a brief time and would be temporary. The effect could occur at a number of drainage areas. **Not significant**
Operation – Inactive		
Most of the existing drop structures and associated channels within the Floodway Right-of-way will be replaced or modified, and the hydraulic capacity at these drainage structures will be increased to accommodate 1 in 100 year design flows. The capacity at all drainage Inlet structures will be maintained or increased, and the ability to accommodate future upgrading of local drainage systems will be improved at four agricultural drainage sites. Substantial benefit will not be realized unless improvements occur upstream.	None required	This minor positive effect will be long-term and will occur throughout the Floodway Channel drainage area. **Not significant**
The Seine River Syphon will be maintained. The new trash rack design will ensure flows enter the syphon and do not overflow until the capacity of the syphon is reached.	None	This minor positive effect will occur in a local area and will be long-term. **Not significant**
Borrow materials for construction of the **West Dyke** will be taken from adjacent ditches resulting in an increase in drainage capacity.	None	This positive effect will be of long-term duration. It will occur in a local area. **Not significant**
A gated culvert will be added	None	This positive effect will be of long-term

Description of Effect	Mitigation	Residual Effects and Significance
through the West Dyke southwest of Labarriere Park to improve drainage to the LaSalle River.		duration. It will occur in a local area. **Not significant**
Operation – Active		
The **increased capacity of the Expanded Floodway** will result in lower water levels during flood events, thus allowing for more drainage capacity and upstream drains.	None	This positive short-term effect would occur infrequently (i.e., during flood events) for a time period of approximately one month. **Not significant**
During extreme flood events of a magnitude of 1:250 or higher, the three downstream drains will need to be closed to prevent backwater flooding.	Mitigation measures will involve the pumping of local drainage during these flood events.	These effects will occur infrequently (i.e., during flood events) for a period of approximately one month. **Not significant**

5.6.5 Monitoring and Follow-up

No monitoring or follow-up required.

5.7 ICE PROCESSES

5.7.1 Approach and Methodology

5.7.1.1 Effects Assessment

A review of previous ice jams north of the Floodway was conducted to determine the conditions when ice jamming typically occurs (Acres 2004a). The operation of Floodway was compared to the conditions when ice jamming occurs to determine if the Floodway has a potential effect on ice jamming (KGS/Acres/UMA 2004a). A detailed hydraulic analysis of the timing of flows in the river and flooding prior to the severe 1996 ice-jamming event was conducted using the U.S. Army Corps of Engineers computer model HEC-RAS-III (Hydrologic Engineering Centre – River Analysis System; KGS/Acres/UMA 2004a). The purpose of this analysis was to determine the river flows and water levels that would have occurred under the following situations (KGS/Acres/UMA 2004a):

- with and without the Existing Floodway;
- with and without the Shellmouth Reservoir and the Portage Diversion; and
- with and without the Floodway Expansion.

There is considerable uncertainty in predicting under what conditions ice jams will occur. This uncertainty exists under the current conditions and will continue after the expansion of the Floodway. Since these uncertainties are common to both the existing conditions and the Project, they do not affect the determination of significance on how the Project could affect ice jamming. There is a great deal of confidence in the relative timing of the flow with and without the Project as assessed by HEC-RAS.

5.7.1.2 Sources of Effects

No sources of effects of the Project on ice jamming could be determined.

5.7.2 Existing Environment

Several locations in the Selkirk area are prone to ice jams; these include the Red River meanders, the Selkirk Bridge, and Sugar Island. Solid ice also accumulates downstream in the Red River and on Lake Winnipeg. Ice jams occur when ice flows transported on or near the water surface are stopped due to a local reduction in the transport capacity of the river or for other reasons (Acres 2004a). When an ice jam occurs, the water level changes and causes an increase in flooding.

Local residents hold a perception that the Existing Floodway contributes to ice jamming. An analysis was conducted to determine if the Existing Floodway could be shown to be the cause of early arrival or increased amounts of runoff in the Selkirk area, which exacerbates ice jams or flooding due to ice jams. Conversely, if it could be shown that flows at Selkirk with the Floodway rise at the same time or later than what would have occurred naturally without the Floodway, this would prove the Floodway does not contribute to ice jamming.

Records of ice jamming were reviewed for the Breezy Point location. This review above showed that: (KGS/Acres/UMA 2004a):

- ice jams rarely occur when flows are greater than 2000 m^3/s;
- ice jams have never occurred at recorded flows greater than 2,600 m^3s; and
- ice jams occur when the spring flow is still rising or has peaked at flows of less than 2,600 m^3/s.

Water levels were calculated for flows in the Red River of up to 2,500 m^3/s and Floodway flows of up to 1,700 m^3/s and used to determine water velocities in the Red River and the Existing Floodway for a wide range of flows. The time it takes for a "parcel" of water to travel from the Floodway Inlet to the Floodway Outlet could then be calculated. Travel times were determined for the Red River and the Existing Floodway. For river flows where ice jamming is known to occur, the Floodway is operating under Rule 1 so the amount of flow that would be diverted into the Existing Floodway could be calculated. The travel times of water in the Floodway during various natural river flows were then calculated and could be compared to the travel times through the Red River that would occur naturally if the Floodway did not exist. The results (KGS/Acres/UMA 2004a), showed:

- travel times through the Floodway are longer than what would occur naturally if the Floodway did not exist for natural river flows of up to 2,800 m^3/s;
- at natural river flows of 2,800 m^3/s, the travel times through the Floodway and through the river if the Floodway did not exist, are approximately equal; and
- at natural river flows of greater than 2,800 m^3/s, the travel time in the river, if the Floodway had not been built, would be less than in the river.

As noted above, ice jamming typically occurs on the rising limb of the hydrograph at flows of less than 2,600 m^3/s. As the results show, for natural river flows of up to 2,800 m^3/s, the travel times of water through the Floodway lower than what would occur naturally (KGS/Acres/UMA 2004a). This indicated that the Floodway does not exacerbate ice jams or flooding due to ice jams.

The hydraulic model was calibrated to 1996 conditions (KGS/Acres/UMA 2004a). The model was then adjusted to represent three other cases:

- no Floodway, no Shellmouth Dam and no Portage Diversion to give a "state-of-nature flows" simulation;
- no Floodway, but with Shellmouth Dam and Portage Diversion; and
- assuming an Existing Floodway, with Shellmouth Dam and Portage Diversion.

These simulations showed the following results (KGS, Acres, UMA 2004b):

- the Existing Floodway resulted in a longer travel time than what would have occurred if the Floodway did not exist and all flow passed through the River – thus, the Existing Floodway actually contributed a modest delay of the increases in flow downstream of the outlet; and
- the Shellmouth Dam and Portage Diversion provide benefits by reducing the rate of rise of river flow and damping the contributing factors to ice jam formation north of the floodway Outlet.

The results of the simulation for the Expanded Floodway are discussed in Section 5.7.3.3.

5.7.3 Effects and Mitigation

5.7.3.1 Construction

Construction activities will not have any effects on ice jams.

5.7.3.2 Operation - Inactive

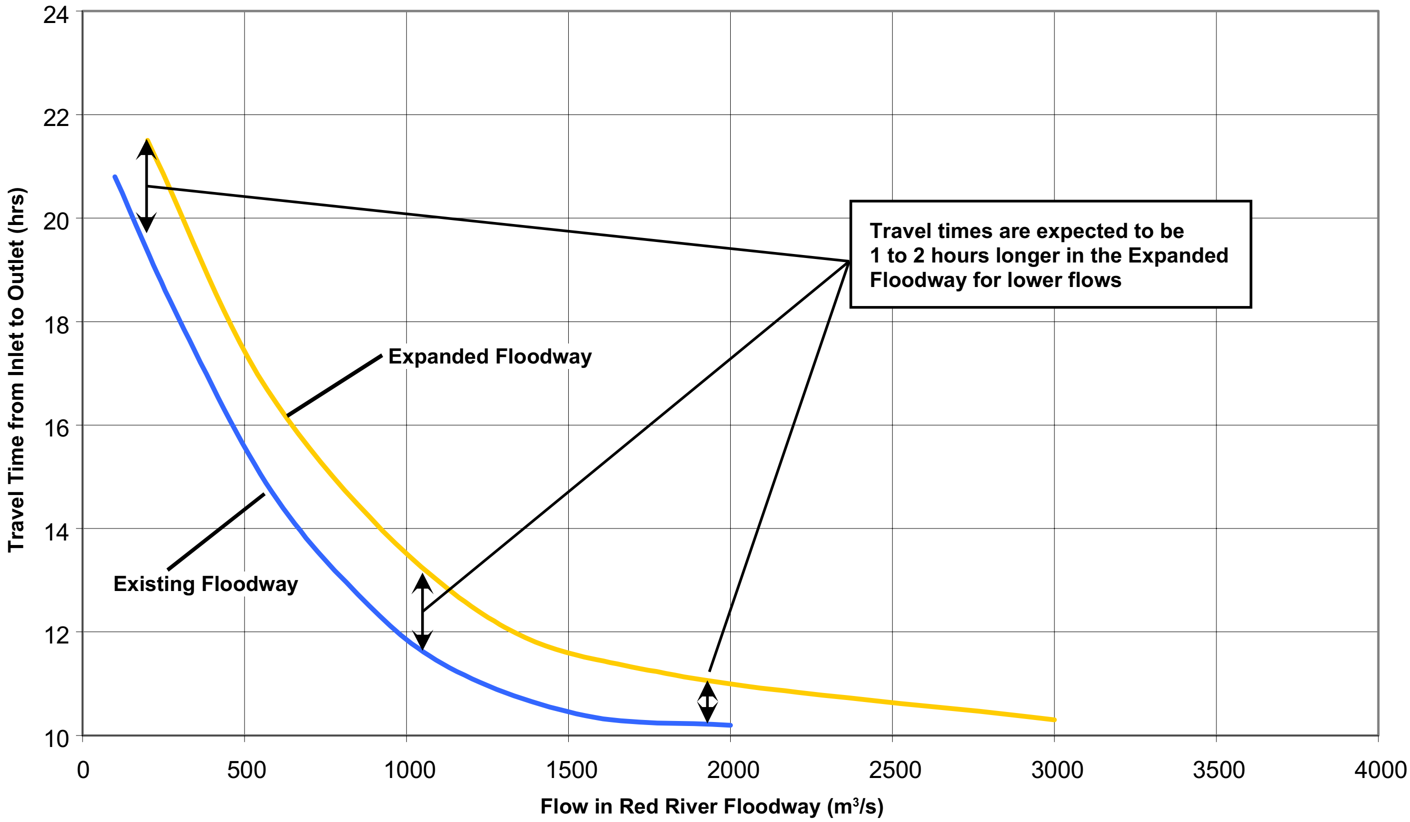
The inactive operation phase of the Expanded Floodway will not have any effect on ice jams.

5.7.3.3 Operation - Active

The results of model simulations of the expected travel times vs. flow in the Existing and Expanded Floodway is shown in Figure 5.7-1 (KGS/Acres/UMA 2004a). As can be seen in this figure, the Project will increase the travel times through the Floodway by 1-2 hours during the rising limb of the hydrograph. This would theoretically reduce the water levels at a given time at Selkirk during the rising of the hydrograph; however, this will not change the existing ice jamming frequency at and downstream of Selkirk. The Project may have a theoretical benefit; however, it is minor and not significant.

5.7.4 Residual Effects and Significance

The residual effects of the Project on ice jamming are shown in Table 5.7-1



Source: KGS/Acres/UMA 2004a

Travel Time on the Red River Floodway (Floodway Inlet to Floodway Outlet) for the Existing and Expanded Floodway

Figure 5.7-1

travtime
ms\01\0211\09

Table 5.7-1
Residual Effects of Ice Jamming

Description of Effect	Mitigation	Residual Effects and Significance
Operation - Active		
The Project is expected to increase the travel times through the Floodway of water by approximately 1-2 hours during the rising limb of the hydrograph (i.e., when ice jamming events have historically occurred). Theoretically, this would have a positive effect on ice jamming by reducing water levels at Selkirk at a given time during the rising of the hydrograph. It is not expected to have any effect on the frequency of ice jamming at and downstream of Selkirk.	None	Minor effect is temporary and beneficial. **Not significant**

5.7.5 Monitoring and Follow-up

Monitoring and follow-up will continue to be done as part of the Water Stewardship mandate.

5.8 CLIMATE, AIR QUALITY AND NOISE

5.8.1 Approach and Methodology

5.8.1.1 Effects Assessment

A long-term weather monitoring station is located at Winnipeg International Airport. Thirty-year climate normals from this site were used to develop a description of the existing local climate and are considered in Section 5.8.2. Local air quality data in the City of Winnipeg was available from Manitoba Conservation. No ambient noise quality data was available.

5.8.1.2 Sources of Effects

Climate could have an effect on the Project, particularly during the operation of the Project. These potential effects were evaluated using information, from studies of the Red River basin and other areas, on the effects of climate on flood frequency, magnitude, and duration. This included an evaluation of potential future flood conditions as a result of climate change.

5.8.2 Existing Environment

Thirty-year climate data normals for the observation station located at the Winnipeg International Airport were obtained from Environment Canada. The mean average temperatures are highly variable ranging from a low daily mean temperature of –17.8^{o} C in January to a high daily mean temperature of 19.5^{o} C in July (Figure 5.8-1). Extreme temperatures well outside the average daily temperature range also occur. Precipitation climate normals are shown in Figure 5.8-2. Precipitation occurs in the form of both rain and snow with the largest amount of precipitation occurring during the month of June. Rainfall occurs from February to December with the largest amount of rainfall occurring during the month of June. Snowfall occurs from September to May with the largest amount of snowfall occurring in the month of January. Prevailing wind direction is typically from the north to north-west.

Manitoba Conservation collects air quality data at one residential and one downtown location in the City of Winnipeg. Data on air quality was available from 1995 – 2001; however, for the purposes of this assessment, data from the two most recent years available was considered sufficient to provide baseline data on air quality. The parameters measured at both locations include carbon monoxide, nitrogen dioxide, nitric oxides, nitrogen oxides, ozone, particulate matter and total suspended particulate. The air quality data for these two years is shown in Appendix 5D. Generally, overall air quality is good, and there are few exceedances of the stipulated objectives or guidelines. The exception is ozone where there were numerous exceedances of the 24-hour maximum desirable and maximum acceptable levels for this parameter at both locations. The total suspended particulate levels occasionally exceeded the 24-hour maximum acceptable levels at both locations, and the particulate matter <10 microns levels occasionally exceeded the maximum acceptable levels at the downtown location, but was not measured at the residential location.

No data was available for ambient noise levels, however, noise levels are expected to be variable with intermittent higher noise levels in high traffic areas and lower noise levels that are typical of rural residential areas in other locations.

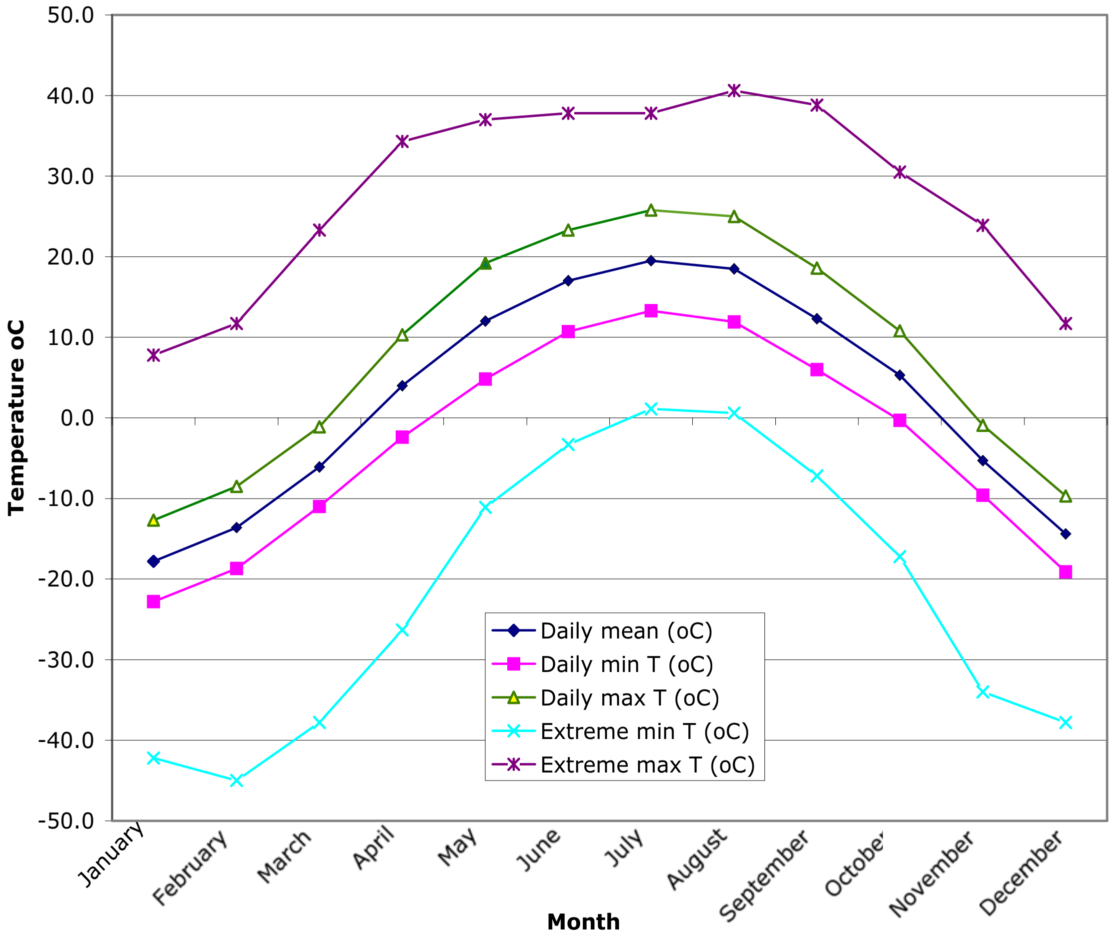
5.8.3 Effects and Mitigation

5.8.3.1 Construction

Potential impacts to air quality during the construction phase of the Project are expected to be associated with emissions from construction vehicles including releases of carbon dioxide and with dust effects from vehicular movement along any temporarily established roadways. Vehicle emissions during construction are unavoidable but of short duration, localized and not significant. Dust emissions will be controlled by good construction practices

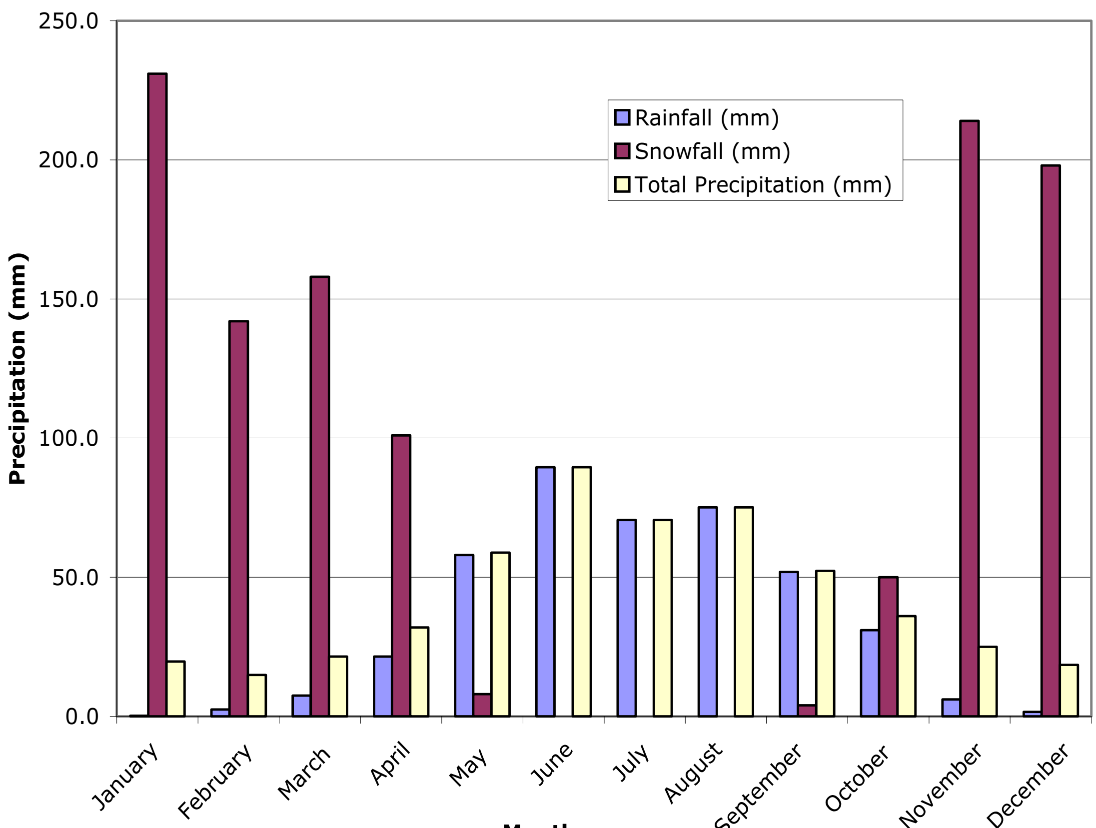
The Province of Manitoba (2002) has publicly stated its intention to meet and exceed Kyoto reduction targets with a goal of a reduction of greenhouse gas emissions of 18% below 1990 levels by 2010. The construction of the Project will result in emissions of greenhouse gases associated with construction equipment; however, this effect is expected to be local, of small magnitude, and of short duration and therefore, is insignificant. The construction of the Project is not expected to affect the province's ability to satisfy its commitment under the Kyoto protocol.

Noise levels are expected to increase during the construction phase of the Project. This effect will be temporary, local and of short-term duration.



Source: Environment Canada 2004

Temperature Normals for the Winnipeg Area
Figure 5.8-1



Source: Environment Canada 2004

Average Monthly Precipitation in the Winnipeg Area
Figure 5.8-2

temp_precip
ms\01\0211\09

5.8.3.2 Operation - Inactive

The operation-inactive phase of the Project is not expected to have an effect on climate change, air quality or noise.

5.8.3.3 Operation - Active

5.8.3.3.1 Effect of the Project on Climate Change

The project will not cause flooding of vegetated land, which could result in greenhouse gas (GHS) emissions, which are a global concern in regard to climate change.

5.8.3.3.2 Effect of Climate Change on the Project

There is the potential for future climate change to affect the frequency and duration of flooding events and thus, have an effect on the operation of the Project. Although the potential effects of climate change on both the local and regional areas are uncertain, the Province of Manitoba (2002) anticipates the average summer temperature could increase 3-4^{o} C by the year 2080, while the winter temperatures could increase 5-8^{o} C. Climate change is also anticipated to affect the weather patterns, and in addition to an increase in temperature, may also result in increased precipitation. The Province of Manitoba (2002) anticipates that increased spring rain could result in increased flooding. In a presentation on the effects of climate change on the water regime in Manitoba, Warkentin (2002) concluded that climate change may result in changes in the magnitude and frequency of flooding. These effects may include decreased frequency in the amount of major prairie spring floods, increased probability of rain-generated floods increasing the likelihood of summer operation for emergency conditions, and more summer flooding due to localized thunderstorms.

Other research suggests (St. George and Nielson, *undated*) that small changes in temperature and precipitation have resulted in increased duration and magnitude of flooding on the Mississippi river. Simonovic and Li (*undated*) modeled possible future flood conditions in the Red River basin under various climate change scenarios using temperature and precipitation data forecasted via General Circulation Models. Their results showed that climate change could potentially result in increased annual precipitation and increased annual stream flows in the Red River basin. Thus, under potential climate change scenarios there could be increases in the frequency and magnitude of flooding events. Siimonovic and Li (undated) used models to assess the need for enhanced flood protection in the Red River basin under different climate change scenarios. They concluded that:

> *The results of this study indicate that the capacity of the existing Red River flood protection system is sufficient to accommodate the future climate variability and change*

if the low reliability criteria is used. In the case of application of high reliability criteria the future increase of flood protection capacity is warranted.

Accordingly, potential changes in climate would not change the need for the Project.

5.8.4 Residual Effects and Significance

The effect of climate change on the Project is not considered significant in terms of the design capacity. The residual effects of the Project on climate are shown in Table 5.8-1.

Table 5.8-1
Summary of Residual Effects and Significance on the Effects on Climate of the Floodway Expansion Project

Description of Effect(s)	Mitigation Measure(s)	Residual Effects and Significance
Construction		
Potential impacts to air quality are expected to be associated with emissions of construction vehicles and dust effects from vehicular movement along any temporarily established roadways.	Dust control, road surface treatment as required	These adverse effects are expected to be local, of small magnitude and of short duration. **Not significant**
Potential impacts of increased noise associated with construction equipment.	None	This adverse effect is expected to be local, temporary and of short-term duration. **Not significant**
Operation – Active		
No effect expected on greenhouse gas emission	None	**Not significant**

5.8.5 Monitoring and Follow-up

The flood frequency assessments for spring and summer events should continue to be updated by Water Stewardship.

5.9 PHYSIOGRAPHY, GEOLOGY AND SOILS

5.9.1 Approach and Methodology

5.9.1.1 Effects Assessment

A review of literature and the Project Description was done.

5.9.1.2 Sources of Effects

The primary source of effects on the physiographic environment is the change in the footprint of the Floodway due to the expansion.

5.9.2 Existing Environment

The physiographic area is a flat to very slightly sloping floodplain. The main natural physiographic feature within the local study area is the Red River. It is a meandering river that flows northward from the Canada-U.S. border, through the City of Winnipeg into Lake Winnipeg. The Red River channel depth ranges from 6 to 15 m (Hurst 1955-1956) with a very slight slope. The total length of the Red River is approximately 885 km, and the direct line distance is 459 km (Hurst 1955-1956). In the local study area, the Red River is fed by the following tributaries (Figure 5.9-1):

- Assiniboine River – flows into the Red from the west in the City of Winnipeg;
- Rat River – flows into the Red from the east in the R.M. of Ritchot;
- Seine River – flows into the Red from the east in the City of Winnipeg;
- La Salle River – flows into the Red from the west near the City of Winnipeg; and
- other smaller tributaries that flow directly into the Red River.

The Existing Floodway and the Seine River Diversion are the most prominent artificial physiographic features. Other human-made physiographic features include the Youville Drain located in southeast and several drainage ditches located in the area south of the City of Winnipeg.

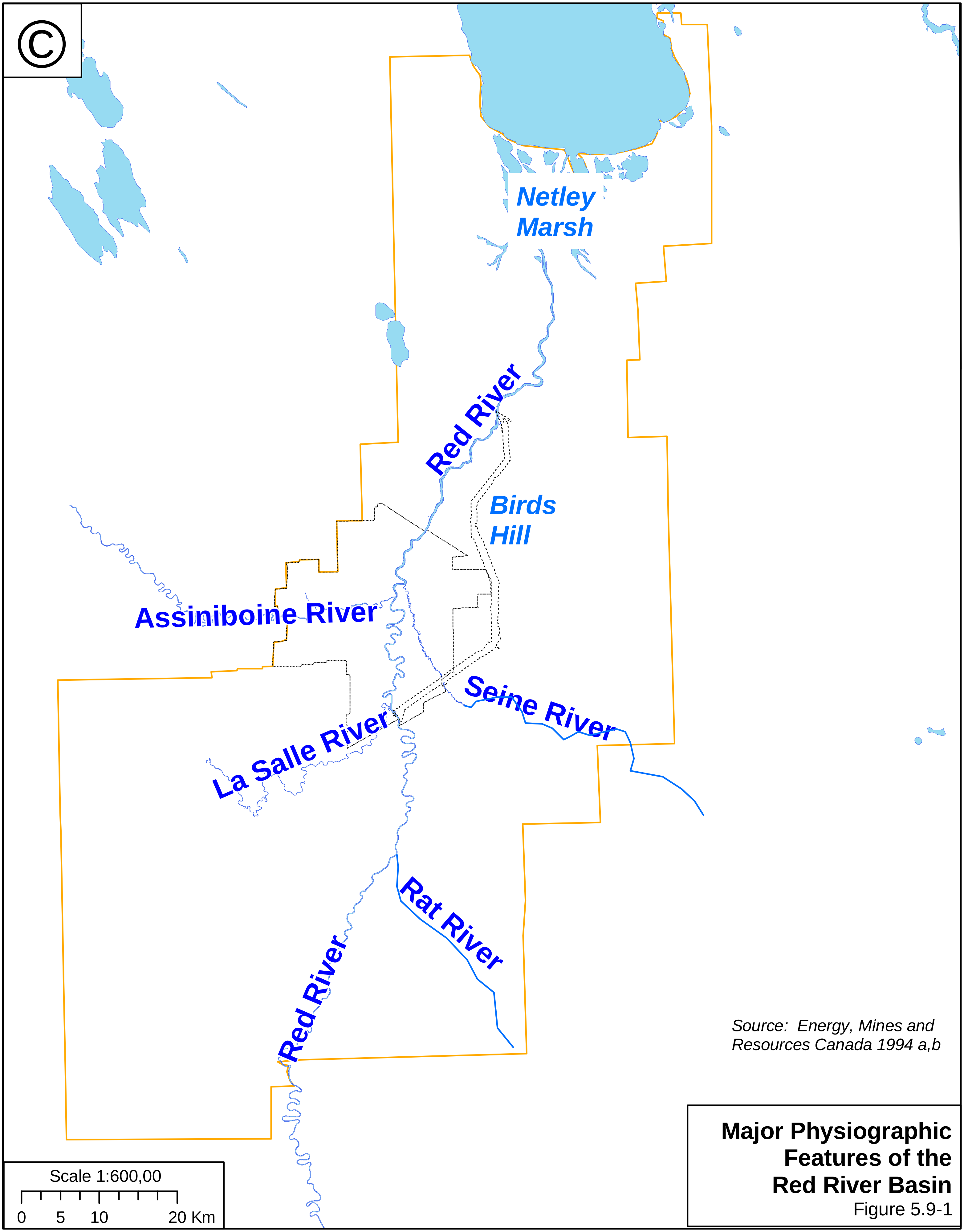
Elevations in the local area range from between 200 to 244 m ASL. The elevations near the Red River become lower closer to the mouth of the River. The elevations around the Red River at the southern portion of the subject site are typically 230 m ASL. This decreases to elevations of 220 m ASL along the Red River north of Selkirk.

Land use throughout the local area includes rural, urban and recreational land use. Birds Hill Park is located to the northeast of the City of Winnipeg. The eastern portion of Oak Hammock Marsh also falls within the boundaries of the local study area.

The major physiographic features associated with the study area are shown in Figure 5.9-1.

The geological characteristics at the Floodway were considered by KGS in the "Final Report on Flood Protection Studies for Winnipeg" (November 2001) and were described as follows:

> *The Floodway is located within the glacial Lake Agassiz clay plain of the Manitoba Lowlands physiographic region, with topographic relief generally less than 25 ft., rising slowly eastward and westward away from the Red River.*
>
> *Surficial sediments overlying Paleozoic carbonate bedrock are comprised of glaciolacustrine clays, and an underlying calcareous silt till, as shown on Plate B-3. Depth to bedrock is quite variable in the City of Winnipeg area, with a thick cover of overburden*



Major Physiographic Features of the Red River Basin

Figure 5.9-1

in areas to the south and southwest. The Birds Hill glaciofluvial complex is part of a larger complex of esker ridges, kames, and kettle holes that extends northward to Lake Winnipeg.

Bedrock beneath Winnipeg is comprised of gently westerly dipping Paleozoic strata. Ordovician aged carbonate rocks underlie the Winnipeg area, and consist predominantly of dolomite, argillaceous dolomite, calcareous shales, and mottled dolomitic limestone commonly referred to as "Tyndall Stone". Typically, the bedrock at shallower depths in the Winnipeg region shows some degree of fracturing, and pressure dissolution. The fractured upper carbonate zone forms the regional aquifer, confined by the overlying till and clay units.

Overlying the bedrock is an assemblage of glacial sediment, deposited by ice during multiple Pleistocene glaciations. Calcareous silt till, situated directly on bedrock is 3 to 30 ft. in thickness. The till surface is fluted in many places, with ridges generally oriented northwest to southeast and up to several feet in areas southwest of the City. Glaciofluvial sediments northeast of Winnipeg, in the Birds Hill area, consist of sands and gravels 50 to 100 ft. thick, deposited in ice contact by glacial meltwater. There are several poorly graded sand and gravel beaches, spit complexes, and nearshore sand and gravel bars around the periphery of the glaciofluvial core of Birds Hill.

Lake Agassiz deposition of the glaciolacustrine clay resulted in sediments on the order of 30 ft. to 50 ft. in thickness near Winnipeg, and thinner from Birds Hill to Lockport. In many areas, massive clay to silty clay is overlain by laminated silt to clayey silt, which is lighter in color and is typically found from the surface to shallow depths in the Winnipeg area. These deposits may also include fine sand and silt in areas adjacent to Birds Hill. The base of the clay sequence is often interbedded with the underlying silt till. Ridges up to 3 ft. in relief formed in the clay plain by iceberg scours, infilled by clayey silt. The variable texture of these upper Lake Agassiz clay plain sediments has resulted in site specific variability in geochemical and shallow groundwater signatures.

KGS (November 2001) further describes the site geology as:

The overburden along the Floodway Channel centreline consists primarily of high plasticity lacustrine clay overlying an uncemented to cemented silt till and Paleozoic limestone bedrock as shown on Plate B-3. The bedrock forms the regional confined Upper Carbonate aquifer. The existing channel invert cuts into glacial till intermittently for approximately 10% (3 miles) of the 29-mile Floodway length. The channel also cuts through 0.5 miles of sand and gravel outwash complex at Birds Hill.

The majority of the soils in the local study area are black earth soils developed on lacustrine-fine-clay parent material (Ehrlich *et al*. 1953). The Red River clay soils found throughout the study area are formed in well to intermediately drained areas, while the Osborne clay soils have been developed on flat or depressional topography and are poorly drained (Ehrlich *et al*. 1953). These soil types appear to be consistent with the silty brown and grey highly plastic clay observed at the Floodway during recent geotechnical investigations (Acres, KGS, UMA 2004a). Transitional grey-black soils developed on glacial parent materials are also found throughout the local study area (Ehrlich *et al*. 1953). The Birds Hill area contains grey wooded soils developed on beach and outwash deposits with textures from clay loam to sandy loam (Ehrlich *et al*. 1953).

5.9.3 Effects and Mitigation

The Existing Floodway excavated spoil. The Project is adding to this excavation. The other projects or developments that have the potential to lead to cumulative effects on soils are infrastructure projects that use borrow materials from the Floodway spoil piles. It is anticipated that each of these infrastructure projects would be reviewed and the effects identified and mitigated. No known future projects are expected to increase cumulative effects on physiography or geology.

5.9.3.1 Construction

The environmental effects associated with the construction phase of the Project include disposal of spoil removed during the excavation, management of organic soils, and effects on Gypsum Rosette Collection. The excavation will result in the removal of 25 million m^3 of soil from an estimated 21,000,000 m^2 area (KGS/Acres/UMA 2004b). This soil will be disposed of in spoil disposal piles. This effect is unavoidable, and specific mitigation practices for spoil disposal will be specified in the Environmental Protection Plan.

5.9.3.2 Operation - Inactive

The Project will result in a permanent expanded footprint, resulting in a permanent change in the local physiography. This change is unavoidable, however, the excavation and spoil berms are planned to remain within the existing Right-of-way. No other effects of the operation on physiography, geology and soils are anticipated.

5.9.3.3 Operation - Active

Operation of the Floodway is not anticipated to have an effect on physiography, geology or soils.

5.9.4 Residual Effects and Significance

The residual effects of the Project on physiography, geology and soils are shown in Table 5.9-1.

Table 5.9-1
Summary of Residual Effects and Significance on Physiography, Geology and Soils related to the Floodway Expansion Project

Description of Effect	Mitigation	Residual Effects and Significance
Construction		
Excavated soil from the Floodway Expansion will be placed on the existing spoil piles, increasing the height of the spoil piles between 2.5 and 5 m.	Specific mitigation practices for spoil disposal will be specified in the Environmental Protection Plan.	This effect will occur in a localized area and will be of long-term duration. **Not significant**
The excavation of the Floodway will expose additional faces available for Gypsum Rosette collection.	None	This positive effect will be continuous and long-term. It will occur in a localized area. **Not significant**
Operation – Inactive		
The Project will result in a permanent expanded footprint, resulting in a permanent change in physiography.	None	This change will occur throughout the Floodway area and will be continuous and long-term. **Not significant**

5.9.5 Monitoring and Follow-up

No monitoring or follow-up is required.