EXECUTIVE SUMMARY

The Inlet Control Structure is a component of the Red River Floodway and is located south of the City of Winnipeg, Manitoba, Canada. This structure spans the Red River upstream of the City of Winnipeg and controls Floodway utilization under emergency conditions. This evaluation explored the historical and current structure's effects on the Red River fish community's upstream movement through the Structure.

The evaluation utilized a multidisciplinary approach involving computer flow modeling, literature values for fish swimming capabilities, and field investigation using an acoustic camera (i.e., DIDSON) to observe fish behavior in the Structure.

The assessment found evidence of upstream fish movement by a number of species occurred during the period when the Structure was not in use controlling Floodway utilization. Fish were noted to be making use of micro-habitat features and interactions between species to traverse the Structure.

During emergency use, the Structure was assumed to block upstream fish movement. The potential environmental effect of this impairment was explored relative to each month of historic usage. May usage was considered to have the highest potential for historic fish community effect; however, any increase in Structure usage in June could also have substantive ecological effect.

The report is available in conventional "paper" format and in a digital version which incorporates linkages to DIDSON surveillance video of fish behavior in the Structure.

STUDY TEAM

The following study team members are employees of Tetr*ES* Consultants Inc.:

George Rempel, M.Sc., P.Eng.	President
Dave Morgan, Ph.D, P.Eng.	Vice President, Environmental Engineer
Don Harron, B.Sc.	Biologist, Senior Environmental Scientist
Marlene Gifford, M.Sc.	Biologist, Senior Environmental Scientist
Jacqueline Taylor, B.Sc.	Environmental Scientist
Mundzir Basir, Ph.D., P.Eng.	Environmental Engineer
Jeannette Haswell	Environmental Technologist

The following subconsultants deployed and operated the DIDSON underwater acoustic imaging camera:

Howard Bailes	President, MagnaPatch Gulf, Inc., Houston, TX, USA

The report was prepared with the help of the following external advisors, whose assistance is appreciated:

Ken W. Stewart, Ph.D.	Retired Ichthyologist, University of Manitoba
Peter N. Johnson, M.Sc.	Fisheries Biologist, BAE Systems, N. Bonneville, WA

Third Party Disclaimer

TABLE OF CONTENTS

LIST OF APPENDICES

LIST OF ILLUSTRATIONS

LIST OF TABLES

LIST OF FIGURES

1.0 INTRODUCTION

The Red River Floodway Inlet Control Structure (hereinafter: Inlet Control Structure) is located in the Red River immediately downstream of the southern end of the Floodway Channel (Figure 1-1). It was constructed in the late 1960s as part of the overall Red River Floodway and regulates river flows between the Red River and the Floodway Channel. To divert excess floodwater into the Floodway Channel, the two gates of the Inlet Control Structure are raised[1] (Figure 1-2). It is assumed that the Inlet Control Structure blocks upstream movements of fish when the gates are partly or fully raised due to the resulting impassable vertical distance and associated high water velocities (Section 4.1). The key question relates to how frequently and to what degree are upstream fish movements being impaired under various Red River flow conditions when the gates are either in the 'up' or in the 'down' (inactive operational) position.

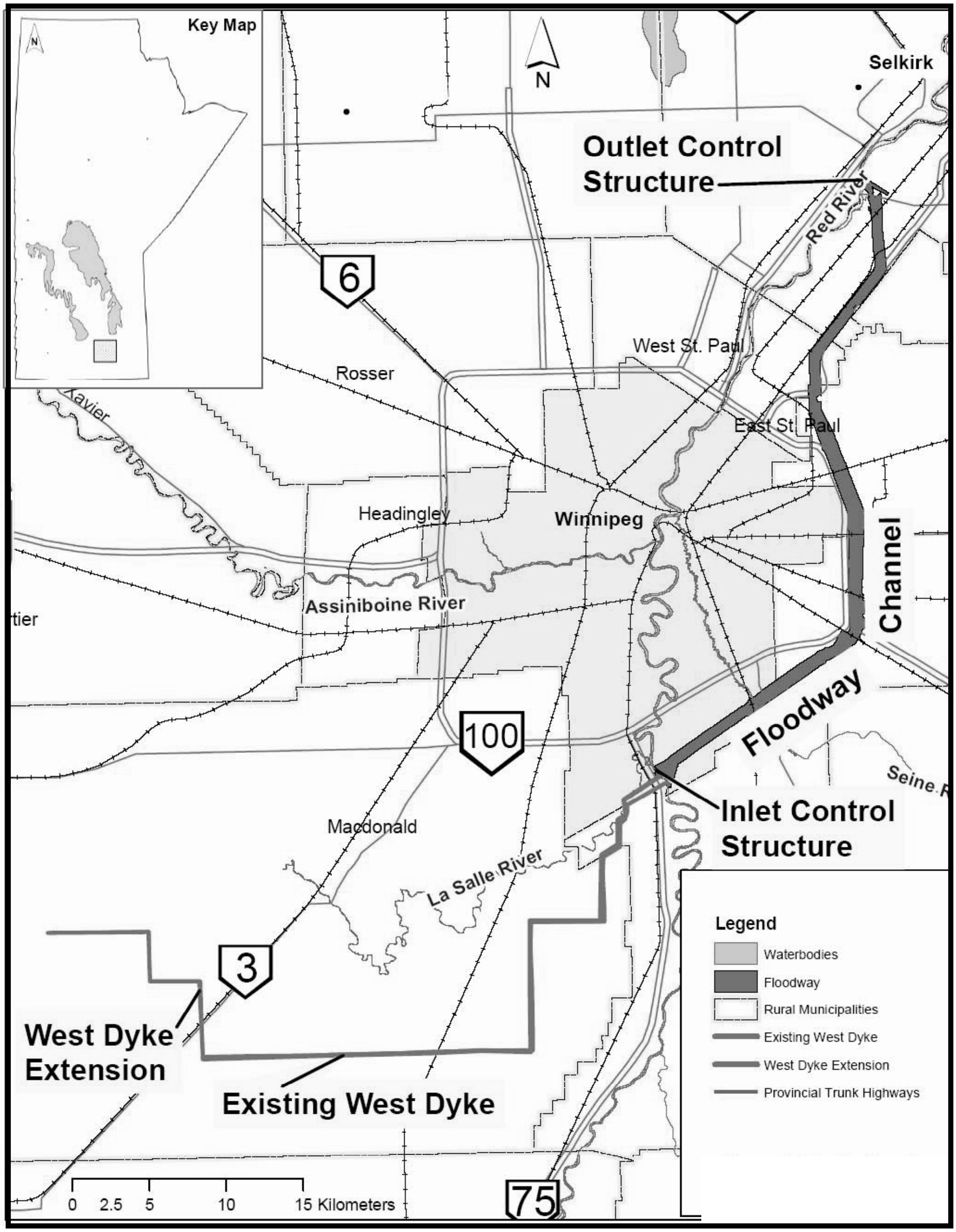
The information provided in this document was not complete at the August 2004 filing of the Environmental Impact Statement (EIS) on the Proposed Red River Floodway Expansion Project (the Project). It is being provided now as supplementary information on the existing environment regarding fish passage at the Floodway Inlet Control Structure. The operation and the fundamental characteristics of the Inlet Control Structure will not be changed as a result of the proposed project. No changes to the Inlet Control Structure gates or operation of the gates are associated with the proposed expansion of the Red River Floodway. The information in this document therefore does not change the assessment or the conclusions of the EIS. It is intended to contribute to the undertaking of describing the existing environment and to assist in guidance for possible future actions.

2.0 APPROACH

The Inlet Control Structure constricts the Red River to approximately one half its width when the gates are down (i.e., inactive operation [Figures 1-3 and 1-4]). When the gates are down, water flows freely over the two gates that are positioned horizontally underwater. The 50% restriction in the width of the river and raised elevation of the 'down position' gates off the river bottom is anticipated to increase water velocities over the gates and through the Inlet Control Structure. These increased water velocities may impede the upstream movements of various fish under different flow scenarios.

To investigate the abilities of fish to move upstream through the Inlet Control Structure when the gates are in the down position, a 'desk-top' modelling approach was developed to theoretically predict the abilities of fish to swim upstream against various water velocity conditions that may occur over the gates under various flow conditions (Section 3.1). Water velocity information required to develop this model was obtained from calculated 3D water velocity profiles developed for the Inlet Control Structure (Section 3.2), and published studies on swimming abilities of various Red River fish species for critical

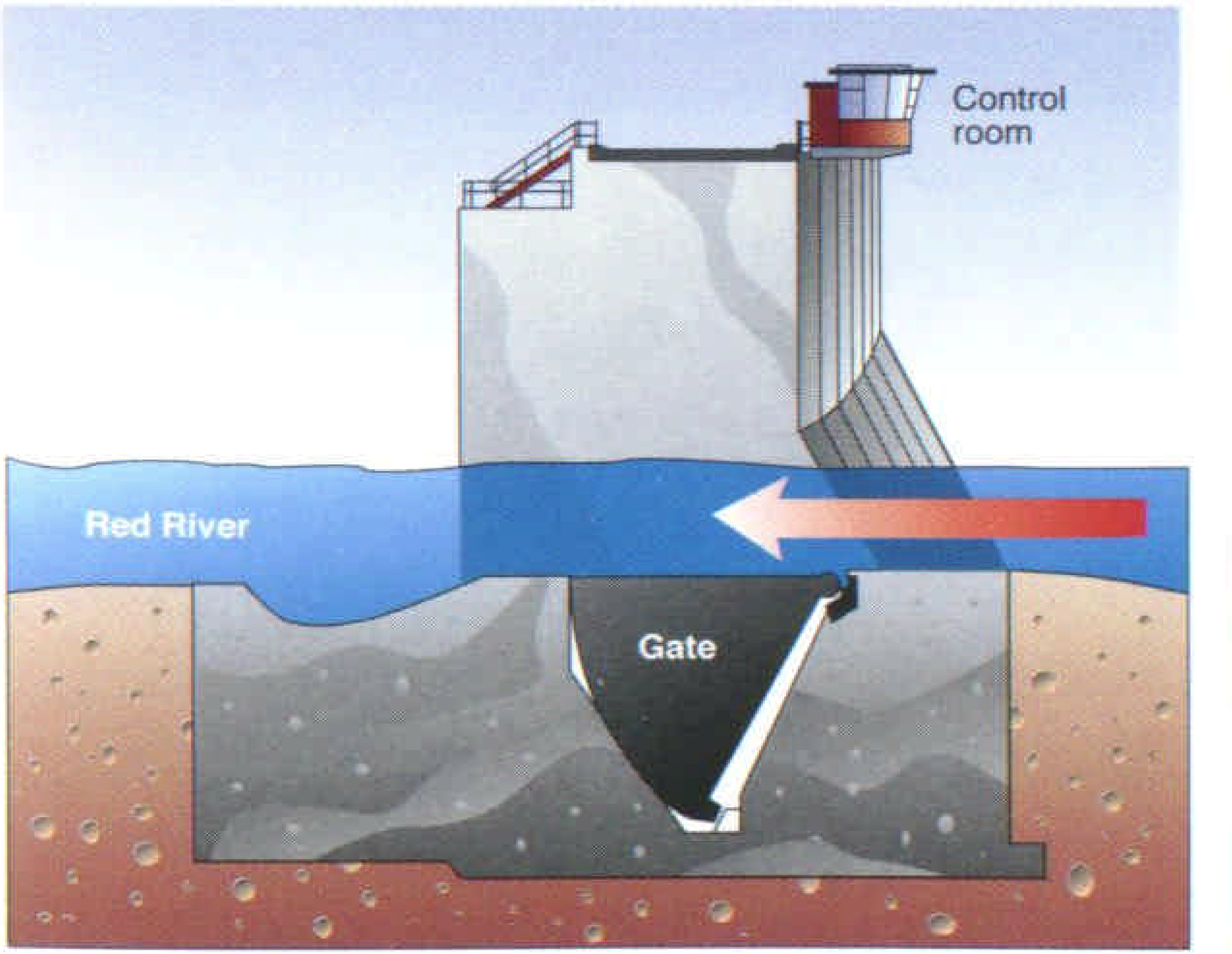
[1] Either gate can be raised to various levels, independent of the other, depending on the volume / flow of water that requires diversion. Typically, both gates are raised in tandem and to similar heights.



Red River Floodway and the Inlet Control Structure
Figure 1-1

Red River Floodway Inlet Control Structure
Active Operations in 1997
Figure 1-2

Red River Floodway Inlet Control Structure
Inactive Operations
Figure 1-3



Note: Inlet Control Structure Operations are described in Section 4.1

Red River Floodway Inlet Control Structure
Figure 1-4

water velocity conditions. This model was then tested against in-field observations of fish behaviour at the Inlet Control Structure during inactive operation (i.e., gates down) in the spring of 2004.

Several alternative in-field methods were considered to test the 'water velocity vs. fish swimming capabilities' model predictions under real-life (in-situ) conditions, which included:

- fish tagging (using either Floy type tags or acoustic tags) to track fish movements through the Inlet Control Structure; and
- an underwater acoustic imaging system (the DIDSON[2] camera) to obtain real-time video images of fish attempting to swim through the Inlet Control Structure under above-normal summer flow conditions.

The advantages and disadvantages of these options were considered and are summarized in Table 2-1 following. The DIDSON acoustic camera was considered the best method to determine the abilities and behaviour of fish to moving upstream through the inactive (gates-down) Inlet Control Structure (Section 3.3).

The DIDSON camera was demonstrated to be effective with respect to observing and quantifying potential fish movement through the Inlet Control Structure. It does not, however, provide information with respect to the broader issues respecting the ecological need for fish to traverse the structure. To provide additional information with respect to fish behavior and broad movement dynamics, the Manitoba Floodway Authority commissioned North/South Consultants to conduct an acoustic tagging movement study of three fish species of the Red River.

[2] **D**ual frequency **id**entification **son**ar

Table 2-1
Advantages And Disadvantages Of Methods For Monitoring Of Fish Movements In The Red River Through The Floodway Inlet Control Structure

MONITORING METHOD	PROS	CONS	USEFULNESS FOR DETERMINING FISH MOVEMENTS THROUGH INLET CONTROL STRUCTURE UNDER HIGHER FLOWS
ACOUSTIC TAGGING	- Potential for some detailed timing of movement information on some target fish species. - Potential to track movements over large area which may assist in determining need to move past the Inlet Control Structure.	- Application limited to a few large-bodied species (not focused on fish community). - Limited tag working life. - Extremely expensive for long-term monitoring study. - External tags may interfere with fish swimming capabilities. Internal tags may have high expulsion rates and cause higher fish-mortality	**LIMITED USE** - Low probability of obtaining fish movement data during critical high flow conditions due to difficulties in deploying acoustic receivers under such conditions (e.g., ice/debris). - Data is limited to a few individual large-bodied fish that may or may not move upstream through the control structure. - Mortality and tag expulsion studies suggest 90% of tagged fish no longer monitorable within six months.
FLOY TAGGING	- Tags can be applied to large numbers of most fish species that occur in the Red River (information potentially obtained on fish community). - Potential to track movements over large area which may assist in determining need to move past the Inlet Control Structure.	- No information on where fish moved (or when) between the tagging location and re-capture location. - Labour intensive to obtain maximal results in shortest time period (i.e., tagging and recapture efforts). - Extremely limited information with respect to when a fish may have moved past Inlet Control Structure.	**VERY LIMITED USE** - Floy tagging and recapture of tagged fish will not provide sufficiently precise information on when (i.e. under which flows) the fish passed upstream through the Inlet Control Structure
DIDSON ACOUSTIC CAMERA	- Provides real-time recorded video images of fish behaviour at the Inlet Control Structure under various flow conditions. - Underwater camera can be positioned at virtually any location to record fish movements through the gates from a variety of angles. - Provides information on the movements and behaviour of a wide variety / size of fish.	- Cannot determine species of all fish with 100% accuracy. - Some logistical limitations regarding positioning of the underwater camera in highest flow conditions. - Limited area of detailed fish surveillance at any one time (e.g., 15 m x 10 m area).	**BEST METHOD** - Is the best method for documenting fish movements and swimming behaviour as they attempt to swim through the Inlet Control Structure under various flow conditions

3.0 METHODOLOGY

3.1 FISH SWIMMING CAPABILITIES

Published and unpublished studies were reviewed concerning the swimming capabilities and behaviour of the range of fish species potentially found in the Red River near Winnipeg. The details and results of this review are provided in Appendix A. The literature review also involved a search for relevant historical information regarding documented fish movement past the Inlet Control Structure.

Documented spawning periods of Red River fish species were also summarized to provide some information on the potential timing of individual fish species movements along the Red River (Table 3-1).

The only study of fish movement past the Inlet Control Structure was completed during the mid 1970s involving the use of tagged fish and recapture methods (Clarke *et al*. 1980). The study documented the movement of five species of Red River Fish through the Inlet Control Structure (Figure 3-1), but could not provide details on when the fish passed through the Structure. The ongoing acoustic tagging study (preliminary status report provided in Appendix B) confirms the results of Clark et al. 1980, respecting the movement of Channel Catfish upstream through the Inlet Control Structure. Further observations of fish behavior near the Inlet Control Structure by Dr. K. Stewart are provided in Appendix C and note an accumulation of Channel Catfish immediately downstream of the structure, which was observed during the July 2004 active operations.

While a range of fish studies have occurred on the Red River during fairly typical summer/fall flows, they are generally site-specific evaluations, and only provide limited information towards the understanding of fish distribution in the Red River. The 1999 fish evaluations reported in Remnant *et. al*. 2000 suggest that the relative occurrence of Channel Catfish increases as you proceed downstream along the Red River through the City of Winnipeg to Lockport. The Remnant *et. al*. 2000 study results also suggest that the relative percentage of goldeye in the aquatic community increases as you proceed upstream to near the Inlet Control Structure (Figure 3-2). However, these apparent trends are biased by the much lower fish sampling effort employed in the upstream reaches of the Red River. When netting effort is taken into account (Table 3-2), no species-specific trends with respect to distribution in the Red River can be concluded. The total catches in the individual net sets have also been highly variable (standard deviations generally equal to or exceeding the mean values) suggesting the results are not significantly different. This highly variable dataset has led to considerable speculation among resource users, managers and scientists regarding potential migratory movements in the Red River (i.e., fall "greenback" walleye run and summer Channel Catfish migrations) for which no supporting evidence exists.

The application of these analyses to the fish passage evaluation is provided in Section 4.0.

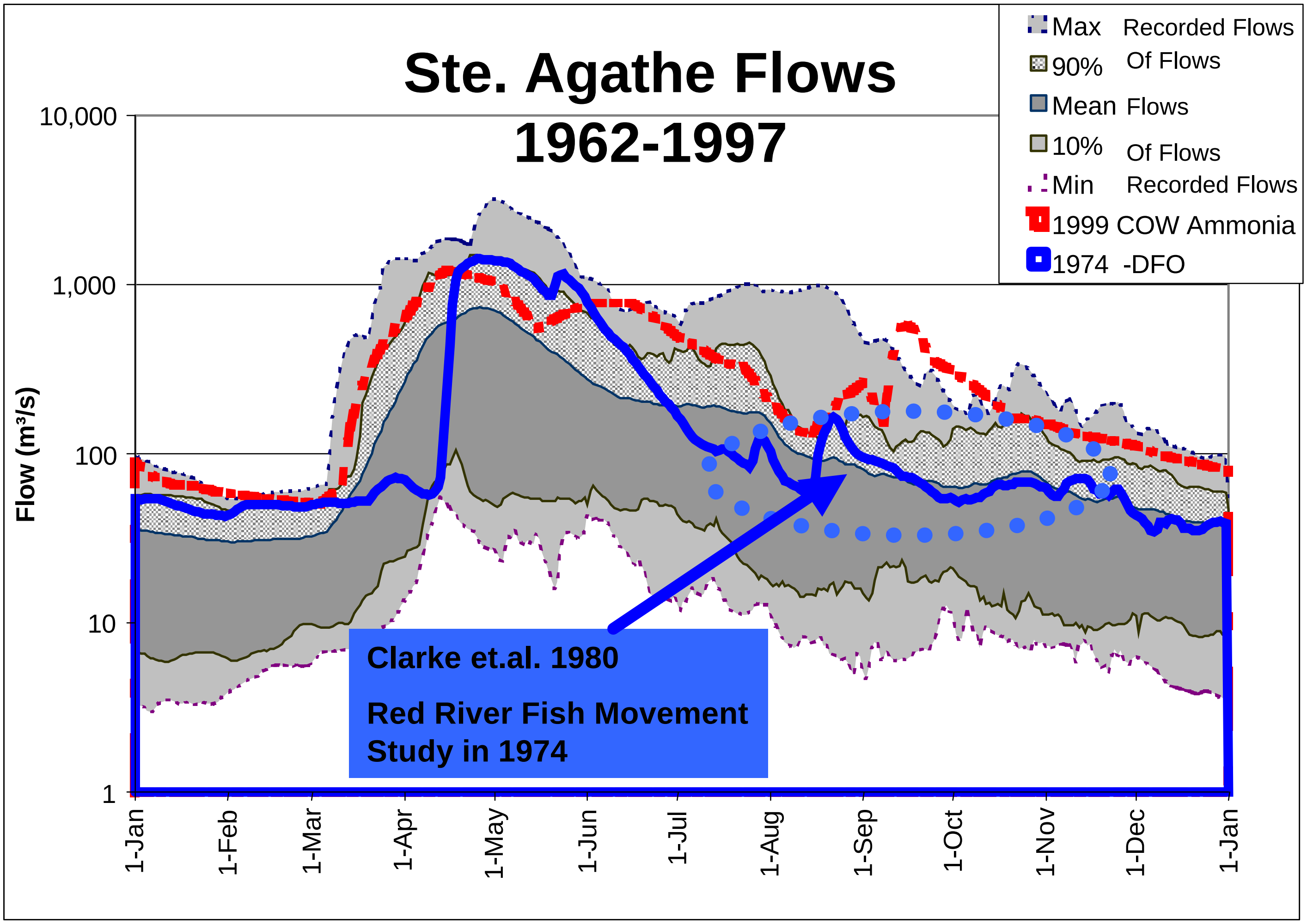
Table 3-1
Spawning Timelines of Fish Species Known or Suspected to be Occurring in the Red and Assiniboine River

GENUS	SPECIES	COMMON NAME	Status	January	February	March	April	May	June	July	August	September	October	November	December
Ichthyomyzon	*castaneaus*	Chestnut lamprey	U												
Ichthyomyzon	*unicuspis*	Silver lamprey	ER												
Acipenser	*fluvescens*	Lake sturgeon	R												
Hiodon	*alsoides*	Goldeye	C												
Hiodon	*tergisus*	Mooneye	C												
Umbra	*limi*	Central mudminnow	U,T												
Esox	*lucius*	Northern pike	C,T												
Carassius	*auratus*	Goldfish	R,I												
Phoxinus	*neogaeus*	Finescale dace	U,T												
Cyprinus	*carpio*	Carp	I,C												
Macrhybopsis	*storeriana*	Silver chub	C												
Notemigomus	*chrysoleucas*	Golden shiner	R,T												
Notropis	*atherinoides*	Emerald shiner	C												
Notropis	*blennius*	River shiner	C												
Notropis	*cornutus*	Common shiner	R,T												
Notropis	*dorsalis*	Bigmouth shiner	R												
Notropis	*hudsonius*	Spottail shiner	C												
Notropis	*spiloptera*	Spotfin shiner	C												
Notropis	*stramineus*	Sand shiner	C												
Pimrphales	*promelas*	Fathead minnow	R,T												
Plalygobio	*gracillis*	Flathead chub	C												
Rhinichthys	*atratulus*	Blacknose dace	C,T												
Rhinichthys	*cataractae*	Longnose dace	C												
Semotilus	*atronaculatus*	Creek chub	R,T												
Carpiodes	*cyprinus*	Quillback	C												
Catostomus	*commersoni*	White sucker	C												
Ictiobus	*cyprinellus*	Bigmouth buffalo	C												
Moxostoma	*anisurum*	Silver redhorse	C												
Moxostoma	*erytrurum*	Golden redhorse													
Moxostoma	*macrolepidotum*	Shorthead redhorse	C												
Ictalurus	*melas*	Black bullhead	C												
Ictalurus	*nebulosus*	Brown bullhead	C												
Ictalurus	*punctatus*	Channel catfish	C												
Noturus	*flavus*	Stonecat	C												
Noturus	*gyrinnus*	Tadpole madtom	U,T												
Lota	*lota*	Burbot	C												
Culaea	*inconstans*	Brook stickleback	R,T												
Peropsis	*omiscomayus*	Trout-perch	U												
Morone	*chrysops*	White bass	I												
Ambloplites	*rupestris*	Rock bass	C												
Lepomis	*macrochirus*	Bluegill	R,I												
Pomoxis	*annularis*	White Crapple	I,R												
Pomoxis	*nigromaculatus*	Black Crapple	I												
Perca	*flavescens*	Yellow perch	U,T												
Stizostedion	*canadense*	Sauger	C												
Stizostedion	*vitreum*	Walleye	C												
Etheostoma	*exile*	Iowa darter	U,T												
Etheostoma	*nigrum*	Johnny darter	C												
Perina	*caprodes*	Logperch	C												
Percina	*maculata*	Blackside darter	C												
Percina	*shumardi*	River darter	C												
Aplodinotus	*grunniens*	Freshwater drum	C												

LEGEND	
Spawning (blue line)	ER - extremely rare
Spawning (red line)	R - rare
"minnow-class species"	C - common
	U - uncommon
	T - tributaries

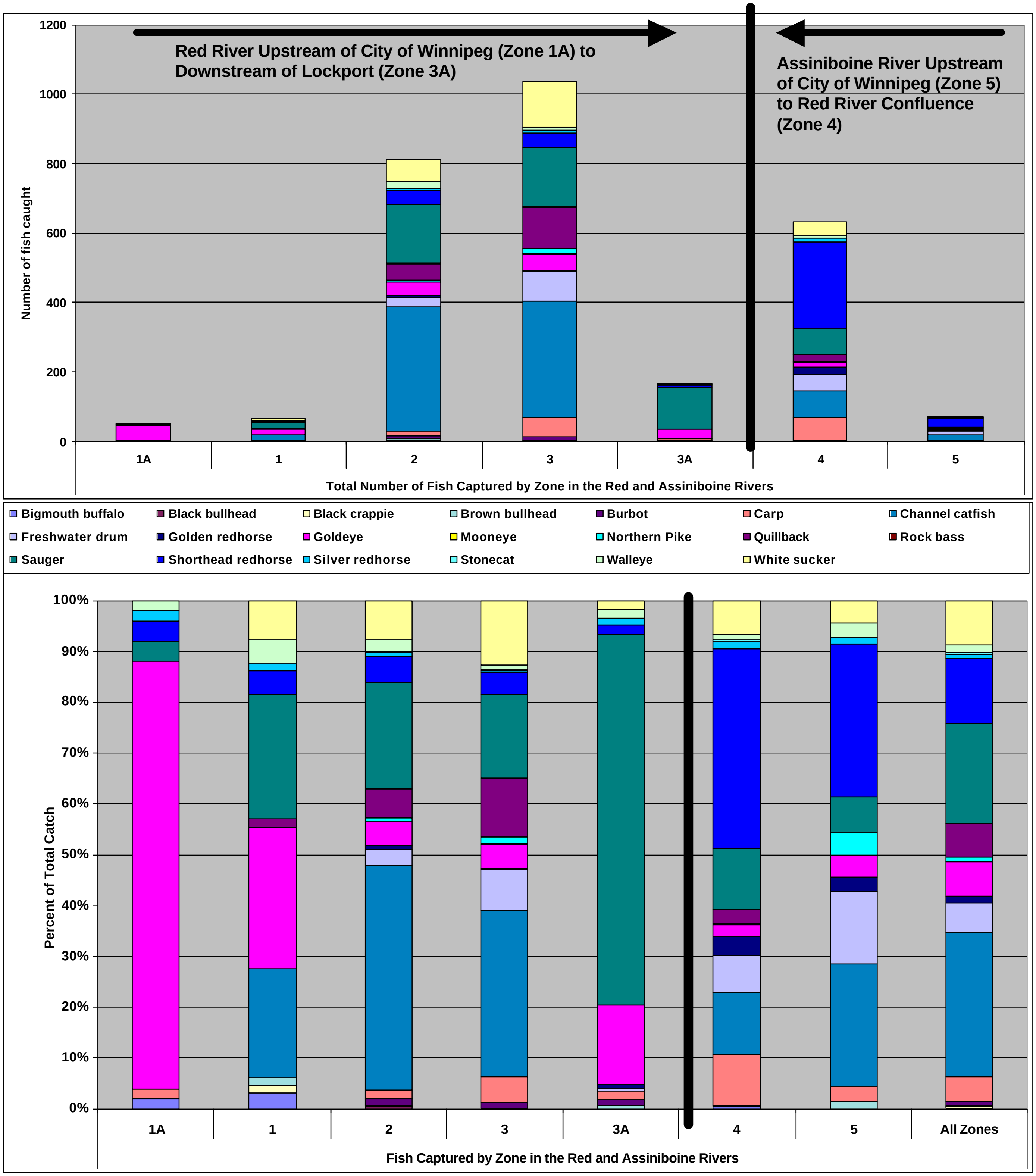
I - Introduced

Source: Kiscicco 1994, Hatch 2002, Ohio Department of Natural Resources nd., Nelson and Paetz 1992, NYB Department of environmental Conservation 1999, rook 1999, and Scott and Crossman 1973.



- Historic studies of fish movements through the Inlet;
  - e.g. Clarke et. al. 1980 - 1974 fish tagging study in Red River,
    - documents some evidence for upstream movements through the Floodgates for 5 sport fish species (includes Channel Catfish & Walleye),
  - Information from previous studies and consultation with Floodway Expansion Project expert advisors (Drs. Ken Stewart and Gavin Hanke) and others
    - possible upstream spawning, foraging & over-wintering areas,
- 1999 City of Winnipeg Ammonia Study provides some perspective with respect to general fish distribution downstream of the Inlet Control Structure during a high flow year.

Red River Flow conditions During Historic Regional Fish Movement Studies
Figure 3-1



- 1999 study demonstrating apparent increase in Channel Catfish populations downstream of the Inlet Control Structure

Red River Fish Distribution
Figure 3-2

Data Source: Remnant *et.al*. 2000

Table 3-2
Apparent Fish Distribution Results of 1999 Gill netting in the Red River

Averages and standard deviations by season					
Season		Number of Net Sets	CPU*		
			Average	Std. Dev	95% Confidence Interval (±)
Winter		33	0.18	0.29	0.10
Summer		15	0.50	0.46	0.23
Fall		6	0.49	0.41	0.33
Averages and standard deviations by season & zone					
Season	Zone	Number of Net Sets	CPU		
			Average	Std. Dev	95% Confidence Interval (±)
Winter	1	12	0.11	0.14	0.08
	2	12	0.08	0.08	0.04
	3**	3	0.00	0.00	0.00
	3A	6	0.59	0.49	0.39
Summer	1	3	0.06	0.10	0.12
	2	6	0.52	0.60	0.48
	3	6	0.69	0.26	0.21
Fall	2	6	0.49	0.41	0.33
Averages and standard deviations by season & substrate					
Season	Substrate	Number of Net Sets	CPU		95% Confidence Interval (±)
			Average	Std. Dev	
Winter	S	9	0.17	0.28	0.18
	M	17	0.09	0.09	0.04
	H	7	0.39	0.51	0.38
Summer	S	5	0.43	0.44	0.39
	M	4	0.66	0.62	0.61
	H	6	0.45	0.42	0.34
Fall	S	2	0.18	0.26	0.36
	M	1	0.30	-	-
	H	3	0.76	0.40	0.45

*CPU = Catch per unit = fish caught per hour of net set

** No fish were caught in the 3 net sets

Source: Remnant, R.A., J.B. Eddy, R.L. Bretecher and S.L. Davies. 2000. Species composition, abundance and distribution of fish in the Red and Assiniboine Rivers within the City of Winnipeg Ammonia Criteria Study. Component of Tetr***ES*** 2002 report to the City of Winnipeg.

3.2 WATER VELOCITY MODEL

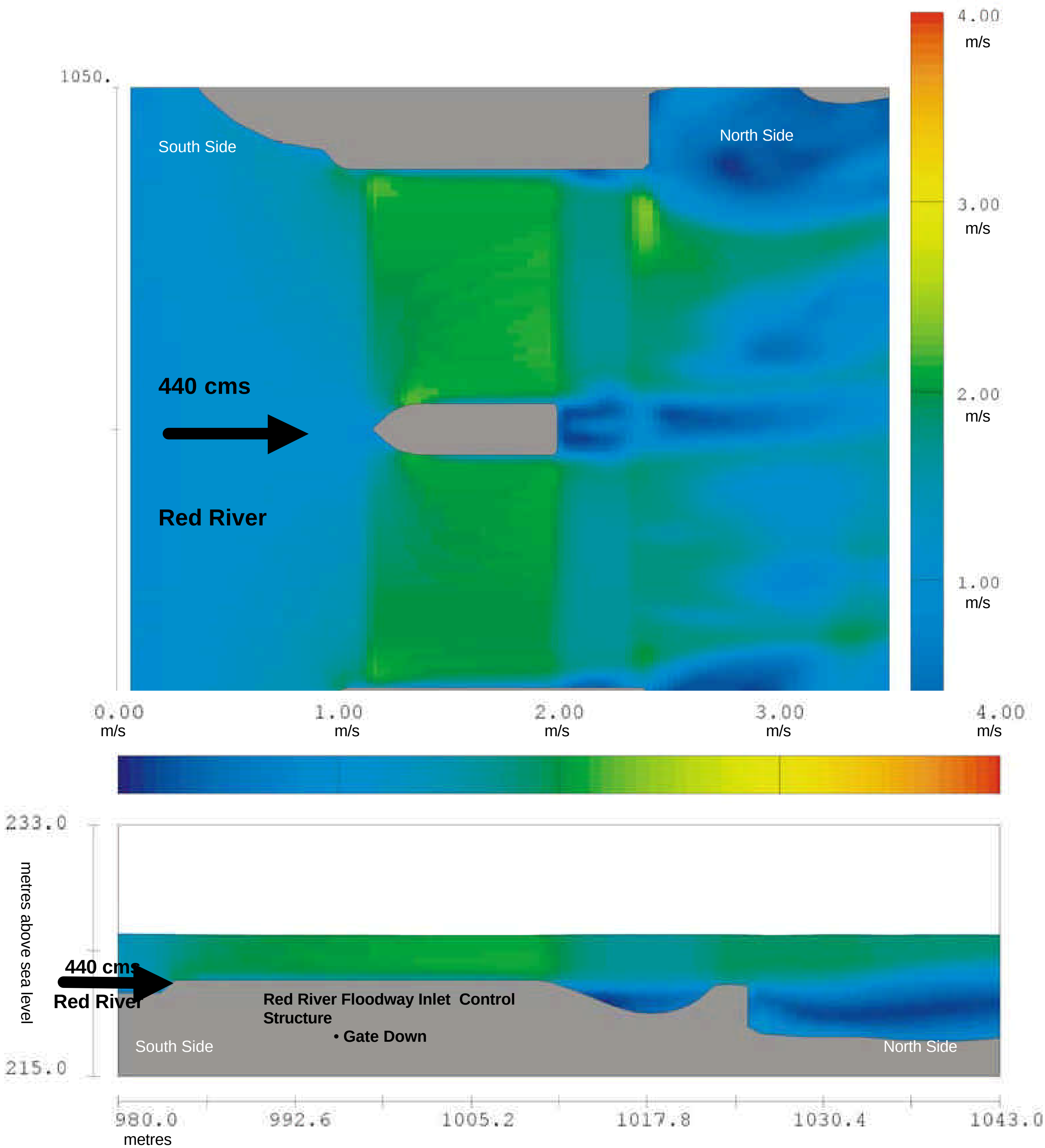
Figure 3-1 demonstrates that total water flows in the Red River are highly variable, both from month to month within an annual cycle, and from year to year. It was anticipated that the various volumes of water flowing down the Red River would result in changes to the water velocity through the Inlet Control Structure. The KGS-Acres-UMA Group involved in the proposed Red River Floodway Expansion Project attempted to characterize this dynamic environment for application to the fish passage evaluation.
Brown (2004) calculated a range of velocity duration curves for a wide range of seasons and potential environmental conditions. These curves were applied to the fish passage analysis. This initial evaluation was supplemented by 3-D modeling of the flow through the Inlet Control Structure (Figure 3-3) conducted by Groeneveld and Fuchs (2004) (provided in Appendix D).

The application of these analyses to the fish passage evaluation is provided in Section 4.0.

3.3 DIDSON UNDERWATER ACOUSTIC CAMERA

The DIDSON underwater acoustic camera was deployed in spring 2004 during high velocity of approximately 1-2 m/sec through the centre of the Inlet Control Structure gates. The camera was positioned underwater adjacent to the far outside walls of the structure over the east gate on April 30 and over the west gate on May 1 (Figure 3-4). The flow in the Red River at this time and location is estimated at 440 cubic metres per second (cms). The camera was housed in a protective metal box, lowered down from the top of the Inlet Control Structure using a winch system of ropes and cables (Figure 3-5) and was pointed in a downstream direction to obtain images of fish swimming upstream over the gates (Figure 3-6). The camera was located at two main positions over the east and west gates: just downstream of the east and west side bulkhead entrance doorways (hereafter: "doorways") to obtain images of the downstream edge of the gates, and just upstream of the leading edge of the east and west gates (Figure 3-7). The field of view of the DIDSON camera varied from 4 to 10 m in length by 1 to 3 m in width. Nine hours of digital surveillance video was obtained over the east gate (between 10:00 hrs and 19:06 hrs) and 6.5 hours of video was recorded over the west gate (between 11:15 hrs and 17:42 hrs) during high spring velocities of approximately 1 to 2 m/sec over the centre of the gates.

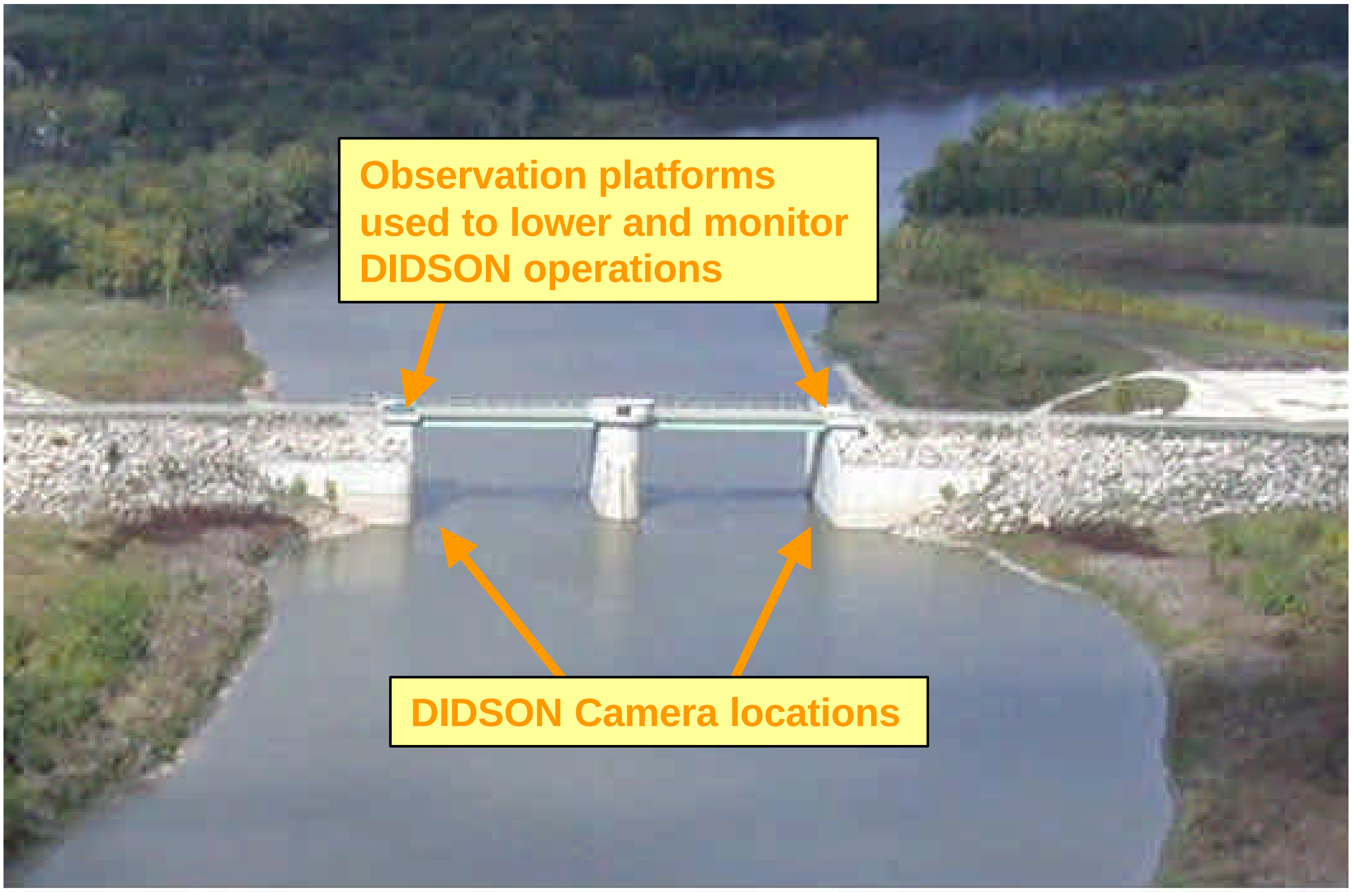
DIDSON video images were burned to compact disc (CD) and visually analyzed in two-minute segments. Fish behaviour was quantified regarding number of fish present, number and location of fish passing upstream over the gates, number of failed attempts to swim past the gates, relative speed and size of fish, relative fish density and fish species (when possible to discern with a high degree of certainty). Observational data tables are provided in Appendix E. Selected images and video clips were also extracted from the DIDSON interpretive program and have been incorporated into this report (note that the conversion process resulted in some degradation of the image quality compared to the native DIDSON format).



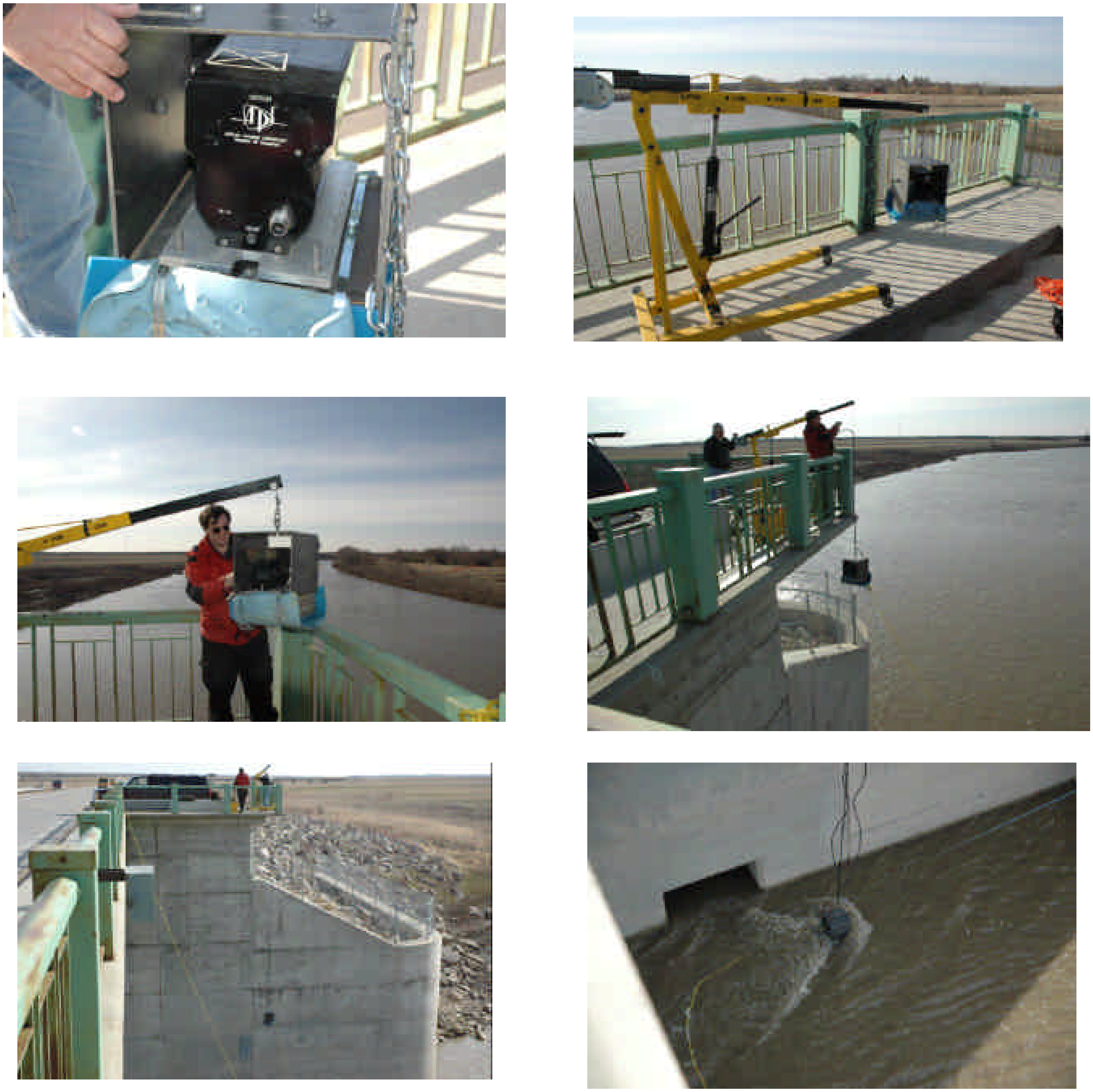
Red River Floodway Inlet Control Structure Inactive – Gates Down in Moderate Flow

Figure 3-3

Data Source: Groeneveld and Fuchs, September 2004 Floodway Inlet Control Structure Three Dimensional Flow Analysis

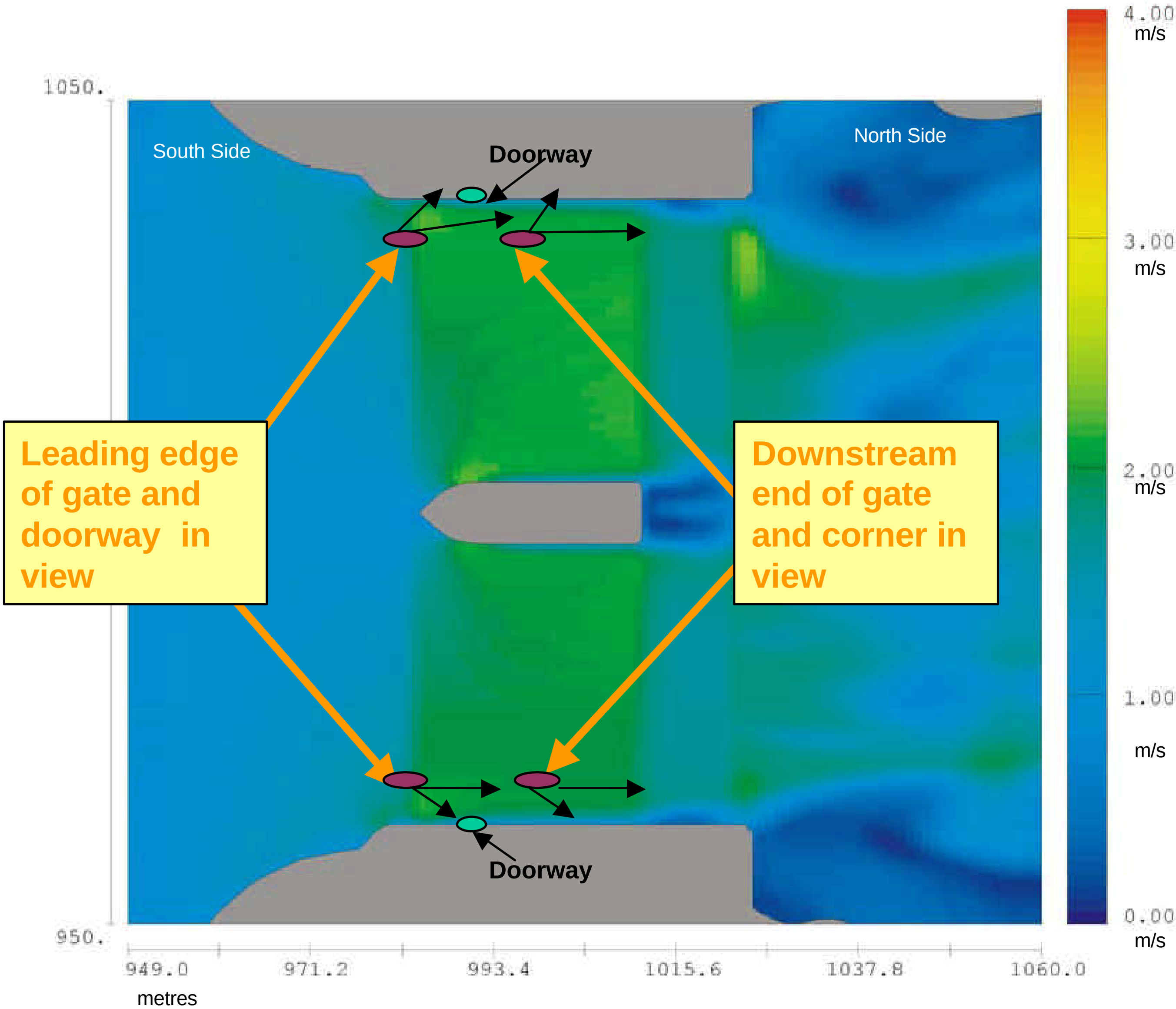


Red River Floodway Inlet Control Structure
Locations of DIDSON Camera Surveillance
Figure 3-4

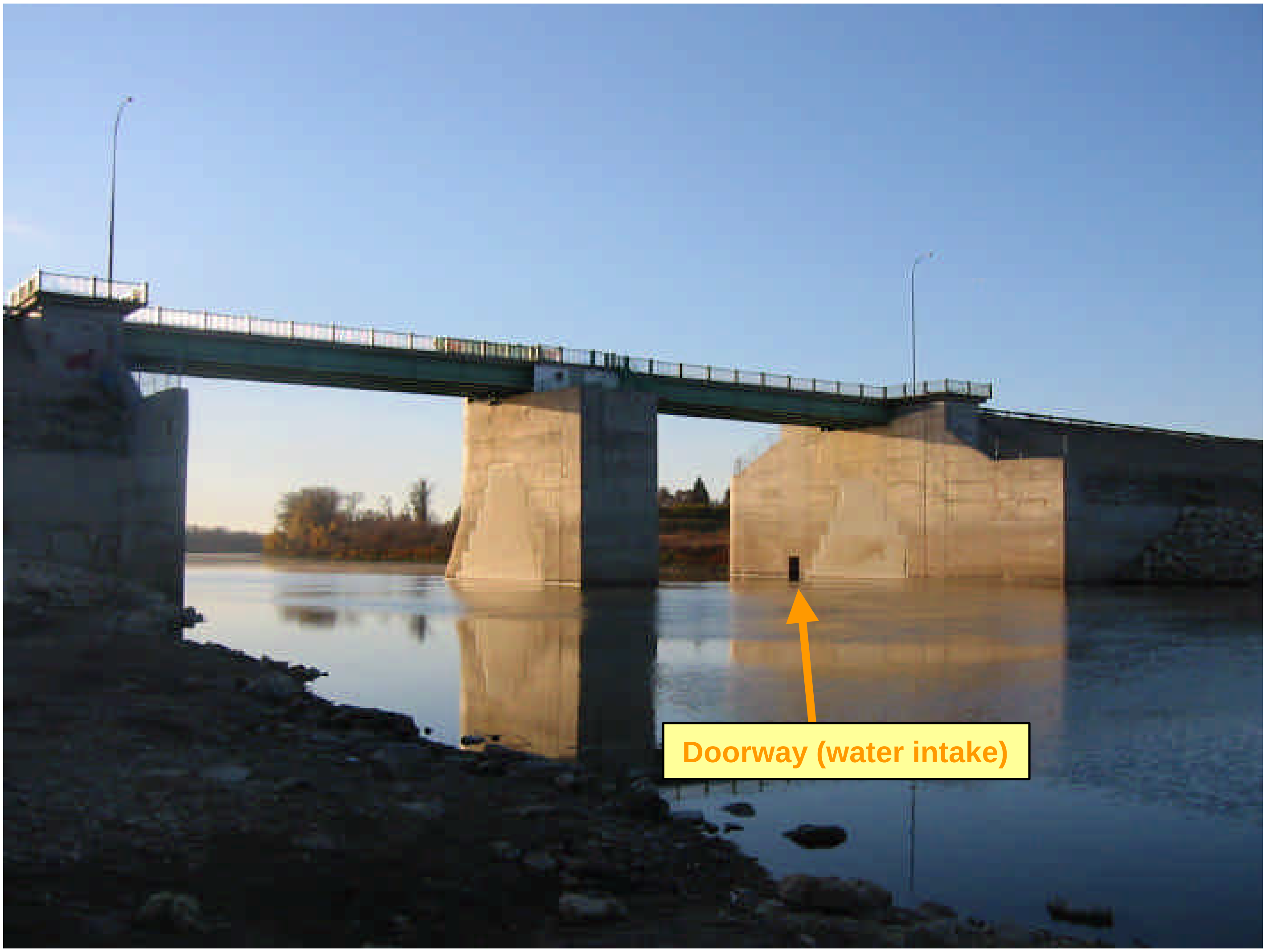


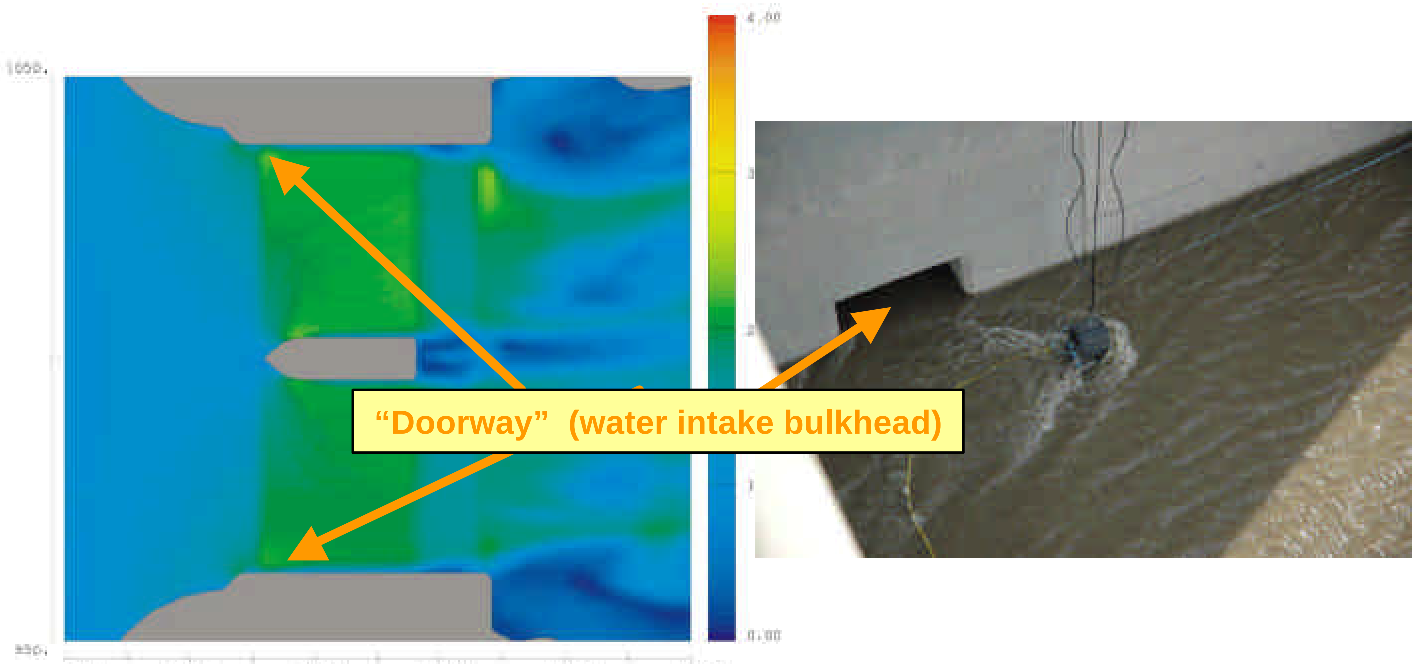
The DIDSON acoustic camera was mounted in a heavy metal box and lowered into position in the Inlet Control Structure using a small wheeled crane from the observation platforms.

Red River Floodway Inlet Control Structure
DIDSON Camera Deployment
Figure 3-5



Red River Floodway Inlet Control Structure
Locations of DIDSON Camera Surveillance
Figure 3-6





Red River Floodway Inlet Control Structure
"Doorways "
Figure 3-7

4.0 RESULTS

4.1 FREQUENCY OF RED RIVER FLOODWAY INLET STRUCTURE OPERATION

The Inlet Control Structure operations can be divided into two general classes: "active" operation and "inactive" operation. During inactive operation, the Inlet Control Structure gates are in the "down" position, allowing water to flow relatively unrestricted through the structure (Figure 1-4). "Active" operation involves the use of the Inlet Control Structure for its designed purpose of controlling water levels downstream in the City of Winnipeg by diverting Red River flood flows through the Red River Floodway Channel. This active operation involves raising the gates of the Inlet Control Structure (Figure 4-1), which controls the flow of water that is allowed to enter the City. As defined by the operator rules (Section 5.3 of EIS), flow is diverted into the entrance of the Red River Floodway, which is situated immediately upstream of the Inlet Control Structure on the Red River.

The Inlet Control Structure was assumed to be a barrier to upstream fish movement during the period of active operations. 3-D modeling (Groenveld and Fuchs 2004) of the probable water velocities over the raised gates of the Inlet Control Structure supports this assumption (Figure 4-2) and suggests peak water velocities of over 8 m/s (well beyond Red River fish swimming capabilities, discussed further in Section 4.4).

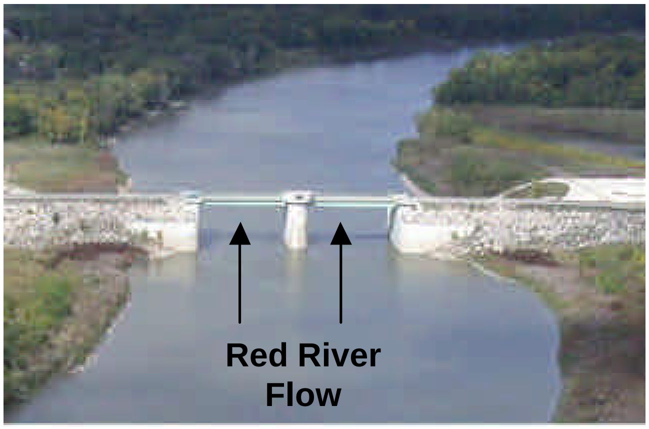
For the purpose of this analysis, it was assumed that the Inlet Control Structure is a barrier to the upstream movements of Red River fish during active operations, or any time the gates are partially or completely raised. Table 4-1 summarized the historic active operations of the Inlet Control Structure. Figure 4-3 provides a summary evaluation of the active operations and notes:

- the gates have been historically used between the months of March and July inclusive;
- the majority of active operation (i.e., more than one interval of time) has occurred during the months of April and May;
  - the overall average frequency and duration of the active operation is similar between April and May;
  - the sequential active operation of the Inlet Control Structure from one year to the next is more common in April than in May.

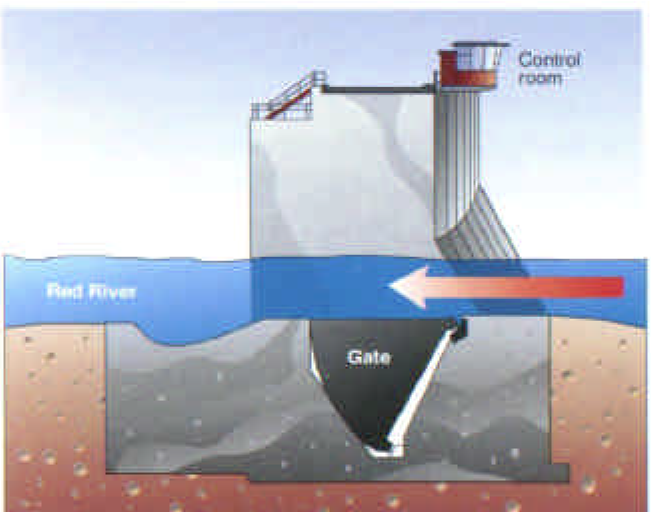
4.2 RED RIVER FLOWS AND WATER VELOCITY THROUGH THE INLET CONTROL STRUCTURE

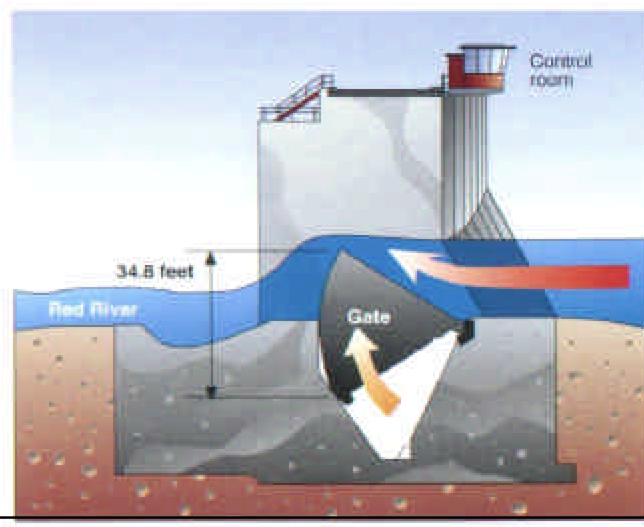
The Red River flows generally follow an annual cycle in which peak flows are usually associated with the spring snowmelt and runoff (Figure 4-4). Historic flows however are highly variable depending on short-term and annual precipitation patterns. It is anticipated that as the total flows in the Red River increase, the average water velocity through the Inlet Control Structure will also increase (Figure 4-5), as confirmed by velocity modelling conducted by Brown (2004) and Groeneveld and Fuchs (2004).

Red River Floodway Inlet Control Structure



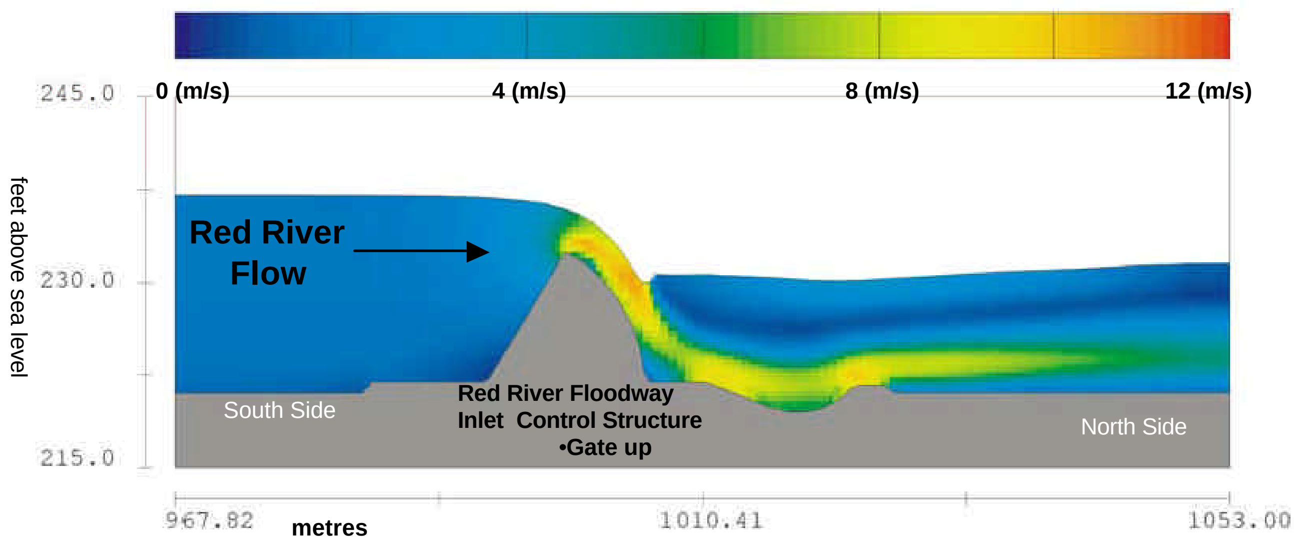
Inactive Operations **Active Operations**





- **Inlet Control Structure was constructed in the 1960's**
- **Consists of two submersible gates**
  - **Each gate is about 35 m wide**
    - **About a 50% constriction of the river**
- **Gates are normally in the down position**
  - **Usually have about 2-3 m of water over the gates in the summer**
- **When the gates are raised, part of the Red River flow is diverted through the Red River Floodway Channel**

Red River Floodway Inlet Control Structure
Design and Operations
Figure 4-1



- The Red River Floodway is assumed to be a barrier to upstream fish movement when the gates are operated (peak velocity of over 8 m/s)
- 3-D velocity modeling of the Inlet Control Structure supports this assumption

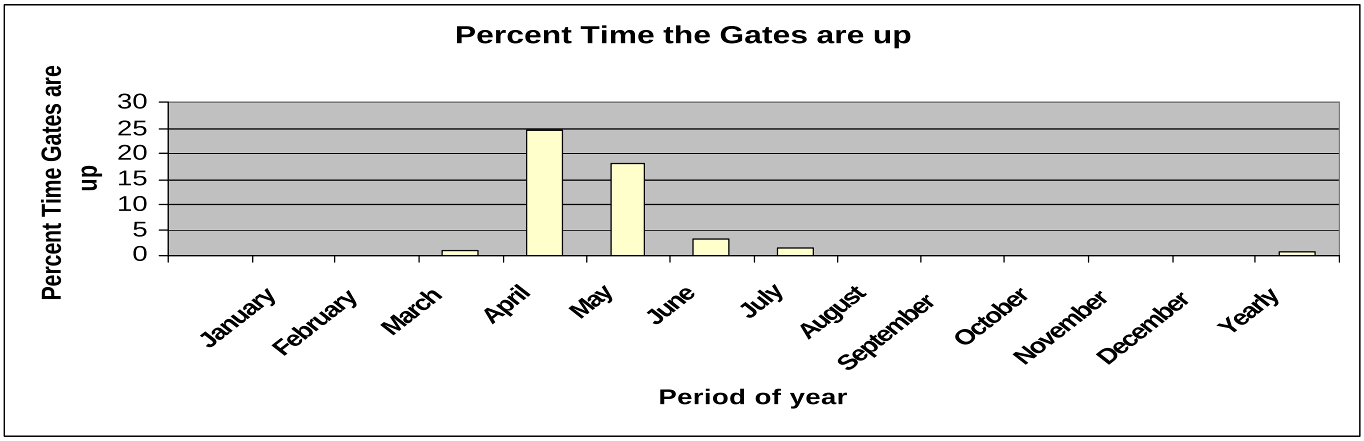
Data Source: Groeneveld and Fuchs, September 2004 Floodway Inlet Control Structure Three Dimensional Flow Analysis

Red River Floodway Inlet Control Structure Operational- Gates Up
Figure 4-2

Table 4-1
Red River Floodway Inlet Control Structure
Historic Operations

Year		January	February	March	April	May	June	July	August	September	October	November	December	Total
1967		0	0	0	21	2	0	0	0	0	0	0	0	**23**
1968		0	0	0	0	0	0	0	0	0	0	0	0	**0**
1969		0	0	0	18	20	0	0	0	0	0	0	0	**38**
1970		0	0	0	11	19	0	0	0	0	0	0	0	**30**
1971		0	0	0	11	0	0	0	0	0	0	0	0	**11**
1972		0	0	0	5	0	0	0	0	0	0	0	0	**5**
1973		0	0	0	0	0	0	0	0	0	0	0	0	**0**
1974		0	0	0	12	30	0	0	0	0	0	0	0	**42**
1975		0	0	0	1	19	0	0	0	0	0	0	0	**20**
1976		0	0	0	12	0	0	0	0	0	0	0	0	**12**
1977		0	0	0	0	0	0	0	0	0	0	0	0	**0**
1978		0	0	0	22	3	0	0	0	0	0	0	0	**25**
1979		0	0	0	11	28	0	0	0	0	0	0	0	**39**
1980		0	0	0	0	0	0	0	0	0	0	0	0	**0**
1981		0	0	0	0	0	0	0	0	0	0	0	0	**0**
1982		0	0	0	6	0	0	0	0	0	0	0	0	**6**
1983		0	0	0	5	0	0	0	0	0	0	0	0	**5**
1984		0	0	0	0	0	0	0	0	0	0	0	0	**0**
1985		0	0	0	0	0	0	0	0	0	0	0	0	**0**
1986		0	0	1	14	6	0	0	0	0	0	0	0	**21**
1987		0	0	0	12	0	0	0	0	0	0	0	0	**12**
1988		0	0	0	0	0	0	0	0	0	0	0	0	**0**
1989		0	0	0	9	3	0	0	0	0	0	0	0	**12**
1990		0	0	0	0	0	0	0	0	0	0	0	0	**0**
1991		0	0	0	0	0	0	0	0	0	0	0	0	**0**
1992		0	0	0	6	0	0	0	0	0	0	0	0	**6**
1993		0	0	0	0	0	0	0	0	0	0	0	0	**0**
1994		0	0	0	0	0	0	0	0	0	0	0	0	**0**
1995		0	0	9	24	0	0	0	0	0	0	0	0	**33**
1996		0	0	0	11	31	7	0	0	0	0	0	0	**49**
1997		0	0	0	11	31	3	0	0	0	0	0	0	**45**
1998		0	0	2	5	0	0	0	0	0	0	0	0	**7**
1999		0	0	0	27	1	0	0	0	0	0	0	0	**28**
2000		0	0	0	0	0	0	0	0	0	0	0	0	**0**
2001		0	0	0	24	20	0	0	0	0	0	0	0	**44**
2002		0	0	0	0	0	13	17	0	0	0	0	0	**30**
2003		0	0	0	0	0	0	0	0	0	0	0	0	**0**
2004		0	0	0	0	0	13	0	0	0	0	0	0	**13**
Total Number of Days over 38 yrs gate was up		**0**	**0**	**12**	**278**	**213**	**36**	**17**	**0**	**0**	**0**	**0**	**0**	**556**
Average Number of Days/Year Gate was up (in years used)		**0**	**0**	**4.0**	**12.6**	**16.4**	**9.0**	**17**	**0**	**0**	**0**	**0**	**0**	**10.5**
Average number of Days gate up (both in years used and not used)		**0**	**0**	**0.3**	**7.3**	**5.6**	**0.9**	**0.4**	**0**	**0**	**0**	**0**	**0**	**2.9**
Percent of time gate is up		**0**	**0**	**1**	**24**	**18**	**3**	**1**	**0**	**0**	**0**	**0**		**0.8**
Number of times the Gate is used in sequencial years	**1 year**			**3**	**4**	**5**	**2**	**1**						
	2 years				**3**	**4**	**1**							
	3 years				**1**									
	4 years				**1**									
	5 years				**1**									
Number of years used		**0**	**0**	**3**	**22**	**13**	**4**	**1**	**0**	**0**	**0**	**0**	**0**	**24**

Data Source:HYDAT 2001, National Data Archive, Water Survey of Canada, 2001. Flood Damage Reduction Section, Water Science and Management Branch, MNS. 2004. Dataset extracted and analyzed from flows recorded at station near St. Norbert , Red River Floodway.

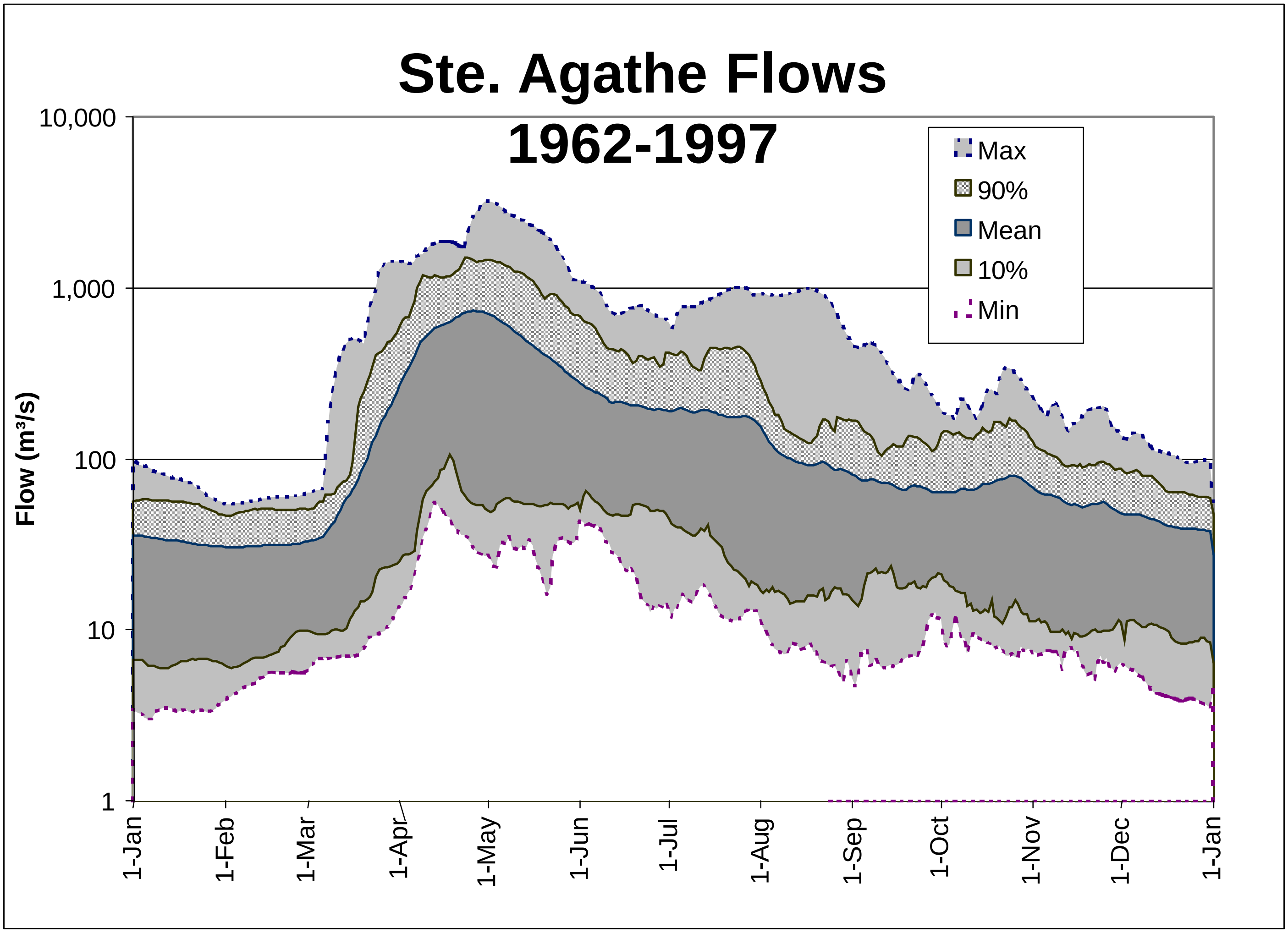


Inlet Control Structure		January	February	March	April	May	June	July	August	September	October	November	December	Total
Total Number of Days over 38 yrs gate was up		0	0	12	278	213	36	17	0	0	0	0	0	556
Average Number of Days/Year Gate was up (in years used)		0	0	4.0	12.6	16.4	9.0	17	0	0	0	0	0	10.5
Average number of Days gate up (both in years used and not used)		0	0	0.3	7.3	5.6	0.9	0.4	0	0	0	0	0	2.9
Percent of time gate is up		0	0	1	24	18	3	1	0	0	0	0		0.8
Number of times the Gate is used in sequencial years	1 year			3	4	5	2	1						
	2 years				3	4	1							
	3 years				1									
	4 years				1									
	5 years				1									
Number of years used		0	0	3	22	13	4	1	0	0	0	0	0	24

The Inlet Control Structure:

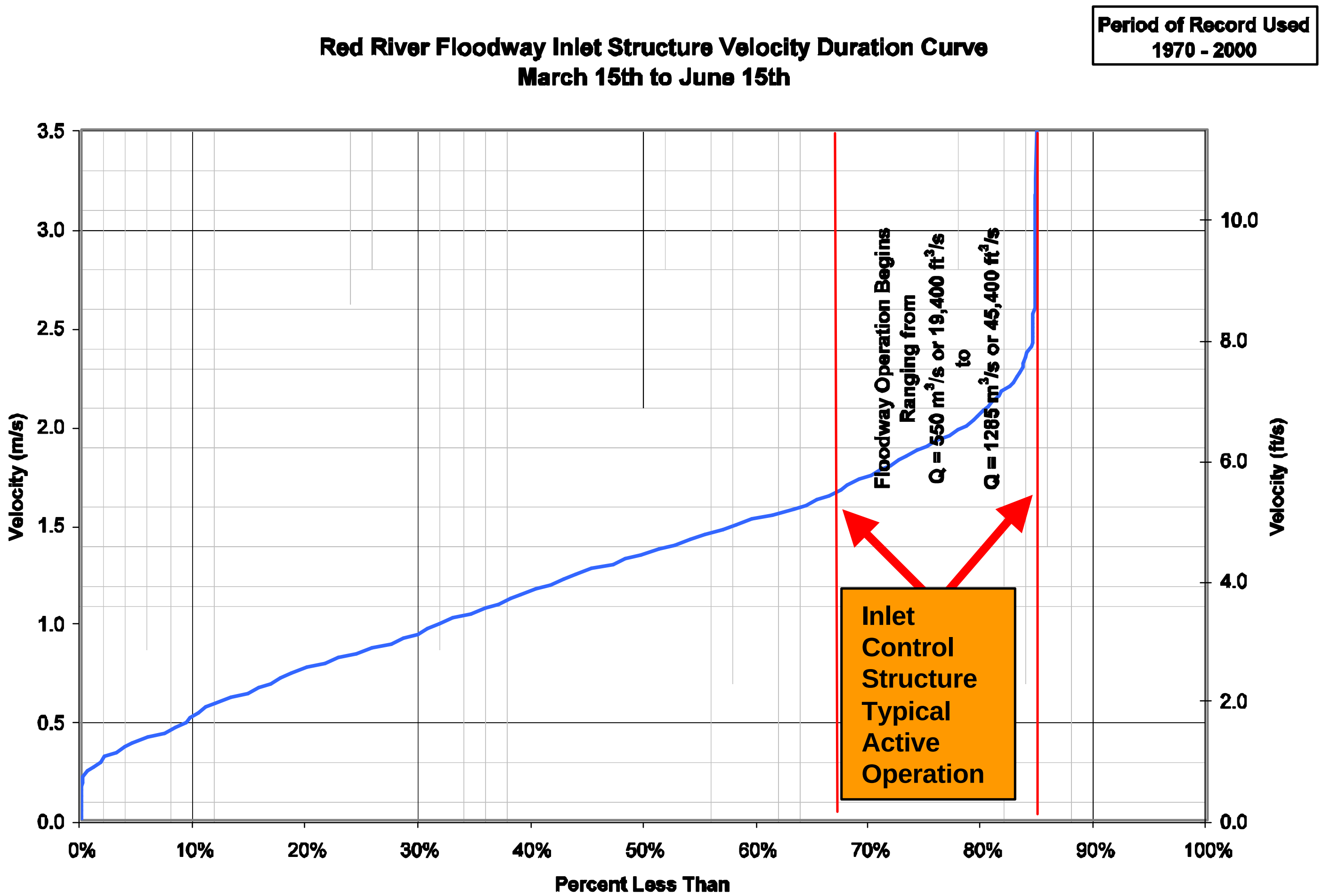
- rarely operational in March, June or July.
- In the month of April;
  - The gates are up an average of 7 days per year;
  - In years when the gates are used;
    - Used a maximum of 27 days,
    - On average the gates are up 13 days,
    - Gates have been used,
      - Five, four, and three years in a row once,
      - Two years in a row three times,
- In month of April
  - The gates are up an average of 6 days per year;
  - In years when the gates are used;
    - Used a maximum of 31 days (all month),
    - On average the gates are up 16 days,
    - Gates have been used
      - Two years in a row four times.

Red River Floodway Inlet Control Structure
Operational Frequency and Pattern of Use
Figure 4-3



Data Source: TetrES 1999

Red River Annual Flow Pattern
Figure 4-4



Note: Values shown do not include operation of the Floodway Gates.
Reference line is to show the point at which the gates would begin to be operated for spring period.

1/20/2004

Data Source: Brown 2004 Velocities through the Floodway Inlet Control Structure and the Seine River Inverted Siphon. January 20, 2004 Memorandum from Dave Brown to Rick Carson of KGS-ACRES-UMA.

Red River Flow Frequency and Potential Water Velocity in the Inlet Control Structure
Figure 4-5

3-D velocity modeling of these flows through the Inlet Control Structure demonstrated that the water velocities near the side abutments and bottom over the gates were much lower than the average velocity through the Structure as a whole (Figure 4-6). The Groeneveld and Fuchs 2004 analysis was conducted at 440, 600 and 1000 cubic metres per second hypothetical Red River flows (Figure 4-7) and generally demonstrate that the zones of lower velocity water associated with the sides and bottom of the Structure are present, although the size of the zones decrease with increasing flow.

The 3-D modeling suggests that areas of less than 1 metre per second velocity water exists in the Inlet Control Structure, primarily associated with the sides and base of the structure, regardless of the flows in the Red River. The 3-D modeling did not model the velocity of the corner interface between the bottom and the sides of the Structure, where water velocities are anticipated to be approximately 50% lower (Figure 4-8). The validity of this estimate is further discussed with respect to the results of in-field fish movement investigations in Section 4.3.

The results of the 3-D modeling suggests that the Inlet Control Structure may provide fish an opportunity to utilize areas of lower velocity and traverse the Inlet Control Structure, even under high summer flows. The in-field fish movement investigations, discussed further in Section 4.3, confirmed that fish are making use of these available microhabitat features to traverse the Structure.

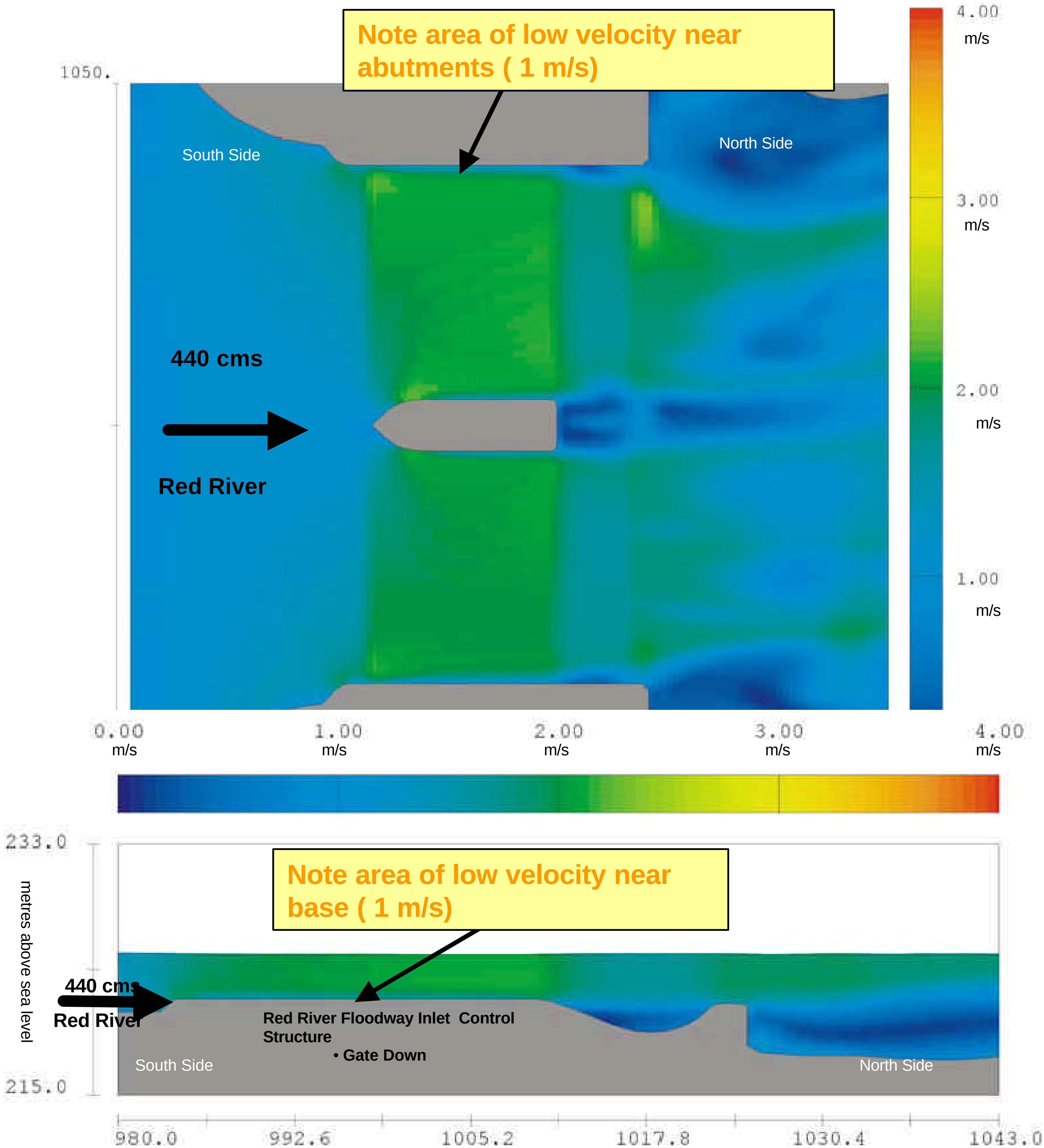
4.3 FIELD INVESTIGATIONS

Positioning of the DIDSON underwater acoustic imaging camera along the bottom of the outside edges of the east and west gates of the Inlet Control Structure as described in Section 3.3 (Figures 3-5 and 3-6) revealed that fish were taking advantage of the lower water velocity areas of the structure (Figure 4-9) that occur:

- within approximately 0.5 m of the outside walls of the structure;
- a 15 cm (6 inch) high "lip" along the leading edge of the gate (Figure 4-10);
- in a 3-4 m wide trough that occurs along the width of the downstream edge of the structure; and
- within the water intake bulkhead "doorways"[3] recessed into the concrete abutments (outside walls) of the structure (Figure 4-11).

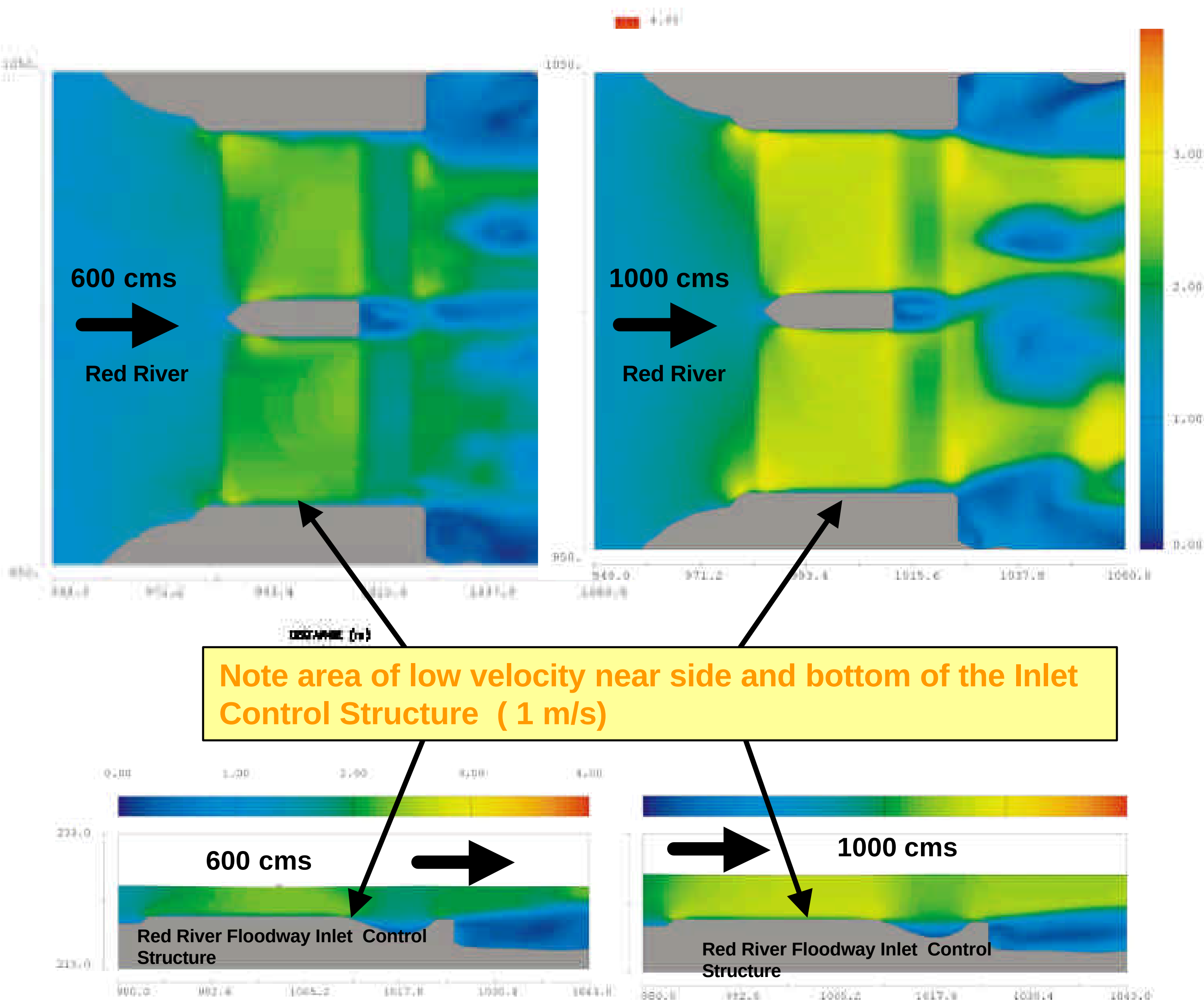
A CD provided with this report contains DIDSON camera video images illustrating fish behaviour and movements at the Inlet Control Structure. Selected still images of these videos are presented throughout Section 4.3. It should be noted that the video file conversion process from the original DIDSON program format results in a slight degradation of the images. Figure 4-12 illustrates the typical pattern of fish concentrations and movements upstream over the Inlet Control Structure gates as observed by the DIDSON underwater acoustic camera on April 30 and May 1, 2004. Fish in some of the DIDSON video

[3] One bulkhead doorway occurs on either side of outer east and west walls of the Floodway Inlet Control Structure. The two bulkhead doorways were closed during the deployment of the DIDSON camera. However when closed, the doorways are recessed into the walls creating an approximate 2m-deep 'chamber' of low-velocity water that fish can access while travelling upstream across the gates.



Data Source: Groeneveld and Fuchs, September 2004 Floodway Inlet Control Structure Three Dimensional Flow Analysis

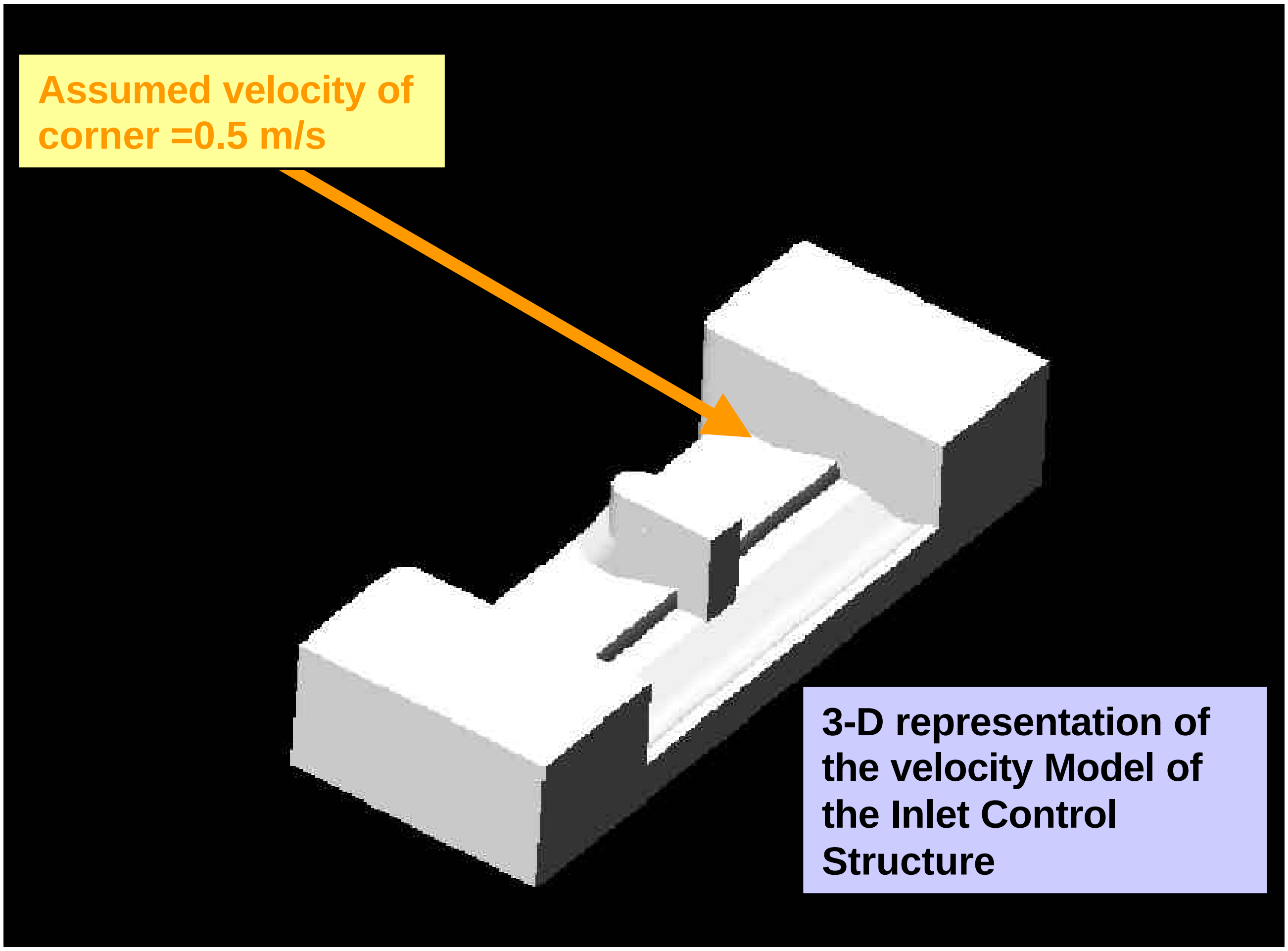
Red River Floodway Inlet Control Structure Inactive – Gates Down in Moderate Flow
Figure 4-6



- The water velocity down the sides and bottom of the Inlet Control Structure appear to remain at about 1 m/s regardless of the flow in the Red River
- As Flows in the Red River increase the area of lower velocity water decreases in size.

Data Source: Groeneveld and Fuchs, September 2004
Floodway Inlet Control Structure Three Dimensional Flow Analysis

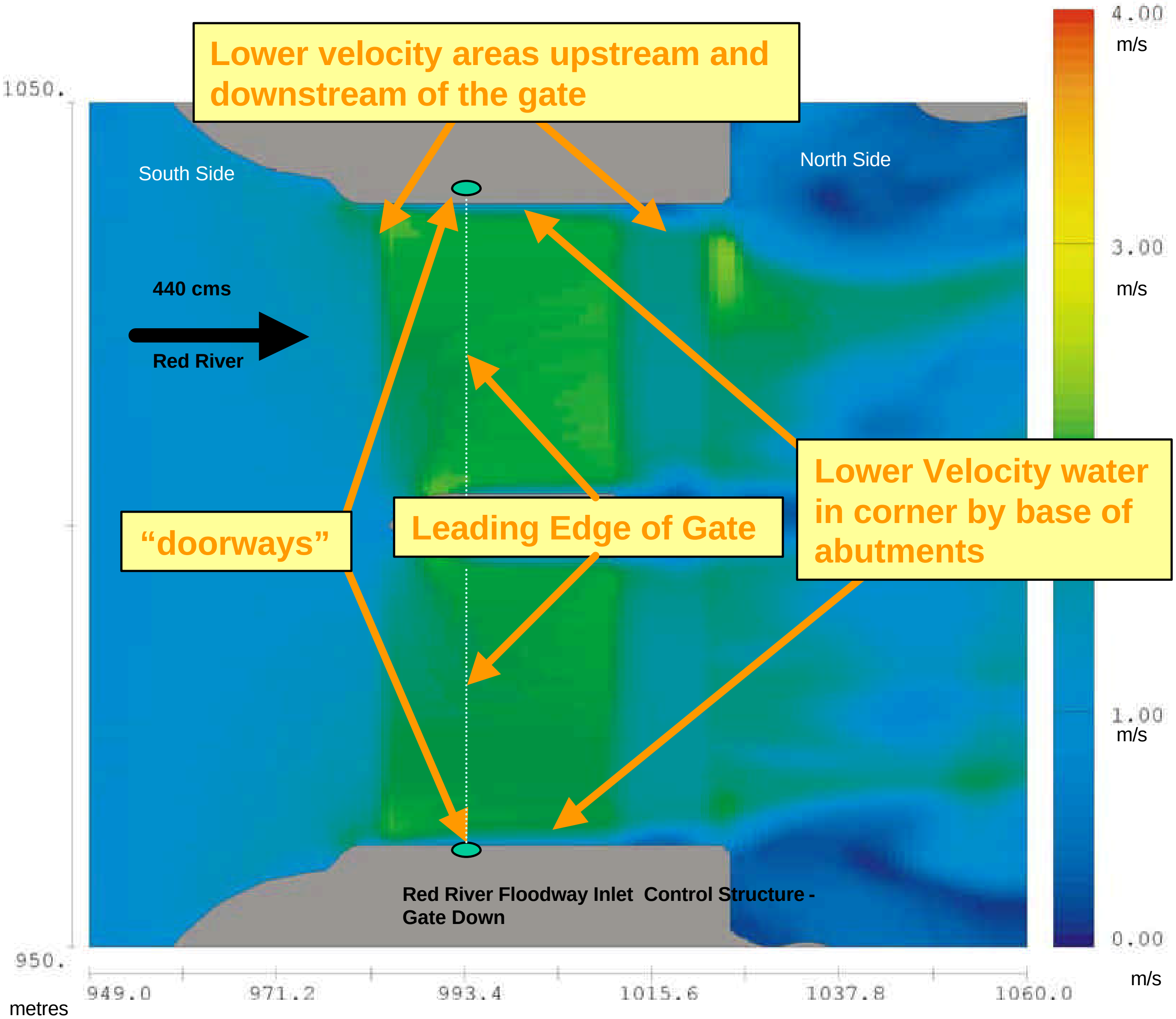
Red River Floodway Inlet Control Structure
Inactive – Gates Down in High Flows
Figure 4-7



- The outside corners of the Inlet Control Structure appear to be the most important areas used by fish to traverse the Structure (going up stream).
- If average velocities down the sides and bottom of the structure are 1 m/s, an average velocity of 0.5 m/s assumed for the corners.

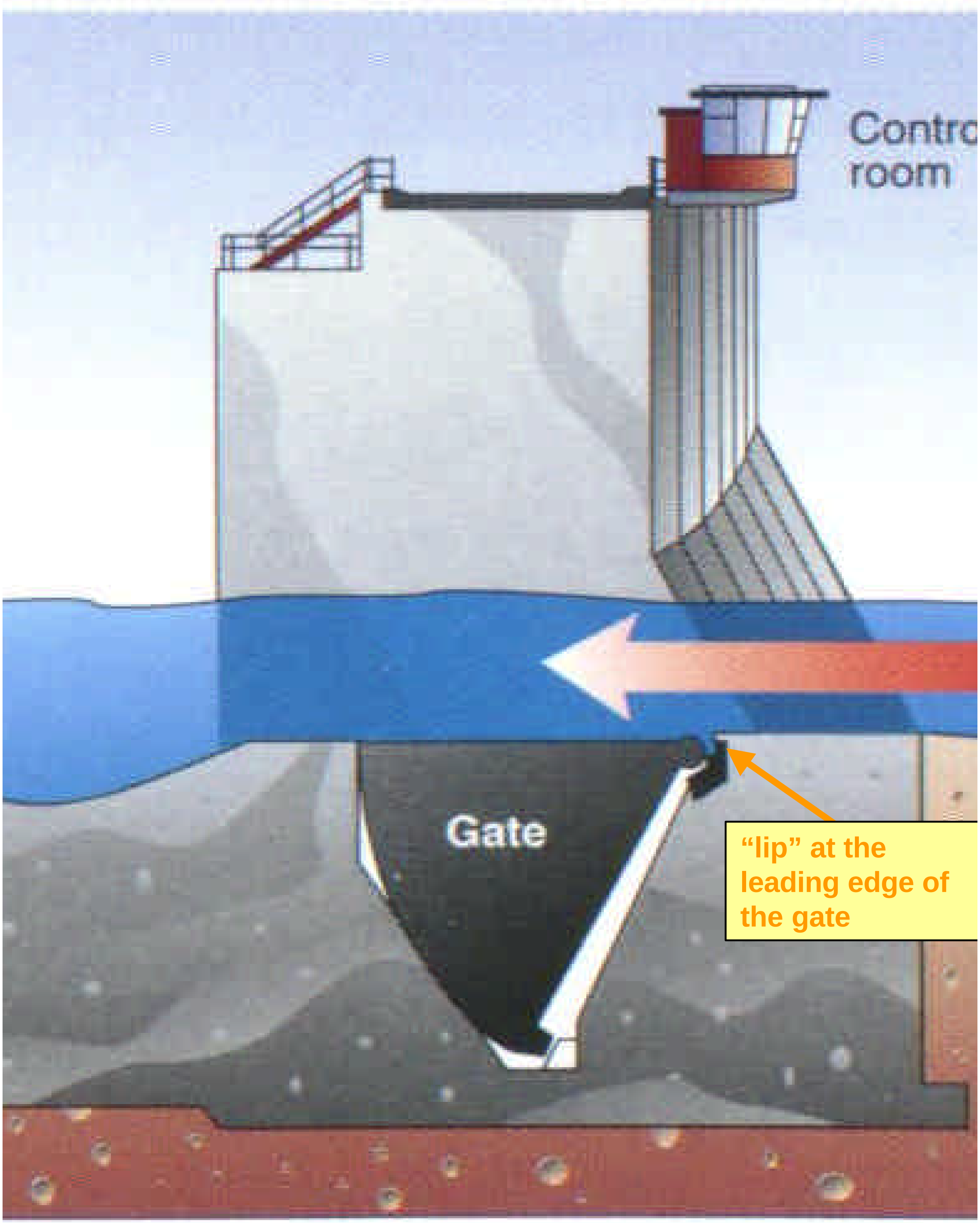
Data Source: Groeneveld and Fuchs, September 2004 Floodway Inlet Control Structure Three Dimensional Flow Analysis

Red River Floodway Inlet Control Structure
Inactive Operation – Corners
Figure 4-8

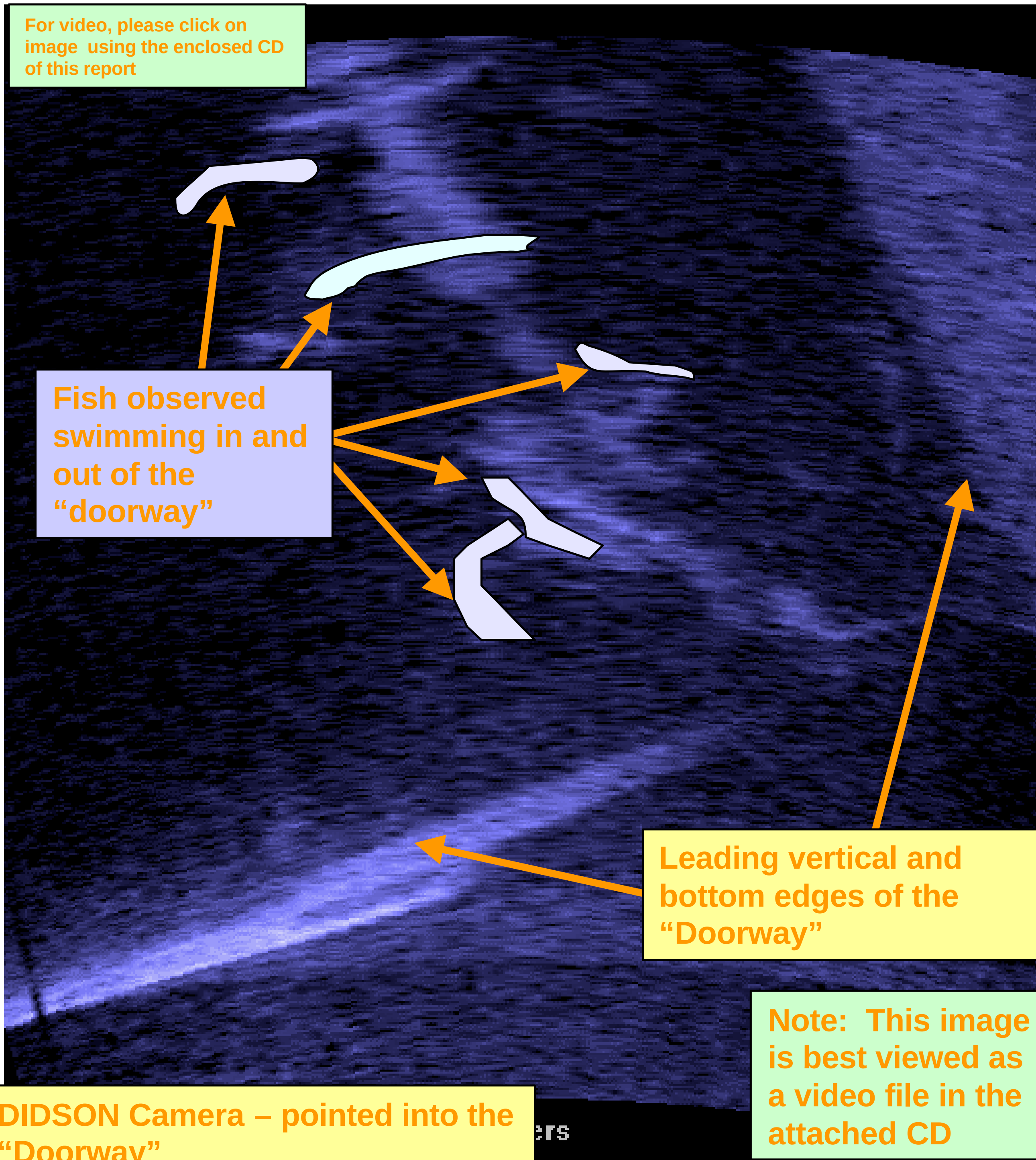


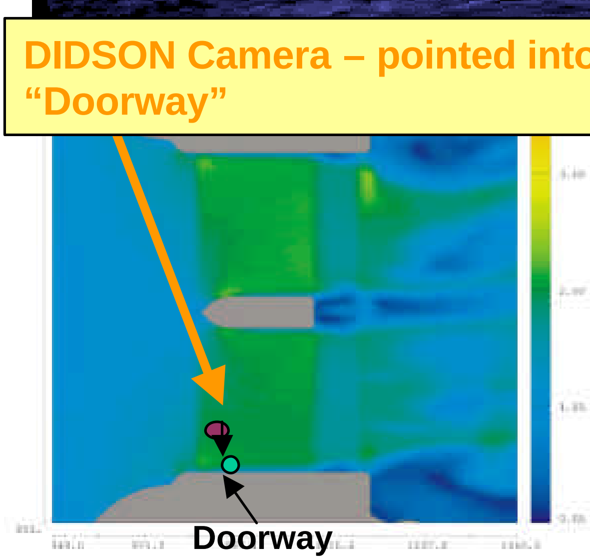
- **Distance between "refuges"**
  - **–About 10 m**
- **Fish primarily use bottom outside corners**
  - **–Confirms Inlet Structure Operator's observation of White Pelican fishing in these corners**

Red River Floodway Inlet Control Structure
Fish Passage Features
Figure 4-9



Red River Floodway Inlet Control Structure
“Lip” at the Leading Edge of the Gate
Figure 4-10

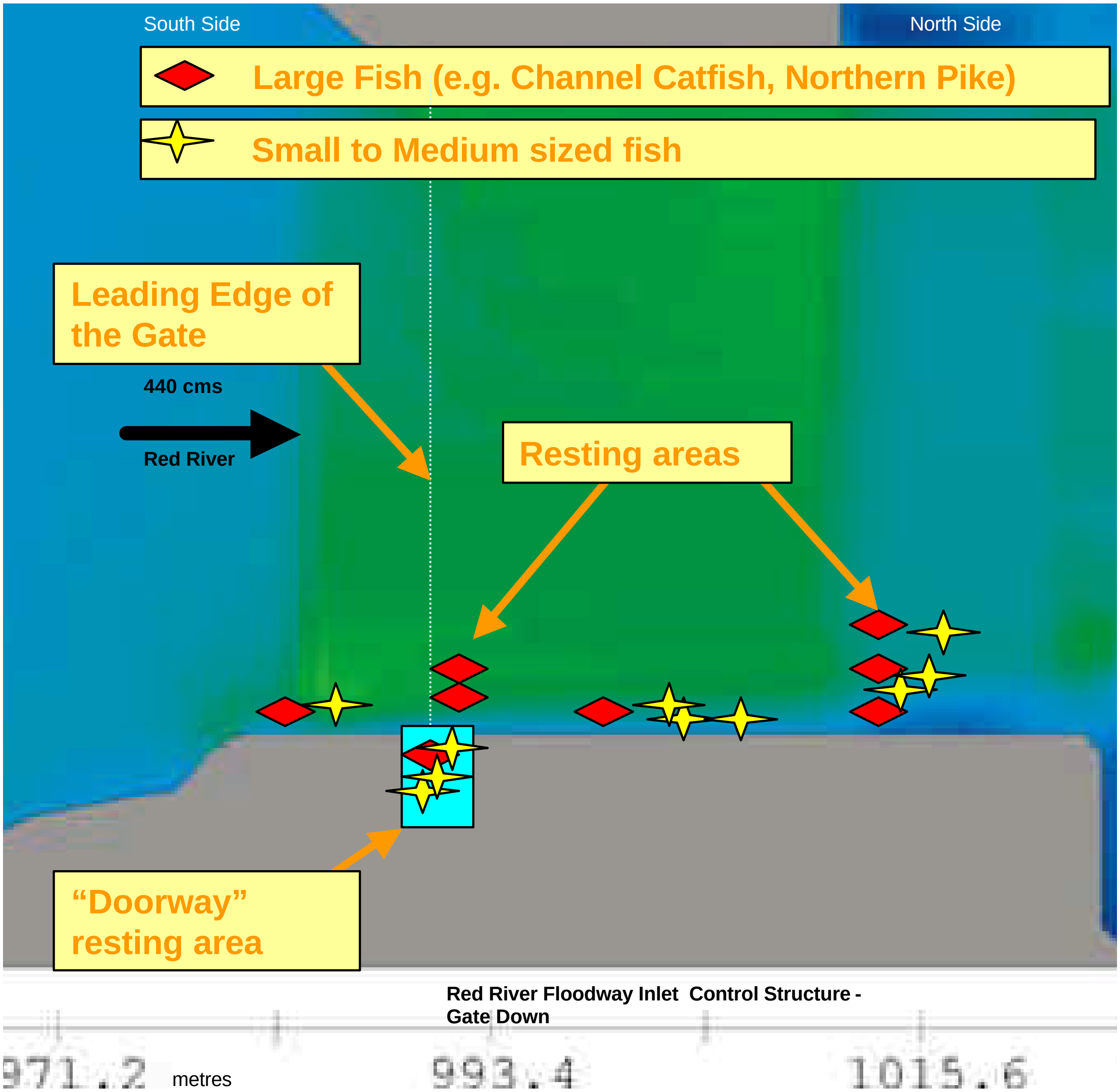




Notes:

- Fish observed moving upstream along the eastern abutment in the bottom corner

Red River Floodway Inlet Control Structure
Fish Movement and Resting in the “Doorway”
Figure 4-11



- **Fish appear to pause in lower flow areas downstream of the leading and tail ends of the gate and in the "doorway"**
- **Medium and smaller fish were often observed following the larger fish through the structure.**

Red River Floodway Inlet Control Structure
Observed Fish behaviour During Passage
Figure 4-12

recordings could be identified to species, specifically some Channel Catfish and Northern Pike, due to distinctive body form features and swimming characteristics (Figure 4-13) and are noted in Appendix A, Tables A-1 and A-2.

In summary, approximately three-times more fish per hour were observed at the downstream outside edge of the west gate compared to the downstream outside edge of the east gate. Approximately half of the fish observed below the west gate swam upstream past the gate: about 42% of fish observed below the east gate swam upstream past the gate. At both the east and west gates, high proportions of very small (<0.15 m) and small fish (0.15 to 0.5 m) were observed to swim upstream past the structure primarily by schooling behind larger fish potentially taking advantage of the lower-velocity slipstreams created larger fish attempting to travel upstream past the structure. The lowest proportion of fish able to swim upstream of the structure were medium-sized fish (0.51 to 0.75 m length). In some cases, fish that were able to swim upstream past the structure could be identified as Channel Catfish and Northern Pike. Some individuals of these species were also identified as failing in attempts to swim upstream of the gates. Additional details of fish movements at the east and west gates of the Inlet Control Structure are described in Section 4.3.1 and 4.3.2.

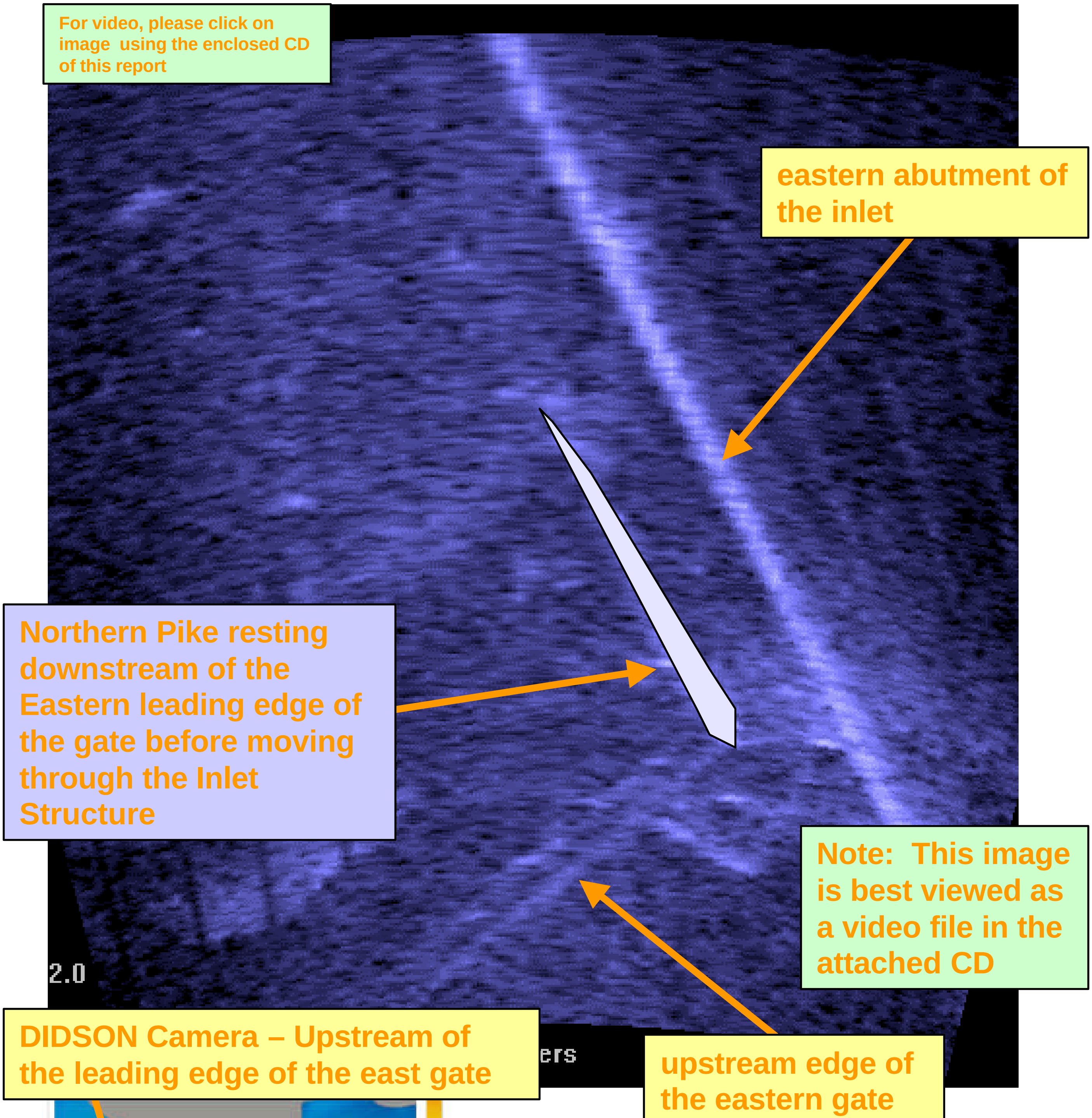
The DIDSON field investigations were also able to provide information that confirmed the estimated 0.5 m/s water velocity near the abutment wall assumed in Section 4.2. Fish that were leaving the sheltered area of the "doorway" were occasionally swept downstream once exposed to the current. Some of these fish were observed being swept downstream broadside to the current, suggesting that the fish was not swimming against this flow, but was being swept away with it. The DIDSON camera video image display provided an estimate of distance from the camera, and at a rate of eight frames per second, it was possible to estimate from the recorded images the rate of fish travel. The observed corner abutment velocity of the Red River, based on the above method, ranged from 0.4 to 0.5 m/s, confirming the estimated velocity detailed in Section 4.2.

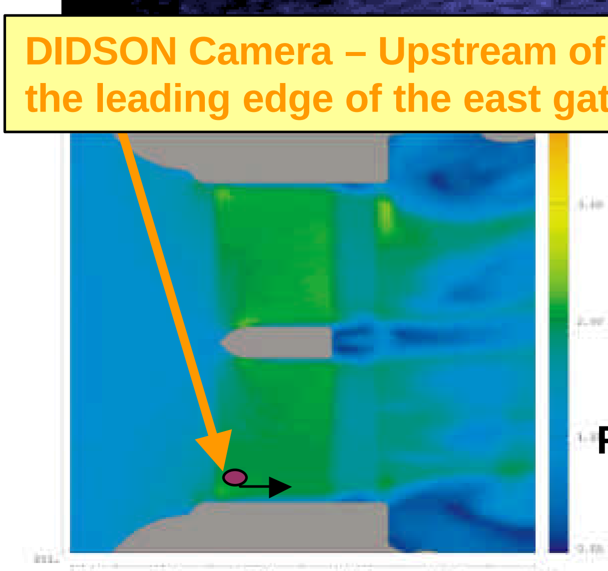
4.3.1 East Gate

During the nine hours of DIDSON acoustic image recording obtained at the east gate (April 30, 2004) of the Inlet Control Structure (Figure 4-14 to 4-16), a total of 874 fish were observed within the camera field of view (97 fish/hour: Appendix E, Table E-1). The majority of fish observed (56% of 851 fish) were in the medium size range with 38% of fish in the small size range, 3.2% in the very small size range and 2.9% in the large size range (> 0.75 m). Of the 179 observations where fish concentrations were described (i.e. the proximity of fish to each other)[4], fish concentrations were low in 63% of observations, medium in 27% of observations and high in 10% of observations.

Of the 851 fish observed, 42% swam upstream out of the field of view of the camera and were assumed to have successfully traversed the Inlet Control structure if the fish were not immediately swept back into the camera field of view (Appendix E, Table E-1). Of all the fish observed, 61% of the very small fish,

[4] Concentrations of fish in proximity to each other: High = >80% of fish observed in 2 min. period were less than 10cm from each other; Medium = >80% of fish observed in 2 min. period were between 10 and 20cm from each other; and Low = >80% of fish observed in 2 min. period were greater than 20cm from each other

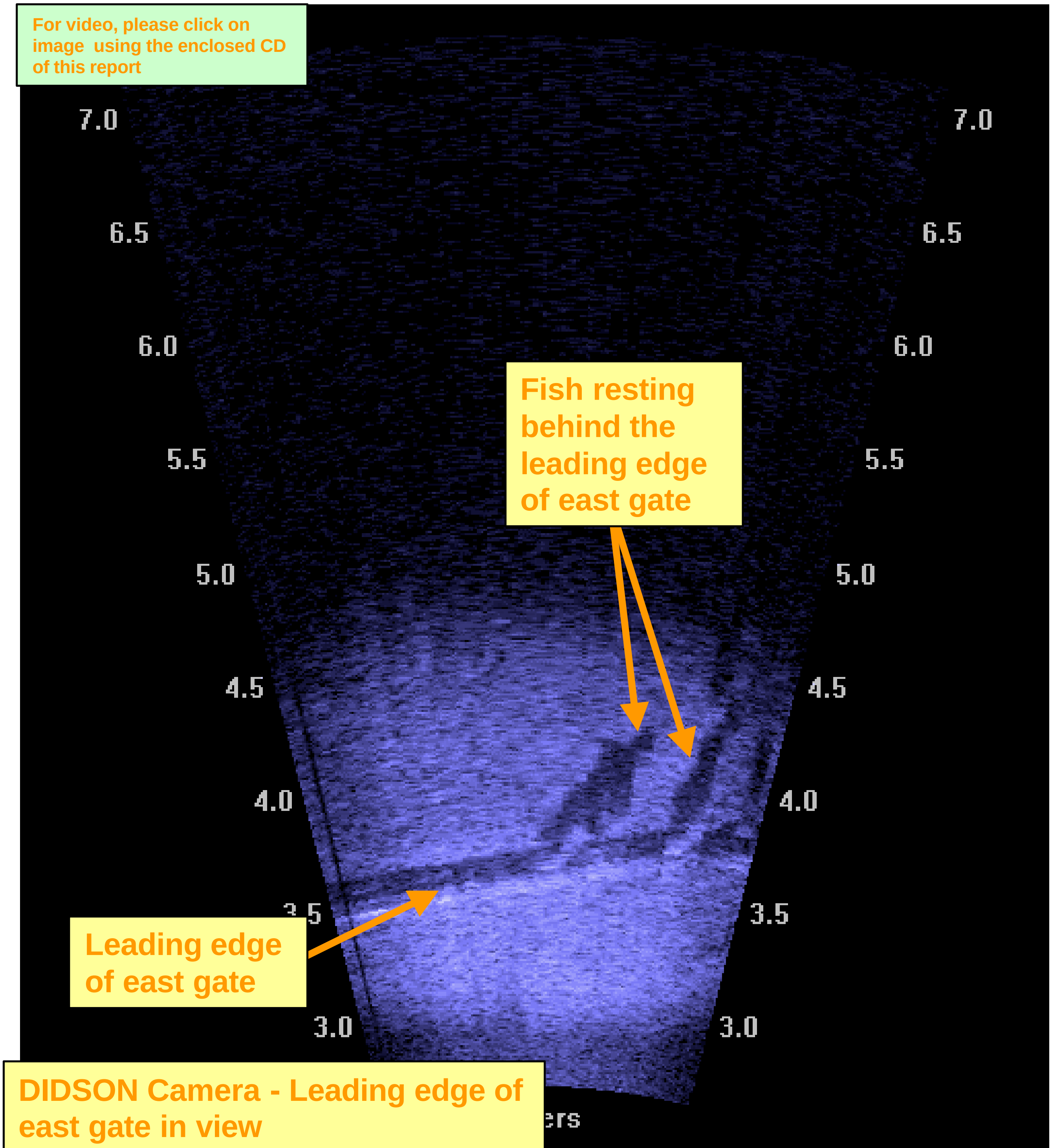


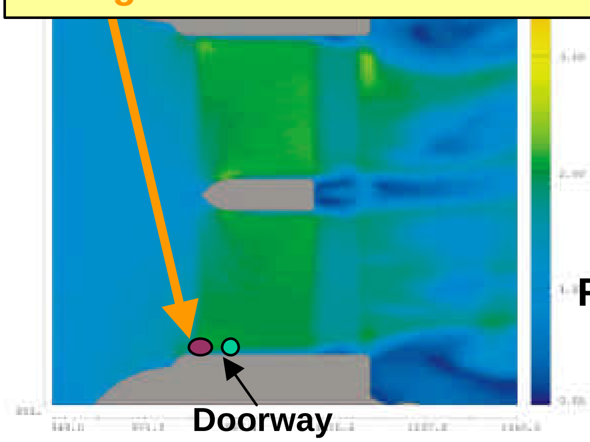


Notes:

- Fish observed moving upstream along the western abutment in the bottom corner

Red River Floodway Inlet Control Structure
Northern Pike Movement Through the Inlet Control Structure
Figure 4-13



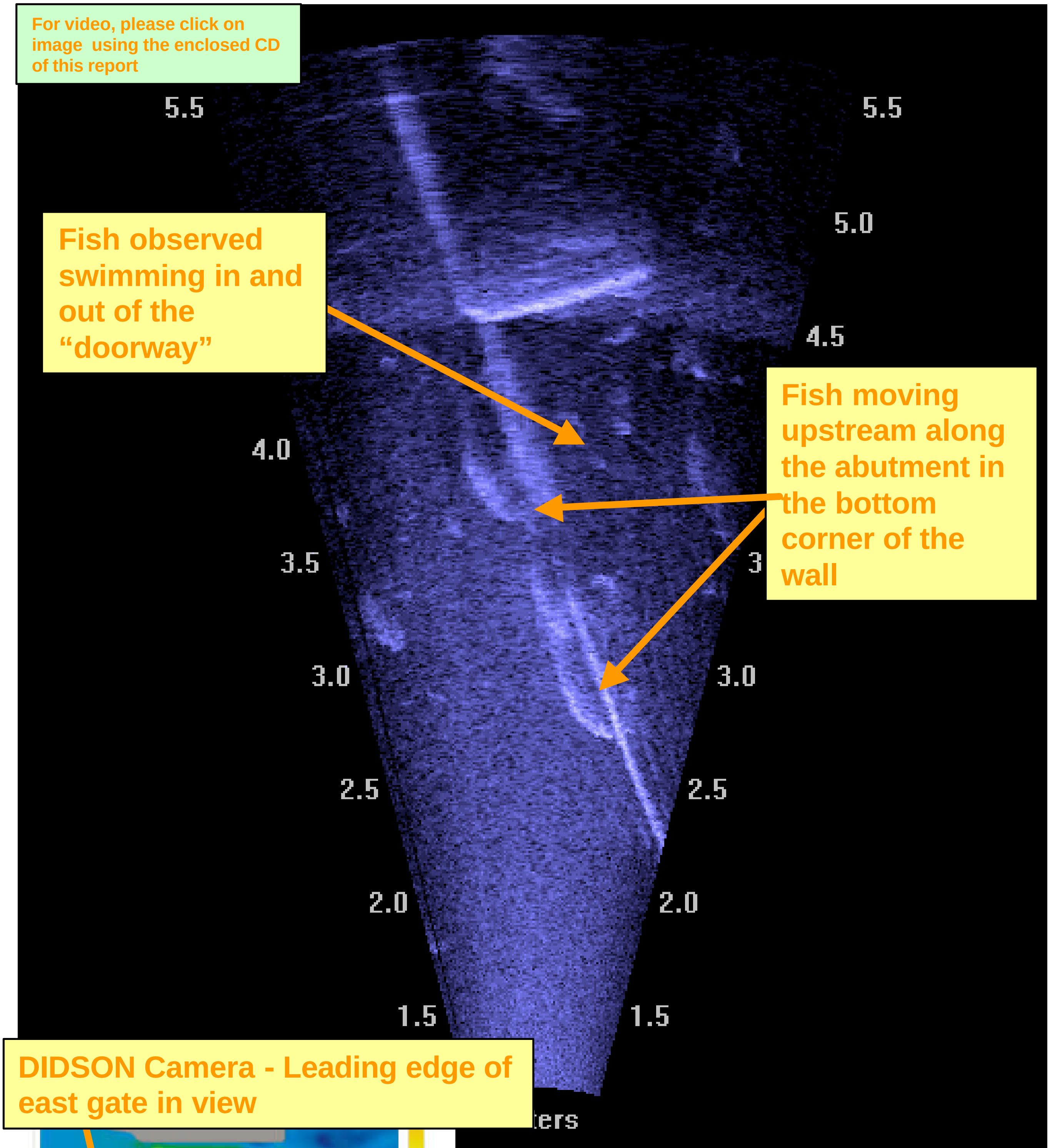


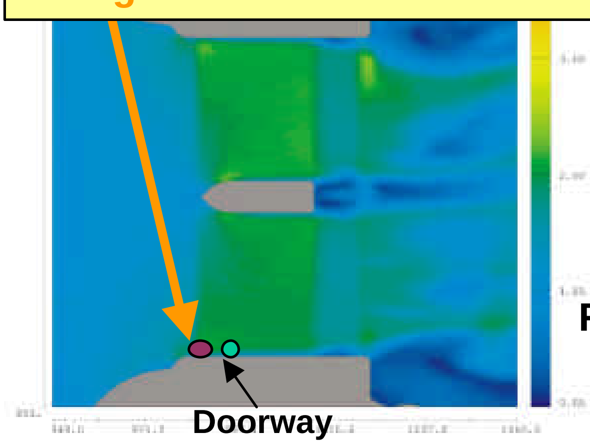
Notes:

•Fish are observed resting behind the leading edge of the east gate.

Red River Floodway Inlet Control Structure DIDSON Surveillance East Side near the Leading Edge of the Gate

Figure 4-14

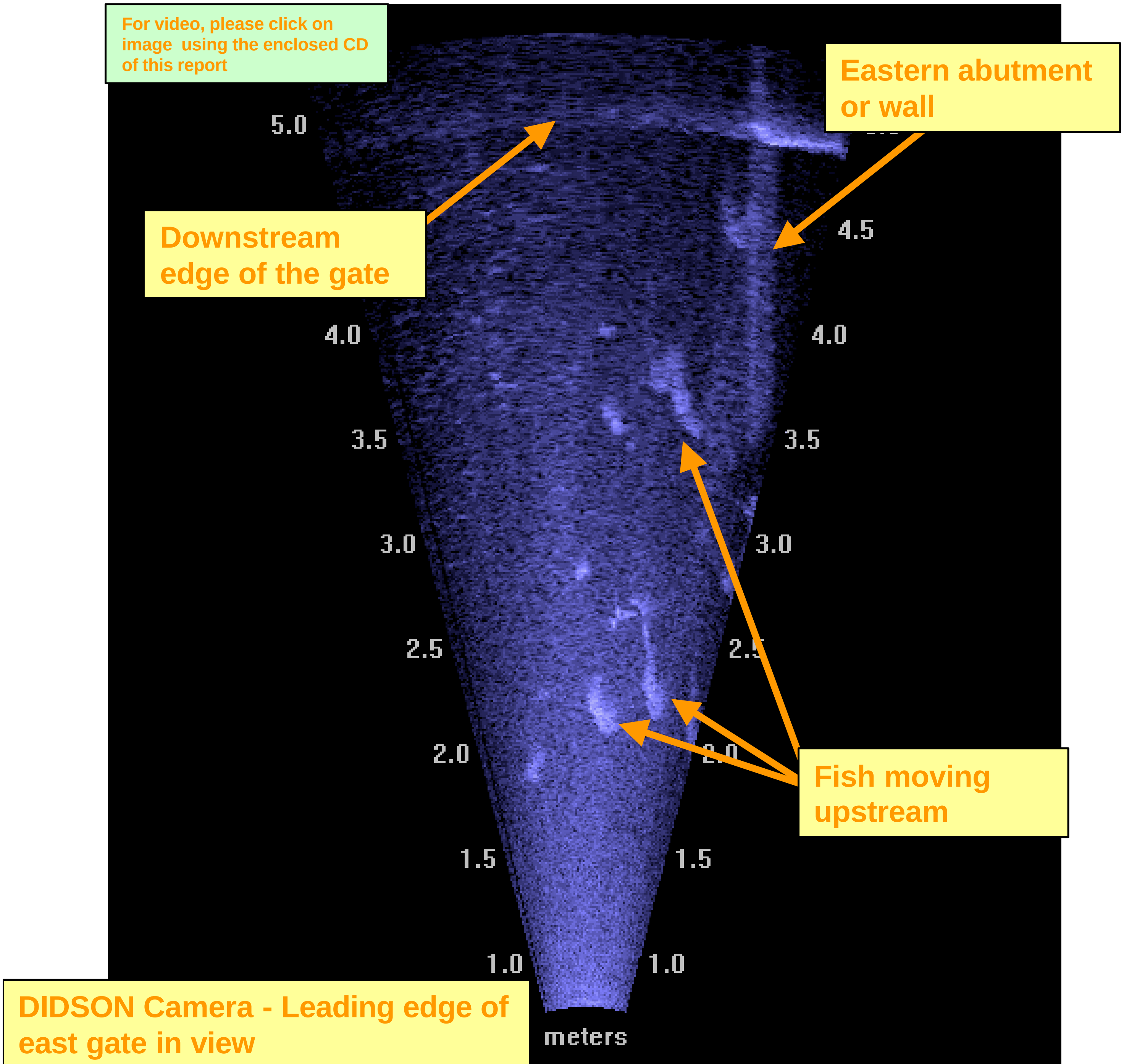


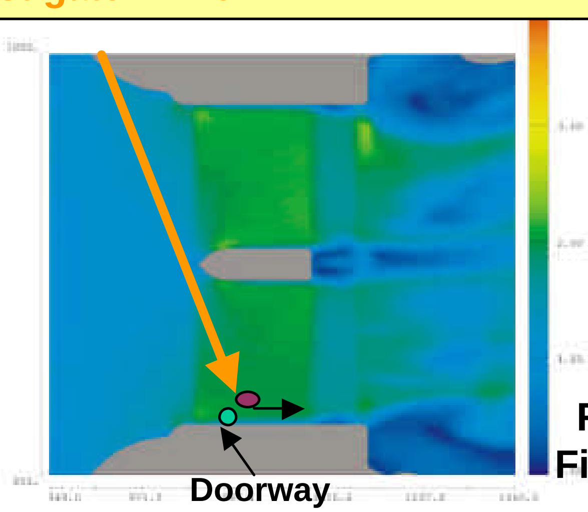


Notes:

- **Fish observed moving upstream along the eastern abutment in the bottom corner**

Red River Floodway Inlet Control Structure
Fish Movement along the East Abutment
Figure 4-15





Notes:

- **Fish observed moving upstream along the eastern abutment in the bottom corner**
- **Fish observed entering and leaving the "doorway".**

Red River Floodway Inlet Control Structure
Fish Movement along the Downstream Edge of the East Abutment
Figure 4-16

45% of small fish, 40% of large fish and 33% of medium fish were able to pass through the Inlet Control Structure over the east gate. The relatively high numbers of very small and small fish were observed being able to swim upstream past the structure by apparently schooling in the lower-velocity slipstreams created behind larger fish attempting to travel upstream past the structure. Of the fish that were observed to swim upstream past the east gate, at least two were medium-sized Channel Catfish and four were medium-sized Northern Pike.

The rate at which fish traversed successfully past the east gate of the Inlet Control Structure was variable (Appendix E, Table E-1). In cases where fish speed could be described, slightly more than half of the fish (51% of 348 observations) swam at a fast rate (taking 4 to 10 seconds to traverse past the east gate). Forty-percent swam at a slower rate past the east gate (taking more than 10 seconds) with only 3% of fish swimming very fast over the east gate (< 3 seconds). Six-percent of the fish observed made several unsuccessful attempts before eventually swimming successfully past the east gate. Of the fish that were swimming at a fast rate over the east gate (n = 173 fish), 50% were medium-sized fish, 45% were small fish and the remaining were very small (5.8%) and large (3.5%) fish. Of the fish that were swimming at a slower rate over the east gate (n = 136 fish), 52% were medium-sized fish, 45% were small fish and the remaining were very small (3.7%) and large (2.9%) fish.

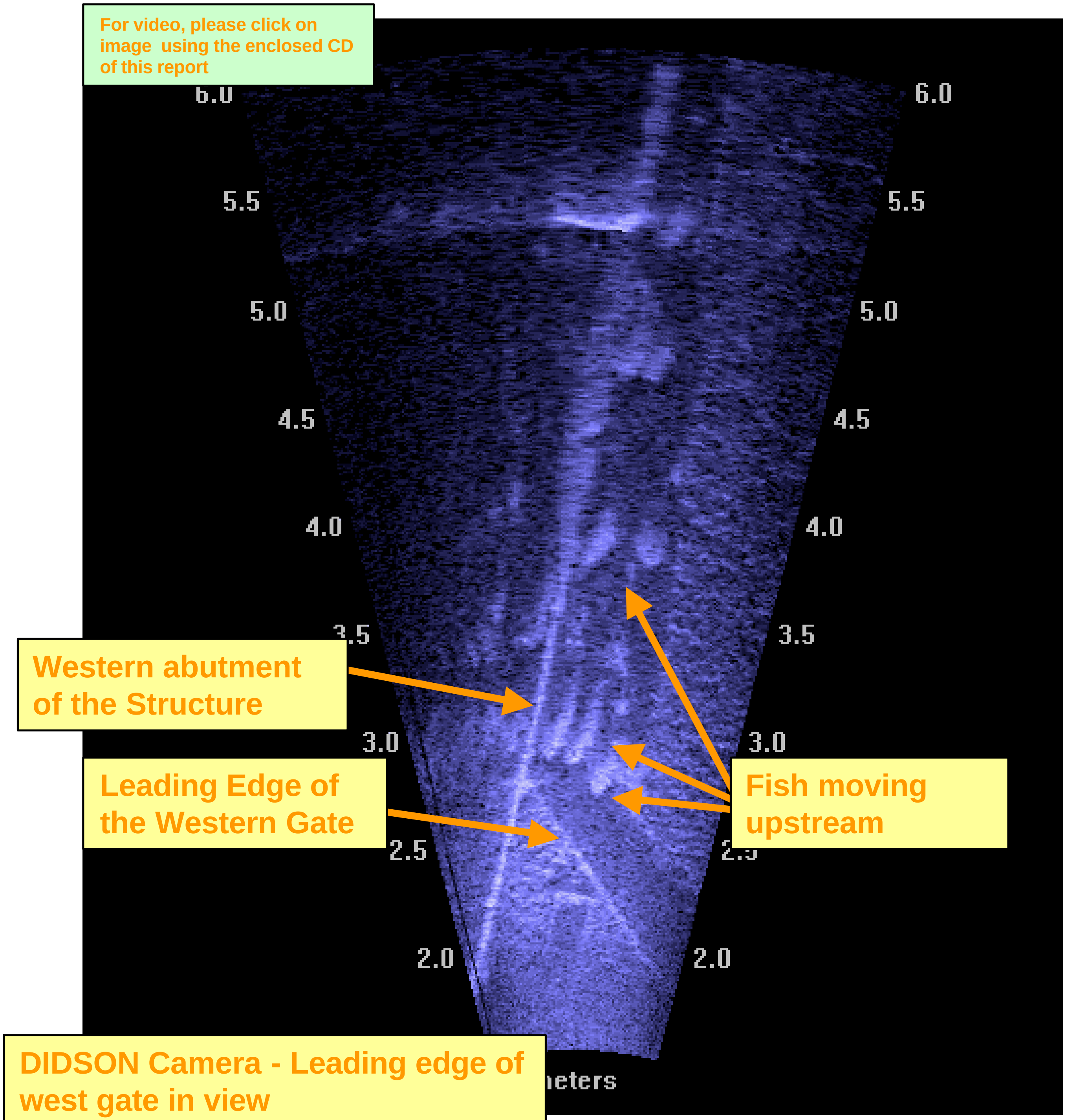
In images and video where the swimming distances of fish from the east wall of the Inlet Control Structure could be determined with accuracy (n = 242 fish), 57% were observed to swim upstream over the east gate at a distance of less than 0.25m from the east wall of the inlet structure (area of probable lowest water velocity).

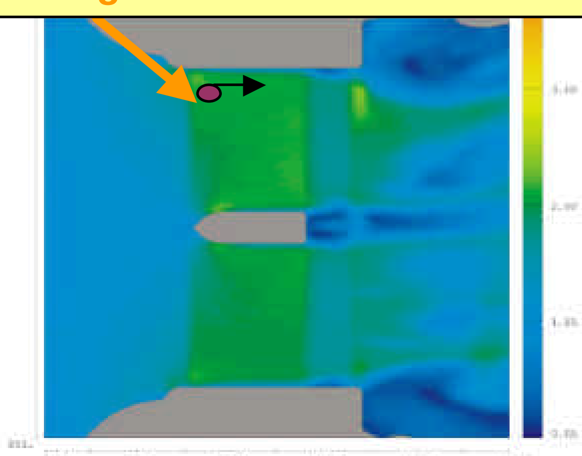
Of the 169 fish that were observed to fail in attempts to swim upstream past the Inlet Control Structure east gate, the majority were medium-sized fish (56%) and small fish (38%). Of the fish that failed in attempts to swim upstream past the gate, at least four of them were Northern Pike (three medium-sized and one small).

4.3.2 West Gate

During the 6.5 hours of DIDSON acoustic image recording obtained at the west gate of the Inlet Control Structure (Figure 4-17 to 4-18), a total of 2,019 fish were observed within the camera field of view near the downstream edge of the structure on May 1, 2004 (311 fish/hour: Appendix E, Table E-2). The Emajority of fish observed (56% of 2,019 fish) were in the medium size range (0.51 to 0.75 m length), with 40% of fish in the small size range (0.15 to 0.5 m), 3.1% in the large size range (> 0.75 m) and 1.1% in the very small size range (< 0.15 m). Of the 169 observations where fish concentrations were described (i.e. the proximity of fish to each other), fish concentrations were high in 52% of observations, medium in 39% of observations and low in 9.5% of observations.

Of the 2,019 fish observed, 52% swam upstream out of the field of view of the camera and were assumed to have successfully traversed the Inlet Control structure if the fish were not immediately swept back into the camera field of view (Appendix E, Table E-2). Of all the fish observed, 67% of large fish, 61% of the very small fish, 54% of small fish and 48% of medium fish were able to pass through the Inlet Control Structure over the west gate. As with the east gate, the relatively high numbers of very

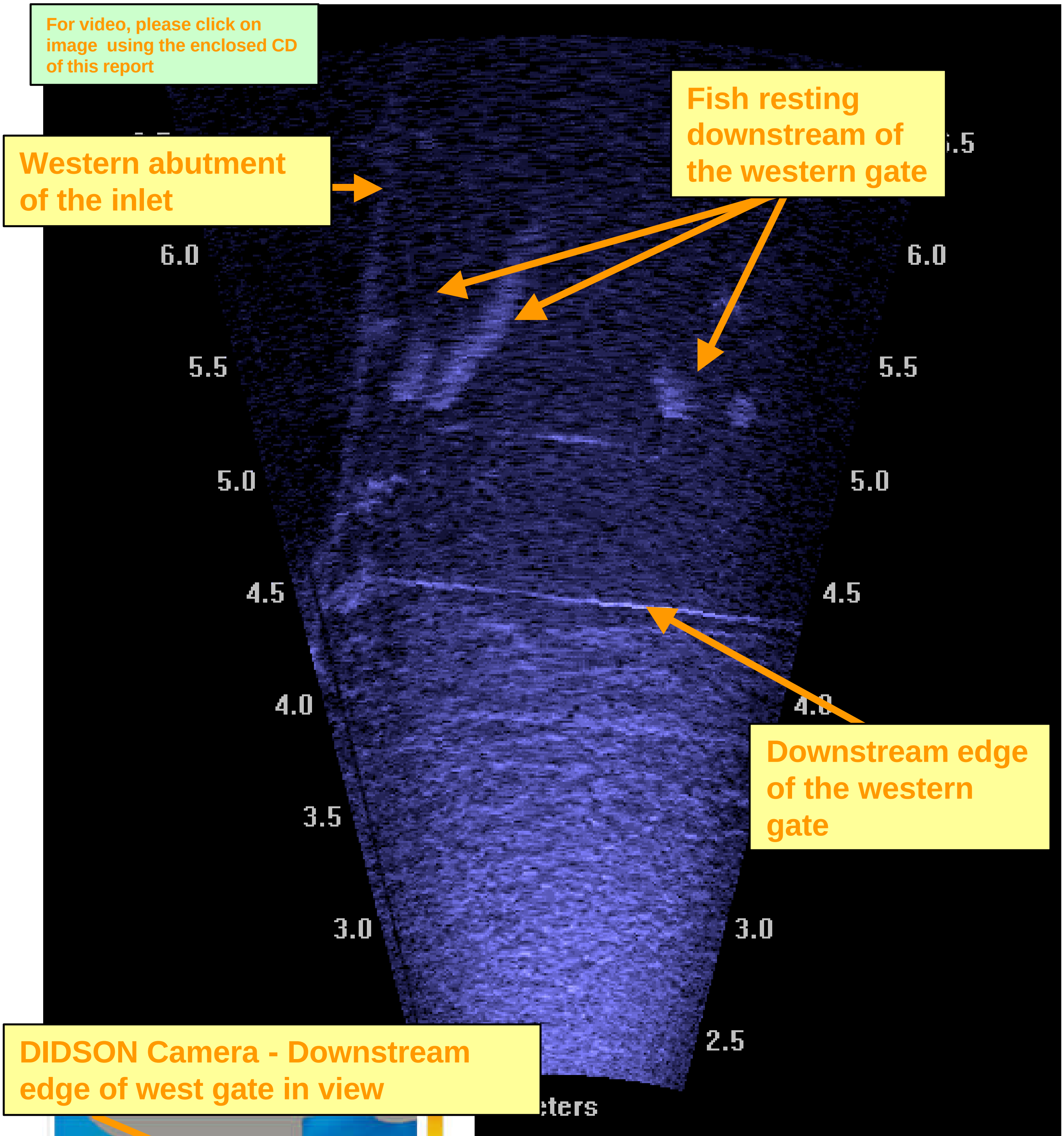


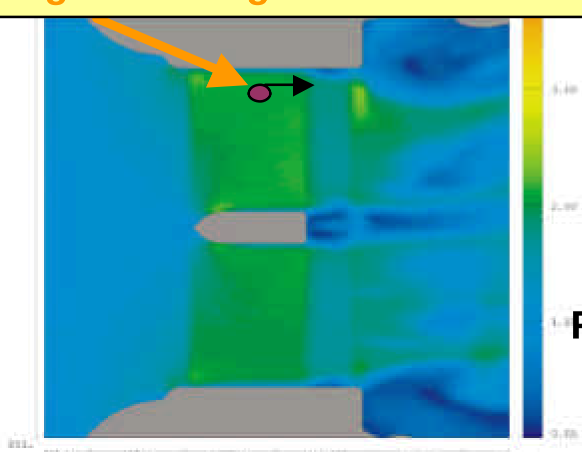


Notes:

- Fish observed moving upstream along the western abutment in the bottom corner

Red River Floodway Inlet Structure
Fish Movement along the West Abutment near the Leading Edge of the Gate
Figure 4-17





Notes:

- Fish observed moving upstream along the western abutment in the bottom corner

Red River Floodway Inlet Control Structure
Fish Movement along the West Abutment near the Downstream Edge of the Gate
Figure 4-18

small and small fish were able to swim upstream past the west gate primarily by schooling in the lower-velocity slipstreams potentially created behind larger fish attempting to travel upstream past the structure. Of the fish that were observed to swim upstream past the east gate, at least six appeared to be Channel Catfish and five appeared to be Northern Pike.

As with the east gate, swimming speed of the fish that traversed successfully past the west gate of the Inlet Control Structure was variable (Appendix E, Table E-2). In cases where fish speed could be described, most of the fish (63% of 1,034 observations) swam at a slow speed (taking more than 10 seconds to traverse past the west gate). Thirty percent swam at a faster speed past the west gate (taking 4 to 10 seconds to traverse past the west gate) with only 2% of fish swimming very fast over the west gate (< 3 seconds). Five percent of the fish observed made several unsuccessful attempts before eventually swimming successfully past the west gate. Of the fish that were swimming at a slow speed over the west gate (n = 653 fish), 57% were medium-sized fish, 38% were small fish and the remaining were large (5%) and very small (0.6%) fish. Of the fish that were swimming at a faster speed over the west gate (n = 309 fish), 56% were small fish, 40% were medium-sized fish and the remaining were very small (2.3%) and large (1.9%) fish.

In images and video where the swimming distances of fish from the west wall of the Inlet Control Structure could be determined with confidence (n = 902 fish), 64% were observed to swim upstream over the west gate at a distance of less than 0.25 m from the west wall of the inlet structure (area of lowest water velocity).

Of the 253 fish that were observed to fail in attempts to swim upstream past the Inlet Control Structure west gate, the majority were medium-sized fish (63%) and small fish (33%).

4.4 FISH SWIMMING CAPABILITIES

The application of the scientific literature regarding fish swimming capabilities to the Inlet Control Structure was complicated by the range of methodologies employed by the various studies. The results of this evaluation are summarized in Appendix A for a range of Red River fish species. The methodological difficulties impaired the application of the review to the Inlet Control Structure.

5.0 DISCUSSION

5.1 INACTIVE OPERATIONS – INLET CONTROL STRUCTURE

The DIDSON acoustic camera based fieldwork provided evidence that was used to support this evaluation of fish passage through the Inlet Control Structure during inactive operation (i.e., gates down). During the relatively high Red River flows (440 m^3/s) experienced during the field program, individuals of both Northern Pike and Channel Catfish were observed to traverse from the downstream to the upstream extents of the Inlet Control Structure. Numerous other fish of a range of size classes and species were also observed to traverse the Structure during the field program. Extrapolating the field program to a standard 24-hour period (i.e. one day) suggests that nearly 5,000 fish are potentially moving upstream through the Structure each day (assuming that after-dark movements were similar to the daytime observed movements).

The field program was conducted during above average flows in the Red River, a period of time in which it was anticipated that fish may have difficulty traversing the Structure due to higher water velocities within the Structure (i.e., the higher spring flows associated with snowmelt). The observation of fish traversing the Structure during this potentially more stressful period suggests that fish are able to traverse the inactive structure all year, therefore the Inlet Control Structure is not anticipated to be a barrier to all fish moving upstream during inactive operations.

While the Structure is not a barrier to all fish movement, the results of the field program do suggest that the Structure may be affecting upstream movement of some fish. The DIDSON evaluation presented in Sections 4.3.1 and 4.3.2 suggests that about half the attempts to traverse upstream through the Structure fail. It is unknown how many of these fish eventually succeed in traversing the Structure after multiple attempts; therefore the magnitude of this effect cannot be quantified. The number of species observed attempting to traverse the Structure can also not be quantified, particularly in the small and medium size classes.

The literature-based evaluation attempted to quantify the species-specific potential effects of the Structure on upstream fish movement. Application of the literature-based values to the Structure was impaired by:

- The range of methodologies outlined by the literature with respect to application to a particular feature, like the Inlet Control Structure, introduced substantial uncertainty with respect to the identification of individual species-specific swimming abilities;
- The DIDSON field program demonstrated the substantive capability of fish to take advantage of microhabitat features in the Structure. The characteristics and detailed velocity profiles associated with these features could not be described, therefore the literature values could not be applied to the site-specific evaluation, and;
- The DIDSON field program demonstrated that some fish species may be taking advantage of inter-species interactions (i.e., small fish following larger fish through the Structure) to traverse the Structure which are not accounted for in the literature dataset.

Considering these variables with respect to the literature-based approach, literature-based information on fish swimming capabilities did not substantively contribute to the quantification of the potential effects of the Inlet Control Structure on upstream fish movement.

In general, the large number and diversity of fish observed traversing from downstream to upstream of the Inlet Control Structure (inactive operations only) suggests that any ecosystem-level effects associated with the Structure are limited in nature. It is therefore unlikely that the Inlet Control Structure during inactive operations is having a substantive eco-system level effect on the overall fish community of the Red River, although individual species-specific effects will be variable.

5.2 ACTIVE OPERATIONS – INLET CONTROL STRUCTURE

While the inactive operation of the Inlet Control Structure is not anticipated to be having a substantial effect on the Red River ecosystem, the evaluation (Section 4.1 and Figure 4-2) supports the assumption that when the gates are up (i.e., active operation) the Structure may be a barrier to the upstream movement of fish (due to peak velocities of over 8 m/s at the gate crest).

Table 4-1 and Figure 4-3 characterize and summarize the active operations of the Inlet Control Structure. The use of the Structure is dominated by the spring and early summer months. The potential ecological effects of the Structure as a barrier to upstream fish movements are therefore anticipated to be dependent primarily upon this seasonal use.

Currently, there is no conclusive evidence that can confirm that any Red River fish species must move upstream past the Inlet Control Structure during a particular season. Spawning activities, which are primarily driven by biophysical factors such as water temperature or photo period, may present a time-sensitive constraint with respect to fish ecology in the area. If it is assumed, for the purpose of this evaluation, that the individual species must migrate to spawning areas, then the species-specific spawning periods can be assumed to represent a period of potentially enhanced ecological effect relating to any movement impairment or blockage. It is also assumed, for the purpose of this evaluation, that those species with fairly narrow spawning windows (i.e., spawning duration of one month vs. three or four months) would also be more affected by any impairment in movement than those with wide spawning windows.

Table 3-1 provides a summary of fish spawning periods anticipated for the fish species present in the Red River. Figure 4-3 summarized the active operations of the Inlet Control Structure when it is assumed to represent a barrier to upstream fish movement. Month by month comparison of this dataset suggests that in:

- March
  - The Structure has been used for three of its 38 years (over the 38-year operational history of the Structure).
    - The Structure is an overall barrier to movement for less than half a day per year on (based on a 38-year average).
  - Only two species are spawning during this time (Burbot are just finishing and Mooneye are just starting to spawn).
- April
  - The Structure has been used for 22 of its 38 years.
    - The Structure is an overall barrier to movement for about seven days per year on (based on a 38-year average).
    - The Structure has been used for up to five years in a row.

  - Six species of fish may be engaged in spawning activities:
    - Yellow Perch, Brook Stickleback and Quillback are just starting multi-month spawning period.
    - Mooneye is in the middle of its three-month spawning period.
    - Northern Pike and Central Mudminnow spawn only during this month.
- May
  - The Structure has been used for 13 of its 38 years.
    - The Structure is a barrier to movement for about six days per year on average.
    - The Structure has been used up to two years in a row.
  - 32 species of fish may be engaged in spawning activities:
    - Seven of these species (Walleye, Sauger, Trout-perch, Golden Redhorse, Bigmouth Buffalo, White Sucker and Creek Chub) have potentially narrow spawning periods of only about a month in duration.
- June
  - The Structure has been used for 4 of its 38 years.
    - The Structure is a barrier to movement for less than one day per year on average.
    - The Structure has only been used more than one year in a row once.
  - 44 species of fish may be engaged in spawning activities:
    - Thirteen of these species (Channel Catfish, Logperch, Walleye, Sauger, Rock Bass, Tadpole Madtom, Silver Redhorse, Bigmouth Buffalo, White Sucker, Creek Chub, Emerald Shiner, Finescale Dace, and Chestnut Lamprey) have potentially narrow spawning periods of about a month.
- July
  - The Structure has only been used once, but it was for a 17-day period.
    - The Structure is a barrier to movement for less than half a day per year on average.
  - 26 species of fish may be engaged in spawning activities:
    - Only the Chestnut Lamprey may be completing a narrow spawning window of about a month.

The evaluation suggests that active operation of the Inlet Control Structure in:

- March – Has had a minor potential for ecological effects (active operation rare, and no species with a narrow spawning window).
- April – Has a minor to moderate potential for ecological effects (frequent active operation, but only two species with narrow spawning windows potentially affected. Repeated sequential use may be particularly harmful on the short-lived Central Mudminnow).
- May – Has the largest potential for ecological effects (frequent active operations, 32 spawning species, seven of which with narrow spawning windows).
- June – Has a minor potential for ecological effects (infrequent active operations, but the largest number of spawning species, including Channel Catfish, 13 of which have narrow spawning windows).

- July – Has a minor potential for ecological effects (infrequent active operations, but has 26 species engaged in spawning activities, but only one with a narrow spawning window). Channel Catfish may also spawn during this month.

This hypothetical assessment assumes that there is a need for the species to move upstream past the Inlet Control Structure to spawn. If upstream migration past the Inlet Control Structure is not required for species to spawn or forage, then the above noted potential effects would not be anticipated to occur.

In general, May is the month with the largest potential historic ecological effects associated with the historic active operations.

Active operations in June, and to a lesser extent July, are not anticipated to have had substantive ecological effects. This result is driven primarily by the rare historic occurrence of active operations in these months. Given the number of spawning species, and in particular those with relatively narrow spawning windows in June, many fish species are likely sensitive to movement disruptions during these months. Any increases to the historic frequency of active operations could result in substantive ecological effects.

6.0 CONCLUSIONS

6.1 ACTIVE OPERATIONS

The Red River Floodway Inlet Control Structure may exert some impairment to the upstream movement of fish in the Red River during active operations.

This impairment is primarily occurring as a result of active operation of the structure, resulting in a barrier to the upstream movement of fish, particularly during the month of May when there is frequent active operations of the Inlet Control Structure. The majority of the potential effects on the fish community are anticipated to result from possible disruptions of upstream movements of up to 32 spawning species during May, of which seven species have narrow spawning windows.

Active operations in the month of June have historically been infrequent, and as a result the potential effects on the Red River fish community are anticipated to be minimal. It is notable that the month of June has the largest number of potentially spawning fish species, and the largest number of fish species engaged in narrow spawning windows. This suggests that the potential ecological effects of an increase in the frequency and/or duration of active operations during the month of June could be higher than any other month and could have substantive potential effects on the Red River fish community. The current infrequent active operations in June have minimized the potential effects on the fish community.

6.2 INACTIVE OPERATIONS

During inactive operation, the Inlet Control Structure is not a barrier to all upstream fish movement, particularly to Channel Catfish and Northern Pike under most flow conditions. Many other small and medium-sized fish are also traversing the Structure, but the range of species in these size classes is unknown. Given the large number of fish anticipated to be moving upstream through the Structure daily (approximately 5,000 fish per day) it is expected that any impairment of species-specific movements during inactive operation is of lesser importance than the barrier effects of active operations discussed above. The DIDSON acoustic camera based field investigations suggest fish are making use of micro-habitat features and inter-species interactions to aid in traversing the structure. It is likely that low water velocity micro-habitat features could be enhanced to improve fish passage during inactive operation of the Inlet Control Structure.

6.3 CONTRIBUTION TO EIS

The information provided in this supplemental document does not alter the conclusion in the Floodway Expansion EIS regarding the effects of the Project on fish. This document provides additional baseline information regarding current and historic fish passage at the Floodway Inlet Structure. Since the Inlet Control Structure will not be fundamentally altered as part of the Project, the noted effects of the Inlet Structure on fish movement were not anticipated to be altered by the Proposed Floodway Expansion.

7.0 REFERENCES

Brown, D. 2004. Memorandum to R. Carson, KGS-Acres-UMA Study Team. Velocities through the Floodway Inelt Control Structure and the Seine River Inverted Siphon. January 20, 2004.

Clarke, R. McV., R.W. Boychuk and D.A. Hodgins. 1980. Fishes of the Red River at Winnipeg, Manitoba. Draft Canadian Technical Report of Fisheries and Aquatic Sciences. Department of Fisheries and Oceans, Western Region. Winnipeg, MB. April 1980.

Decicco, F. 1994. Arctic Char. Alaska Department of Fish and Game. Downloaded from http://www.state.ak.us/local/akpages/FISH.GAME/noteboo on May 02, 2002.

Groeneveld, J. and D. Fuchs. 2004. Memorandum to R. Carson, KGS-Acres-UMA, Floodway Inlet Control Structure Three dimensional Flow Analysis. September 2004.

Hatch, J. 2002. Chestnut lamprey. Minnesota Department of Natural Resources. Downloaded from http://www.gen.umn.edu/faculty_staff/hatch/fishes/chestnut_lamprey.html#reproduction on May 2, 2002

Manitoba Floodway Expansion Authority (MFEA). 2004. Red River Floodway. Proposed Floodway Expansion Project. Environmental Impact Statement. August 2004.

MNS. 2004. Dataset from the Flood Damage Reduction Section Water Science and Management Branch. Manitoba Water Stewardship.

Nelson, J.S and M.J. Paetz 1992. The Fishes of Alberta. University of Alberta Press. Edmonton, Alberta.

New York State Department of Environmental Conservation 1999. Silver chub fact sheet. Downloaded from http://www.dec.state.ny.us/website/dfwmr/wildlife on May 02, 2002.

Ohio Department of Natural Resources unknown. Common Carp. Downloaded from http://www.dnr.state.oh.us/wildlife/resources/aquanotes/pub on May 02, 2002.

Remnant, R., J.B. Eddy, R.L. Bretecher, and S.L. Davies. 2000. Species composition, abundance, and distribution of fish in the Red and Assiniboine Rivers within the City of Winnipeg Ammonia Criteria Study Area, 1999. TM to Tetr*ES* Consultants as a component of Phase 2 Technical Memorandum for Red and Assiniboine Ammonia Criteria Study #FP02. November 2000.

Rook, E.J.S. 1999. Central Mudminnow. Downloaded from http://www.rook.org/earl/bwca/nature/fish/umbra.html on May 6, 2002.

Scott, W.B. and E.J. Crossman. 1985. Freshwater Fishes of Canada. Bulletin 184. Fisheries Research Board of Canada, Ottawa. 1973.

Stewart, K.W. and D.A. Watkinson. 2004. The Freshwater Fishes of Manitoba. University of Manitoba Press, Winnipeg, Manitoba. 275 pp.

Tetr*ES* Consultants Inc. 2002. Red and Assiniboine Criteria Study – Final Technical Report. Report to the City of Winnipeg, Water and Waste Department. November 2002. Winnipeg.

Water Survey of Canada. 2001. HYDAT 2001, National Data Archive.

APPENDIX A

APPLICATION OF FISH SWIMMING CAPABILITY LITERATURE TO THE INLET CONTROL STRUCTURE

TABLE OF CONTENTS

LIST OF ATTACHMENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS AND ABBREVIATIONS

BCF: body and caudal fin propulsion; refers to one (1) the two (2) main groups of swimming modes of fishes.
MPF: median and/or paired pectoral fin propulsion.
BL/s: body length per second.
m/s: metres/second.

GLOSSARY OF TERMS

Ectothermic: Able to maintain a constant body temperature with an external heat source.

Thunniform mode: Thunniform mode is by far the most efficient locomotion mode evolved in the aquatic environment, where thrust is generated with a lift-based method, allowing high cruising speeds to be maintained for long periods. Significant lateral movements occur only at the caudal fin (producing more than 90% of the thrust) and at the area near the narrow peduncle. The body is very well streamlined, while the caudal fin is stiff and high, with a crescent-moon shape often referred to as lunate. Despite the power of the caudal thrusts, the body shape and mass distribution ensure that the recoil forces are effectively minimized and very little sideslipping is induced. Although the design of thunniform swimmers is optimized for high-speed swimming in calm waters, it is particularly inefficient for other actions such as slow swimming, turning manoeuvres and rapid acceleration from stationary, as well as for turbulent water.

Ostraciiform mode: Ostraciiform locomotion is the only purely oscillatory BCF mode. It is characterized by the pendulum-like oscillation of the (rather stiff) caudal fin, while the body remains essentially rigid. Fish utilizing ostraciiform mode are usually encased in inflexible bodies and often swim at low speeds using MPF propulsion. Caudal oscillations are employed as auxiliary locomotion means to aid in thrust production at higher speeds, to ensure that the body remains adequately rigid, or to aid prey stalking. Despite some superficial similarities with thunniform swimmers, the hydrodynamic adaptations and refinements found in the latter are missing in ostraciiform locomotion, rendering it a generally inefficient swimming method.

Undulatory motions: involve the passage of a wave along the propulsive structure (i.e., body length).

Oscillatory motions: the propulsive structure swivels on its base without exhibiting a wave.

1.0 INTRODUCTION

This evaluation is in support of a description of the current and historic effects potentially associated with the Inlet Control Structure of the Red River Floodway (hereafter the Inlet Control Structure).

1.1 IMPORTANCE OF FISH MIGRATION AND LOCAL MOVEMENTS

Fish migration both up and down stream within lake, river, and stream ecosystems is a necessary component for most fish species to complete their life cycles. In general, downstream movement is a feature of the early life-stages of fish (i.e., fertilized eggs, larvae, yolksac fry and fry), while upstream movement is commonly associated with adult life-stages (Katopodis and Gervais 1991).

Fish migrate in order to complete a number of life cycle requirements such as to spawn, to feed and to seek refuge from predators or hazardous environmental factors (i.e., the complete freeze up of a stream or lake). Timing of these tasks can vary over large periods of time depending on the task to be accomplished. Movements for actions such as spawning[1] and movements in reaction to the onset of seasonal variation, generally occur during the same period of time on a yearly basis, while feeding movement will vary dependant on availability of adequate food sources (Katopodis and Gervais 1991). Spawning behaviour is species-specific but is often associated with a movement upstream (into more sheltered areas to aid in increasing hatch-out success rates) associated with mature adult fish, while feeding and predator avoidance movements occur both upstream and downstream for all ages of fish. Fish movements into over-wintering pools to avoid complete freeze-up are usually triggered by lower flows in rivers and streams (Katopodis and Gervais 1991).

1.2 DESIGN CONSIDERATIONS OF STRUCTURES PLACED WITHIN STREAMS AND RIVERS POSSIBLY AFFECTING FISH MIGRATION AND LOCAL MOVEMENTS

Design consideration must be given to all structures (i.e., culverts, fishways, stream crossings, etc.) placed in rivers and streams that may affect the migration and/or local movement of fish in order *"to allow free and unobstructed fish passage through stream crossings so that fish may migrate to spawning, rearing, feeding, over-wintering, or other important areas without harmful delay"* (Manitoba Natural Resources and Fisheries and Oceans 1996). Migration blockage, sedimentation, removal of vegetation and the addition of deleterious substances to the watercourse have been identified by Manitoba Conservation (formerly Manitoba Natural Resources) and Fisheries and Oceans (1996) as sources of concern and are considered here. With regard to culverts, increased water velocities at the outlet, inlet and through the length of the culverts may form barriers to fish migration and/ or local movements if velocities exceed fish swimming performance (Katopodis and Gervais 1991). For the health of fish populations, structures must be designed to provide water velocities within the ability of fish to traverse

[1] Spawning migration is dependant on the sexual maturity of the fish and can last from three (3) weeks to four (4) months depending on the species [see Section 3.1 Table 3-1] and environmental conditions such as water temperature.

these structures, and these velocities must not require so much energy on the part of the fish so as to leave it in a physically weakened state once through the structure.

1.2.1 Migration Blockage and/or Local Movement Hindrance

One of the most common issues associated with structures placed in rivers and streams that may affect the migration and/or local movement of fish is associated with the resultant increased water velocities through the structure.

Information obtained from calculated 3-D water velocity profiles (Appendix C) indicate water velocities through the Inlet Control Structure are expected to be higher than those experienced both upstream and downstream of the structure due to the 50% width constriction of the river channel and the raised elevation of the 'down position' gates off the river bottom. The increase in velocity assumed to be experienced through the Inlet Control Structure may hinder the migration and local movement during periods of high flow (i.e., during spring freshet and/or storm events) when the gates are in 'active operations'. The extent to which movements are blocked and/or hindered during periods of 'inactive operations', is uncertain. A review of published and unpublished documentation of fish swimming capabilities was undertaken to support the evaluation of the degree of impairment of fish movement through the Inlet Control Structure that may be occurring and is found in this document.

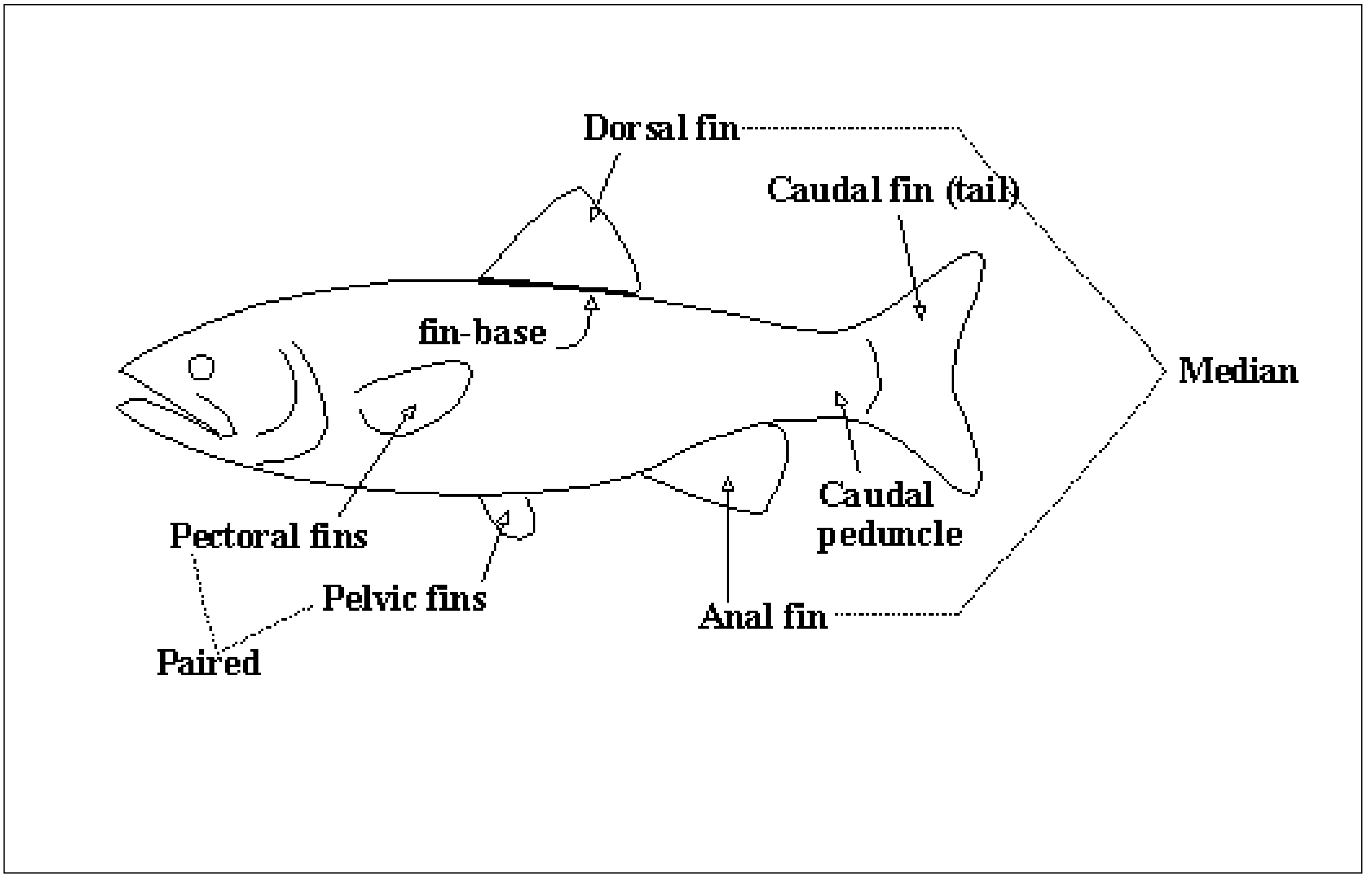
2.0 FISH SWIMMING CAPABILITIES

For the purposes of this document, the Inlet Control Structure is considered analogous to a culvert of length of 30m. Of the approximate 76 species known or expected to reside in the Red River, the swimming capabilities of 28% (21 species) are represented in the public domain of published and unpublished material (see Attachment A, Table A-1). This represents a 56% of the 18 total families of fish known or expected to reside in the Red River.

In order to understand how swimming capabilities of fish pertain to fish migration and/or local movement through the Inlet Control Structure, an understanding of fish locomotion is required. This will provide insight to the reasoning behind why some species and/or life-stages may be able to traverse areas of increased water velocities and why some species and/or life-stages may not be able to. Understanding and interpreting a fish's swimming pattern can lead to a better understanding of the fish's feeding patterns, predatory activities, prey avoidance techniques, breeding styles and overall health, thereby indicating why fish may or may not be required to pass through the Inlet Control Structure.

2.1 PROPULSION AND SWIMMING MODES

Fish traverse the water column by utilizing several techniques generally referred to as swimming modes. Swimming modes are generally divided into two (2) basic groups based on physiological mechanics: body and caudal fin propulsion (BCF) and median and/or paired pectoral fin propulsion (MPF). Figure 2-1



Source: FLAPPS, unknown

Terminology used to identify morphological features of fish, as it is most commonly found in literature
Figure 2-1

outlines the general terminology used to identify morphological features of fish, as it is most commonly found in literature.

BCF propulsion is undulatory in nature. Forward movement is achieved through undulations of the body and caudal fin so that a propulsion wave traverses the fish body in a direction opposite to the overall movement, at a speed greater than the overall swimming speed. It is the main source of thrust for most fish species.

While undulations of the body is the basis for forward propulsion and speed in fish swimming, undulation of median or paired pectoral fins allow fish to achieve more precise control and maneuverability such as both forward and backward movement, rapid reversal of direction without turning, allowing the body axis to remain straight and the ability to hover and "drift" into confined apertures with precision (Lindsey 1978).

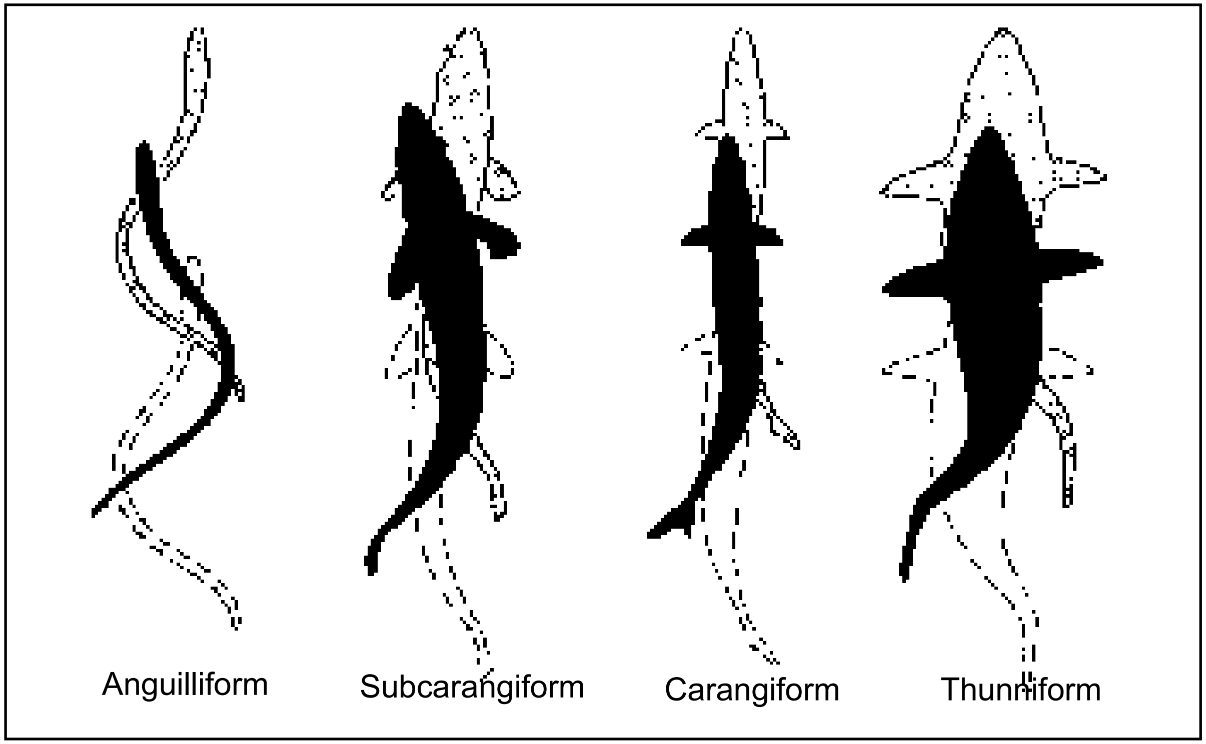
Table 2-1 Description of Swimming Modes

SWIMMING MODE	PROPULSION TYPE	DESCRIPTION	UTILIZED IN RED RIVER
Anguilliform	BCF	using the body plane through undulations; 1 or more wavelengths per body length (eel, lamprey, burbot)	√
Subcarangiform	BCF	between 1/2 and 1 wavelength per body length (Salmonids).	√
Carangiform	BCF	less than 1/2 wavelength per body length.	√
Thunniform	BCF	low drag, highly fusiform, lunate tail (tunas and sailfishes)	
Ostraciform	BCF	Sculling motion of the isocercal caudal fin (Boxfish)	
Rajiform	MPF – undulations	Horizontal undulations of large pectoral fins (rays and skates)	
Amiiform	MPF – undulations	Vertical undulations of the dorsal fin (bowfin, seahorses, and pipefish)	
Gymnotiform	MPF – undulations	Vertical undulations of anal fin (knifefish)	
Diodontiform	MPF – undulations		√
Balistiform	MPF – undulations	Simultaneous vertical or horizontal undulations of dorsal and anal fins (triggerfish, halibut, and some cichlids)	
Labriform	MPF – oscillations	Thrusting of long pectoral fins in an "oaring motion" (wrasses)	√
Tetraodontiform	MPF - oscillations		

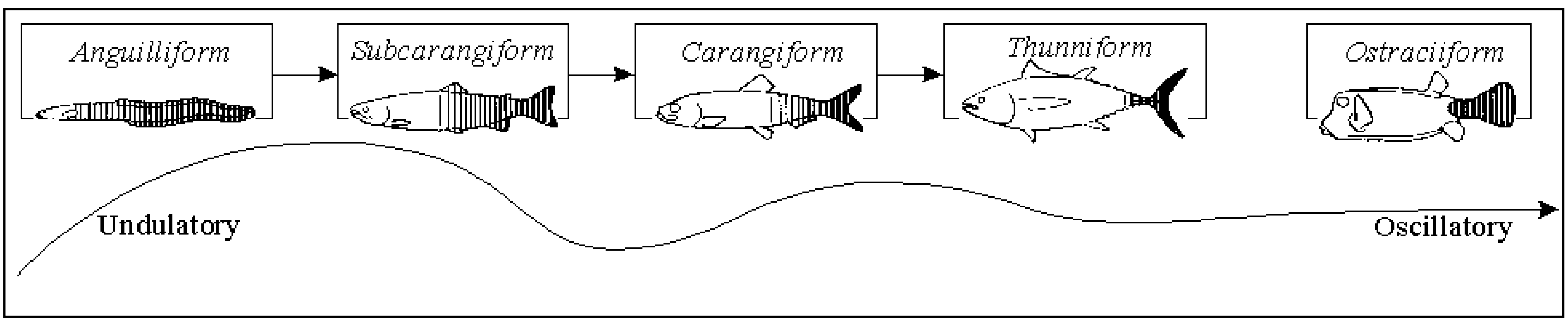
Source: Unknown 2004.

2.1.1 Propulsion by Body and/or Caudal Fin

In general, most fish swim utilizing undulations of their bodies and/or fins to push back against the water in which they live (Lindsey 1978). The different types of propulsive fish movements utilizing contributions of body and fins are classified as ostraciiform, thunniform, carangiform, subcarangiform and anguilliform (see Figure 2-2). Most often in freshwater species, the swimming modes of carangiform, subcarangiform



#1 (Dorsal View)



#2 (Plan View)

Body / Caudal Fin Propulsion Modes
(Based on Lindsey [1978])
Figure 2-2

fishswim
ms\01\0211\09

and anguilliform are seen and will be discussed here. Table 2-2 outlines the swimming modes associated with the families of species known or expected to reside in the Red River. Attachment B, Table B-1 outlines the swimming modes generally associated with species of each family.

Table 2-2 Fish Families of the Red River and Associated Swimming Modes Involving the Body and/or Caudal Fin Propulsion

CARANGIFORM	SUBCARANGIFORM	ANGUILLIFORM
Moronidae	Acipenseridae	Petromyzontidae
Centrarchidae	Hiodontidae	Gadidae
	Cyprinidae	
	Catostomidae	
	Ictaluridae	
	Esocidae Umbridae	
	Osmeridae Salmonidae	
	Percopsidae	
	Fundulidae	
	Gasterosteidae	
	Percidae	

Source: Lindsey 1978 and DFO 1995

2.1.1.1 Anguilliform Mode

Anguilliform is a purely undulatory mode of swimming, in which most or all of the body participates. The side-to-side amplitude of the wave is relatively large along the whole body, and it increases toward the tail. The body is long and thin, while the caudal fin is typically small and rounded, often missing altogether (see Figure 2-2). The inclusion of at least one wavelength of the propulsive wave along the body means that lateral forces are adequately cancelled out, minimizing any tendencies for the body to yaw. In the Red River, typical examples of species exhibiting this common locomotion mode are burbot and lamprey (Lindsey 1978). Most larval forms of species utilize anguilliform swimming mode until adult characteristic become apparent (Lindsey 1978; Attachment B, Table B-1).

2.1.1.2 Subcarangiform Mode

Body movements in subcarangiform swimmers (e.g., trout) are very similar to the anguilliform mode, with the main difference being that the side-to-side amplitude of the undulations is small anteriorly, and expands significantly only in the posterior half or one-third of the body (see Figure 2-2 #2; Lindsey 1978). The body shape of subcarangiform swimmers tends to be heavier and more rounded anteriorly with fairly deep peduncles (Lindsey 1978). The caudal fins tend to be flexible and can 'fan' the caudal rays thereby altering the fin area as much as 10% at different phases of one beat (Bainbridge 1963 in Lindsey 1978). This highly developed caudal fin is likely a response for the requirement for high acceleration, fast turning, and high-speed maneuverability (Webb 1973 in Lindsey 1978). In the Red

River, categories of species exhibiting this type of locomotion include minnows, suckers and darters (see Attachment B, Table B-1).

2.1.1.3 Carangiform Mode

For carangiform swimming, the body undulations are further confined to the last third of the body length, and a rather stiff caudal fin provides thrust (Lindsey 1978). Since less energy is lost in lateral water shedding and vortex formation, efficiency is improved and carangiform swimmers are faster than anguilliform or subcarangiform swimmers. However, their turning and accelerating abilities are compromised, due to the relative rigidity of their bodies and there is an increased tendency for the body to recoil, because the lateral forces are concentrated at the posterior (Lindsey 1978). Lighthill (1969; in Lindsey 1978) identified two main morphological adaptations associated with the minimization of the recoil forces: (i) a reduced depth of the fish body at the point where the caudal fin attaches to the trunk (the *peduncle*) and (ii) the concentration of the body depth and mass towards the anterior part of the fish (Lindsey 1978). In the Red River, categories of species exhibiting this type of locomotion include catfish and sunfish groups (see Attachment B, Table B-1).

2.1.2 Propulsion by Undulation of Median or Pectoral Fins

Undulating and oscillating median and pectoral fins are generally used as auxiliary propulsors, as well as for maneuvering and stability. At low speeds (less than 3 BL/s) median and pectoral fins can be used as the sole source of locomotion (Sfakiotakis *et al.* 1999). Their versatility in structure (varying span and stiffness and two degrees-of-freedom movement ability) allow them to provide fish with the ability to engage movements such as both forward and backward movement, rapid reversal of direction without turning, allowing the body axis to remain straight and the ability to hover and "drift" into confined apertures with precision (Sfakiotakis *et al.* 1999 and Lindsey 1978).

In general, applicable modes of MPF oscillating swimming modes to families found in the Red River include labriform and diodontiform. As the majority of species in the Red River exhibit BCF swimming modes as their primary mode of locomotion (see Attachment B, Table B-1), it is not surprising that species exhibiting undulating MPF swimming modes are not represented in the Red River.

2.1.2.1 Diodontiform

A mainly undulatory mode, diodontiform mode achieved propulsion by passing undulations down broad pectoral fins. Undulations are often combined with flapping movements of the fin as a whole (Sfakiotis *et al.* 1999).

2.1.2.2 Labriform

A mainly oscillary mode, Labriform swimming mode is based on two (2) main types of fin oscillations: drag-based mode and lift-based mode.

2.2 SWIMMING PERFORMANCE OF FISH

Swimming performance of fish, as a characteristic of the relation of swimming speed and endurance time, was classified by Webb (1975) and Beamish (1978) into three (3) categories: *sustained*, *prolonged*, and *burst*. A special category of prolonged swimming speed, the *critical* swimming speed, first employed by Brett (1964) describes a velocity that a fish can maintain for a maximum of 60 minutes before fatiguing. Table 2-3 outlines the variations between the swimming speeds of fish.

Attachment C, Table C-1 outlines the available *critical, burst, prolonged* and *sustained* swimming speeds of fish species known or expected to reside in the Red River. Speeds recorded in body lengths per second (BL/s) were converted into metres/second (m/s) values when fish length data was provided.

Table 2-3 Variations of Swimming Speeds of Fish and Associated Activities

TYPE	DESCRIPTION	ASSOCIATED ACTIVITIES
SUSTAINED	Covers a wide spectrum of swimming activities can be maintained for indefinite periods of time (i.e., > 200 minutes), utilizing energy generated from aerobic metabolic pathways and therefore does not involve fish fatigue.	Used for accomplishing routine activities including foraging, station holding, schooling, exploratory movements and territorial behaviour.
PROLONGED	Comprised of swimming efforts that are characterized by steady swimming with intermittent periods of vigourous efforts during time periods between 20 seconds and 200 minutes – if maintained, will end in fatigue.	Associated with activities of requiring periods of cruising with occasional bursts; critical swimming speeds fall into this category.
BURST	High velocities maintained for less than 20 seconds, utilizing energy generated by anaerobic processes therefore fish fatigues rapidly and may be left in a weakened state.	Utilized sprint and acceleration activities such as prey capture, predator avoidance, and negotiations of areas of rapid currents.
CRITICAL	Special category of prolonged swimming speed determined through set incremental increases during specified duration employed continuously until the individual fails to swim for the entire time interval. Critical swimming speed is calculated as the sum of the penultimate velocity attained and a fraction of the velocity increment proportional to the time spent swimming at the final velocity.	Utilized as a means of comparing ;like to like – based in Jones et al. 1974 and has become the standard in developing guidelines and criteria for maximum water velocities in culverts and fish passage structures.

Source: FLAPS unknown, Katopodis and Gervais 1991 and Webb 1975

Many biological and physical factors influence swimming performance. Swimming performance varies with species, size, time effort is maintained, water temperatures and a number of other parameters. It is species-specific in that body shape, fin form, muscle function and swimming mode that determine a fish's ability to maintain a high swimming performance (Wolter and Arlinghaus 2003). Other factors affecting swimming performance include body size, water temperature and ontogenetic stage of the fish (i.e., swimming performance increases with increased body size and absolute swimming speed increases with fish size and is temperature dependant; Wolter and Arlinghaus 2003).

The effects of other environmental factors such as pH, salinity, oxygen and carbon dioxide, maturity, and photoperiod on swimming performance are also outlined.

2.3 METHODS EMPLOYED TO DETERMINE SWIMMING PERFORMANCE

Of the reviewed literature, two (2) general methods of determining *sustained, prolonged, burst* and *critical* swimming speeds were implemented: direct field measurements and laboratory measurements.

2.3.1 Direct Field Measurements

Direct field measurements (such as employed by Wales 1950) are difficult to quantify, as they do not allow for the identification of specific categories of swimming performance attained by the fish through failure record fish progress for sufficient time periods or provide a measure of fatigue (Beamish 1978).

2.3.2 Laboratory Experiments

The majority of laboratory experiments utilize forced activities to measure swimming performance. Fish (one fish or groups of fish) are generally placed in a flume (swimming chamber) where water is forced past test specimens at pre-determined velocities by pumps, impellers and/or propellers (Beamish 1978). Calculations are employed to correct for the effect of the fish's location within the flume and effects of the fish's body on the current velocity (Jones et al. 1974 and Kolok 1991).

A limitation to the laboratory methods of determining fish swimming speeds is that no procedural uniformity is in place regarding the rate and magnitude of velocity increments. Across studies, stepwise increments vary in both time period that a fish must swim at a given speed and magnitude of the velocity increase (see Atachment C, Table C-1).

2.4 FACTORS POTENTIALLY AFFECTING SWIMMING PERFORMANCE

2.4.1 Temperature

Temperature is an important environmental factor that affects fish physiology and ecology. Within a species thermal tolerance range, swimming performance increases are directly related to increases in temperature to a maximum and then declines (Smiley and Parsons 1997 and Beamish 1978).

Temperature appears to have little influence on burst swimming speed but has an increased influence on sustained and prolonged swimming speeds (Webb 1975).

For example, in walleye, as temperature increases, critical swimming performance increases (Peake *et al.* 2000).

2.4.2 Water Velocities

Simonson (1990) examined the importance of current velocity during smallmouth bass (*Mictopterus dolomieu*) development in the nest and after dispersal from the nest and determined that:

- while in the nest, high velocities may displace young resulting in increased mortality;
- after young-of–the-year have dispersed from the nest, velocity may influence growth and subsequent over-winter survival (growth during the first summer has direct impacts on over-winter survival and ultimately to the strength of year-classes); and
- high stream velocities may increase metabolic costs to young fish and lower foraging activities.

2.4.3 Effect of Body Size on Swimming Performance

Taylor & McPhail (1985) suggested that body form may be a factor in swimming mode and performance. According to the Hydromechanical Theory, deep, robust bodies are considered to yield high burst swimming performance indicating fish may be better at burst swimming while fusiform bodies may reduce swimming drag, indicating fish may be better at prolonged swimming performance.

Webb (1975) determined that levels of swimming are based on locomotion in a primary locomotor mode involving body and caudal fin propulsion. Between each level (see Table 2-1), a transitional zone characterized by extensive variance in swimming behaviour as fish move from one level to another, is observed. Comparison of body length/second is more useful in comparing the performance of fish of different sizes under various conditions.

2.4.4 **Migration Effects on Swimming Performance**

Understanding habitat-specific swim speeds is critical for discerning river reaches that may prove difficult for fish migration. Reaches with relatively high-velocity and turbulent flows may impose large energetic costs on upriver migrants possibly substantially reducing the limited stores of energy available for successful migration and spawning (Hinch and Rand 1998).

Hinch and Rand (1998) found that individual fish and fish sex appeared to be relatively strong contributors to variations on observed swim speeds. Their studies indicated that small males swam harder than large males, implying that small fish were less energetically efficient at migrating. Small males may have less thrust-generating abilities than larger fish or other subtle differences in shape between small and large fish making small fish more readily influenced by drag imposed by downstream currents. Small fish would therefore be required to swim harder in order to arrive at spawning grounds at the same time as larger fish so as not to lose breeding opportunities.

Hinch and Rand's (1998) studies also indicted that fish sex also contributed to variation in swim speeds and energy use per metre. Males swam faster and used more energy than females, thereby indicating that females are more energetically efficient at migrating.

2.4.5 Effects of Photoperiod on Swimming Performance

Kolok (1991) found that largemouth bass (*Micropterus salmoides*) *critical* swimming performance is affected by photoperiod. In water temperatures of 5 and 10 degrees Celsius, *critical* swimming speed, long photoperiods significantly reduced swimming performance while water temperatures of 15, 17 and 19 degrees Celsius tended to be insensitive to changes in photoperiod (Kolok 1991).

2.4.6 Use of *Critical* Swimming Velocities

Measuring endurance over a range of swimming velocities can identify *prolonged, sustained and burst* speeds. *Critical* swimming velocity is a measure of prolonged swimming first described by Brett (1964). It represents the maximum velocity a fish can maintain for a prescribed time period and is represented by the following equation:

$$U_{crit} = V_p + [(V_f - V_p) X (t_F/t_I)]$$

where: V_p= penultimate water velocity (cm/s);
V_f = final water velocity (cm/s);
t_F = time to fatigue at V_f (s); and
t_I = time between velocity increments (s).

Determining of the endurance and *critical* swimming speeds of a species often evaluate endurance, the amount of time a fish can swim at a particular velocity.

Jones *et al.* (1974) conducted research to determine the swimming performance of 17 species found in the Mackenzie River system. Assumptions included a culvert length maximum of 100 metre and a distance travel time period of 10 minutes for fish to maintain in order to traverse the culverts. *Burst* speeds were not considered as it was assumed that the much higher speed would not carry a fish through culverts of that length. *Sustained* speeds were not considered as it was assumed that this speed would be too low for an economically feasible culvert design. *Critical* velocities were determined both in the laboratory and in the field and results were analyzed with respect to body length.

Jones (1973 and 1974) utilized *critical* velocity tests in order to obtain a measure of the maximum ***steady*** swimming performance that fish can maintain for ten minutes. The majority of researchers have utilized this approach in order to compare like against like, however in the case of the Inlet Control

Structure, utilizing critical velocities is biased. As previously stated, the Inlet Control Structure in considered analogous to a culvert 30 metres in length. Results from the DIDSON work performed in the spring of 2004 at the Inlet Structure indicate that species traversing upstream in water velocities of 0.5 m/s do so in 10 metre increments over about one (1) minute. This being the case, it is more likely that fish are utilizing a combination of *burst* and *prolonged* swimming speeds to traverse the Inlet Control Structure.

Species found in the Red River studied by Jones *et al.* (1974) included: northern pike, burbot, yellow walleye, arctic grayling, flathead chub, longnose sucker, white sucker, arctic char, least cisco, emerald shiner, trout-perch, and goldeye (Attachment C, Table C-1).

2.4.6.1 Drawbacks to Utilizing Critical Swimming Speed in Criteria Development

There are a number of drawbacks to utilizing critical swimming velocities for determining fish passage through a structure. Most laboratories studies place test organisms in small plexiglass water tunnels where fish are enclosed and forced to swim at speeds slowly increased in a step-wise progression until the organism becomes fatigued and collapses. The length of the tunnel is limited to approximately twice the length of the test organism preventing it from attaining positive ground speed thereby assuming that the swimming speed is to be considered numerically equivalent to the water speed at any time during the test (Peake 2001).

3.0 APPLICATION OF SWIMMING SPEEDS AND EXPECTED SUCCESS/FAILURE RATES OF SPECIES

Available literature was reviewed and indicated that in order to determine the water velocities that fish can successfully traverse and continue to have a positive ground speed, *critical* swimming velocities must be examined. Water velocities were determined assuming that fish must maintain their *critical* swimming speed for a minimum of 10 minutes in order to traverse through a culvert length of 100 metres (see Appendix C, Table C-1). In the case of the Inlet Control Structure, as previously stated in Section 1, fish passage will be considered successful at the Inlet Control Structure if the fish can maintain positive ground speed (i.e., the speed at which a fish will move relative to the ground as it ascends the structure) for a time period of three (3) minutes through a 'culvert" of length 30 metres[2].

The critical information required to estimate the maximum allowable water velocity for fish passage through structures are:

[2] Time measurements and distances are based on information obtained from the DIDSON Underwater Acoustic Camera field work conducted in spring 2004. Fish were observed traversing the field of view of the DIDSON Camera (4 to 10 metres) within approximately 60 seconds. Extrapolation of this information would indicate that fish will be able to traverse the total length of the Inlet Control Structure (30 metres) within 120 seconds. In the interest of overestimating water velocities that fish will be able to withstand and still pass through the Inlet Control Structure, a distance value of 30 metres and time required of 3 minutes is utilized in all calculations.

- the length of the structure;
- the relationship between the speed at which a fish swims and the maximum time it can maintain that speed before becoming exhausted (i.e., endurance); and
- the amount of time the fish will require to clear the structure (Peake 2001).

The length of fish passage structures can be determined with a high degree of certainty, however, determining the relationship between fish swimming speeds and endurance and determining the time required for a fish to clear a structure contain high degrees uncertainty (Peake 2001). Uncertainty is added in many ways thereby adding uncertainty to results to be utilized in real world applications including:

- the utilization of forced activities, unnatural to fish life-cycles, to measure swimming performance in most laboratory studies;
- the arbitrary assignment of a value for the amount of time required for a fish to pass through a structure; and
- the accuracy of the measurement and recognition of fish fatigue.

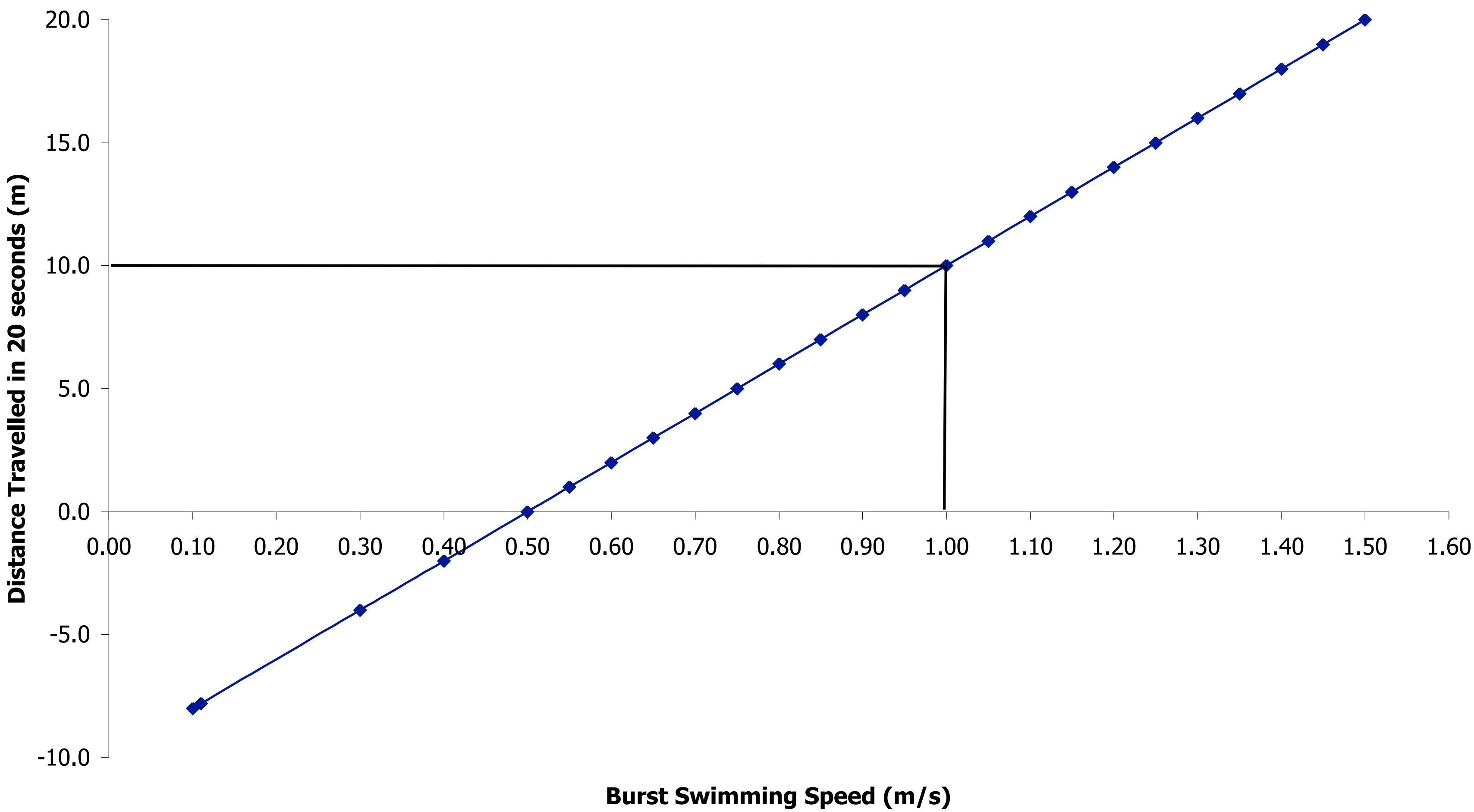
In general, when two time increments were studied in determining *critical* swimming velocities (for example $Ucrit_{10}$ and $Ucrit_{60}$), *critical* swimming velocities of fish are higher in smaller time increments than in larger increments (see Appendix C, Table C-1). *Critical* swimming speeds are based on a maximum of swimming for ten (10) minutes at a certain water velocity before the velocity is increased, so it stands to reason that if a fish is only required to swim at a certain water velocity for three (3) minutes before the velocity is increased, it will take longer for the fish to fatigue and therefore will be able to traverse higher water velocities.

While it is generally accepted that *critical* swimming velocities be utilized in setting fishway and culvert water velocity criteria, recent studies have shown that the assumptions made in determining these velocities are flawed and *critical* speed should not be used to set culvert water velocities (Peake 2004). Therefore *critical* swimming velocities are only supplied for information.

For the purposes of this study (based on DIDSON field observations at the Inlet Control Structure) *burst* and *prolonged* speeds appear to be more appropriate for supporting the analysis of impairment of fish passage through the Inlet Control Structure.

3.1 *BURST* SWIMMING SPEEDS

Figure 3-1 shows the range of *burst* swimming speeds (based on a maximum duration of 20 seconds) maximum water velocities based on the following equation (based on Peake [2000]):



Note: negative travel distances indicate that the fish is not attaining positive ground speed and is in fact being pushed back

Burst Swimming Speeds and Distances Travelled at a Water Velocity of 0.5 m/s
Figure 3-1

Maximum allowable water velocity = *burst* swimming speed – minimum ground speed

where *burst* swimming speed is equal to the and minimum ground speed is calculated as culvert length/time interval. Assumptions for the length and time for successful fish passage through the Inlet Control Structure (as indicated in Section 1.3) indicate that a minimum positive ground speed of 0.017 m/s will be required. In order for fish to successfully pass through the Inlet Control Structure within five (5) minutes, their *prolonged* and/or *burst* swimming velocities can not be less than 0.52 m/s.

3.2 *PROLONGED* SWIMMING SPEEDS

Figure 3-2 shows the *prolonged* swimming speeds (based on a maximum duration of 5 minutes) that fish must maintain at different water velocities in order to be able to pass through the Inlet Control Structure based on water velocities of 0.5 m/s. Culvert lengths are based on the equation provided above with *prolonged* swimming speeds replacing *burst* swimming speeds.

4.0 RESULTS

Estimated fish passage success through the Inlet Control Structure at water velocities of 0.5 m/s are summarized in Attachment C, Table C-1.

5.0 REFERENCES

Bainbridge, R. 1960. Speed and stamina in three fish. Journal of Experimental Biology. 37:129-153.

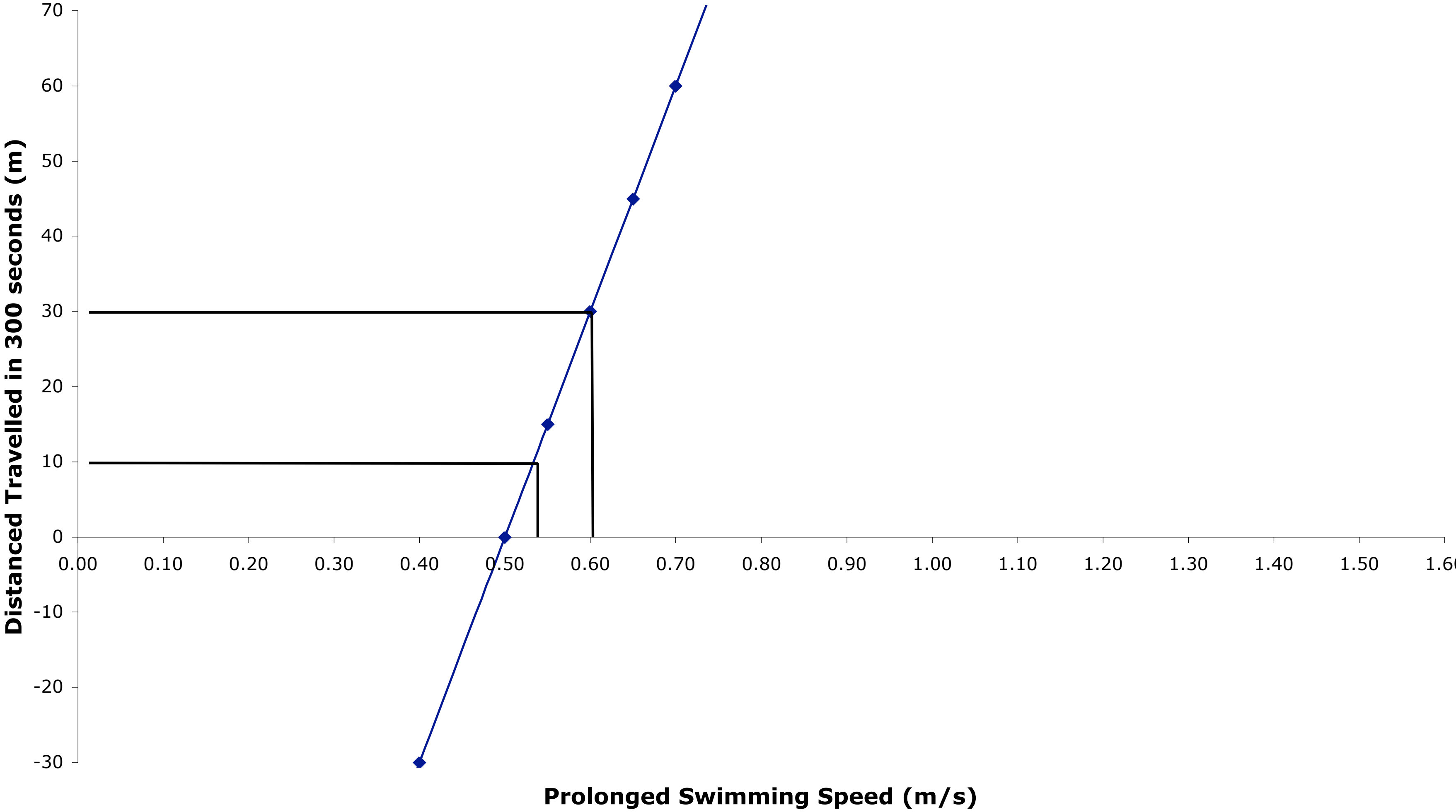
Beamish, F.W.H. 1978. Swimming capacity. Pages 101-187 *in* W.S. Hoar and D.J. Randall, editors. Fish Physiology, Volume 7. Academic Press, New York.

Bernatchez L. and J.J. Dodson. 1985. Influence of temperature and current speed on the swimming capacity of lake whitefish (*Coregonus clupeaformis*) and Cisco (*C. artedii*). Canadian Journal of Fisheries and Aquatic Sciences. 42:1522—1529.

Blundell, Adam 2003. The basics of fish locomotion. Advanced Aquarists On-Line Magazine – An Advanced Aquarist Short Take. Downloaded from http://www.advancedaquarist.com/issues/may2004/short.htm, November 02, 2004.

Brett, J.R. 1964. The respiratory metabolism and swimming performance of young sockeye salmon. Journal of Fisheries Resource Board of Canada. 21:1183-1226.

Department of Fisheries and Oceans (DFO). 1995. Freshwater intake end-of-pipe fish screen guideline. Department of Fisheries and Oceans. Ottawa, Ontario. March 1995.



Note: negative travel distances indicate that the fish is not attaining positive ground speed and is in fact being pushed back

Prolonged Swimming Speeds and Distances Travelled at a Water Velocity of 0.5 m/s
Figure 3-2

Farlinger, S. and F.W.H. Beamish. 1977. Effects of time and velocity increments on the critical swimming speed of largemouth bass (*Micropterus salmoides*). Transactions of the American Fisheries Society. 106(5):436-439.

*Fl*exible *A*ppendage for *P*ositioning and *S*tabilization (FLAPS). Unknown. Body/Caudal Fin Propulsion. FLAPS, Ocena Systems Laboratory, Heriot-Watt University, Edinburgh, Scotland. Downloaded from http://www.ece.eps.hw.ac.uk/Research/oceans/projects/flaps/bcfmodes.htm on March 25, 2004.

Hinch, S.G. and P.S. Rand. 1998. Swim speeds and energy use of upriver-migrating sockeye salmon (*Oncorhynchus nerka*): a role of local environment and fish characteristics. Canadian Journal of Fisheries and Aquatic Sciences. 55:1821-1831.

Jones, D.R., J.W. Kickeniuk, and O.S. Bamford. 1974. Evaluation of the swimming performances of several fish species from the Mackenzie River. Journal of Fisheries Research Board of Canada. 31:1641-1647.

Katopodis, C. and R. Gervais 1991. Ichthyomechanics. Winnipeg, Manitoba: Fisheries & Oceans Canada, Freshwater Institute, 1991. Working document. June 1991.

Kolok, Alan S. 1991. Photoperiod alters the critical swimming speed of juvenile largemouth bass, *Micropterus salmoides*, acclimated to cold water. Copeia. 4:1085-1090.

Manitoba Natural Resources. 1984. Recommended Fish Protection Procedures for Stream Crossings in Manitoba. Fisheries Branch. 1984.

Manitoba Natural Resources and Fisheries and Oceans. 1996. Manitoba Stream Crossing Guidelines for the Protection of Fish and Fish Habitat. May 1996.

Lindsey, C.C. 1978. Form, function and locomotory habits in fish. Pages 1-100 *in* W.S. Hoar and D.J. Randall, editors. Fish Physiology, Volume 7. Academic Press, New York.

Parsons, G.R. and J.L. Sylvestor, Jr. 1992. Swimming efficiency of the white crappie, *Pomoxis annularis*. Copeia. 4:1033-1038.

Peake, Stephan, R.S. McKinley and D.A. Scruton. 2000. Swimming performance of walleye (*Stizostedion vitreum*). Canadian Journal of Zoology. 78:1686-1690.

Peake, Stephan. 2001. Passage efficiency of free-swimming northern p[ike (*Esox lucius*) through culverts: a new approach for establishing fish passage criteria. Report to Manitoba Department of Highways – Bridges and Structures Division. 2001.

Peake, Stephan. 2004. An evaluation of the use of critical swimming speed for determination of culvert water velocity criteria for smallmouth bass. Transactions of the American Fisheries Society. 133:1472-1479.

Richards, F.P., W.W. Reynolds, and R.W. McCauley. 1977. Temperature preference studies in environmental impact assessments: an overview with procedural recommendations. Journal of the Fisheries Research Board of Canada. 34:728-761.

Scruton, D.A., R.S. McKinley, R.K. Booth, S.J. Peake, and G.F. Goosney. 1998. Evaluation of Swimming Capability and potential velocity barrier problems for fish Part A. Swimming performance of Selected

Warm and Cold Water Fish Species Relative to Fish Passage and Fishway Design. CEA Project 9236 G 1014, Montreal, Quebec. xiv + 62pp., 2 appendices.

Sfakiotakis, M., D.M. Lane, and J.B.C. Davies. 1999. Review of fish swimming modes for aquatic locomotion. IEEE Journal of Oceanic Engineering. 24:237-252.

Simmonson, T.D. and W.A. Swenson. 1990. Critical stream velocities of young of the year smallmouth bass in relation to habitat use. Transaction of the American Fisheries Society. 119:902-909.

Smiley Jr., P.C. and G.R. Parsons. 1997. Effects of photoperiod and temperature on swimming performance of white crappie. Transactions of the American Fisheries Society. 126:495-499.

Stewart, K.W. 2004. E-mail communication between Marlene Gifford, Biologist, TetrES Consultants and Dr. K.W. Stewart, Senior Scholar (retired), Department of Zoology, University of Manitoba re: Species and Status of Fishes Found in the Mainstem of the Red River table. December 28, 2003.

Stewart, K.W. and D.A. Watkinson. 2004. The Freshwater Fishes of Manitoba. University of Manitoba Press. Winnipeg, Manitoba. 276pp.

Taylor, E.B. and J.D. McPhail. 1985. Variation in burst and prolonged swimming performance among British Columbia populations of coho salmon, *Oncorhynchus kisutch*. Canadian Journal of Fisheries and Aquatic Sciences. 42:2029-2033.

Wales, J.H. 1950. Swimming speed of the western sucker, *Catostomus occidentalis* Ayres. California Fish and Game. 36:433-434.

Webb, P.W. 1975. Hydrodynamics and energetics of fish propulsion. Bulletin of the Fisheries Research Board of Canada. Bulletin 190.

Wolter, C. and R. Arlinghaus. 2003. Navigation impacts on freshwater fish assemblages: the ecological relevance of swimming performance. Reviews in Fish Biology and Fisheries. 13:63-89.

Unknown. The fishes. Downloaded from http://chamisa.freeshell.org/fish.htm#return1 on November 03, 2004 Cristi Cave, B.S., Fisheries, 1998, School of Fisheries, University of Washington.

Unknown. 2004. Swimming and morphology PowerPoint Presentation downloaded on November 07, 2004 from wfs.sdstate.edu/wls%20714/Lectures/Fish%20Swimming.ppt South Dakota State University, Wildlife and Fisheries Science Department.

ATTACHMENT A

SPECIES LIST TABLES

TABLE A-1
List Of Species Known or Expected to Reside in The Red River and Associated Swimming Performance Literature

SCIENTIFIC NAME	COMMON NAME	SPECIES STATUS		LITERATURE
		KWS[1]	MC[2]	
Ichthyomyzon castanaeus	Chestnut lamprey	N	U	
Ichthyomyzon unicuspis	Silver lamprey	N	U	
Acipenser fluvescens	Lake sturgeon	N, R		
Hiodon alsoides	Goldeye	N	C	
Hiodon tergisus	Mooneye	N	R	
Carassius auratus	Goldfish	I		
Couesius plumbeus	Lake chub	O	U	
Cypinella spiloptera	Spotfin shiner	N		
Cyprinus carpio	Carp	I	C	
Hybognathus hankinsoni	Brassy Minnow	N	U	
Luxilus comutus	Common shiner	N, tributaries	U	
Macrhybopsis storeriana	Silver chub*	N	C	
Margariscus margarita	Pearl dace	N	U	
Nocomis biguttatus	Hornyhead Chub	N, 1 record?	U	
Notemigomus chrysoleucas	Golden shiner	N, R	U	
Notropis atherinoides	Emerald shiner	N	A	
Notropis blennius	River shiner	N	U	
Notropis dorsalis	Bigmouth shiner	N	U	
Notrpois heterodon	Blackchin shiner	O	U	
Notropis heterolepis	Blacknose shiner	O	U	
Notropis hudsonius	Spottail shiner	N	C	
Notropis rubellus	Rosyface shiner	O	U	
Notropis stramineus	Sand shiner	N, tributaries	U	
Notropis volucellus	Mimic shiner	O	U	
Phoxinus eos	Northern redbelly dace	N		
Chrosomus neogaeus	Finescale dace	N		
Pimephales notatus	Bluntnose minnow	N, 1 record	U	
Pimephales promelas	Fathead minnow	N	C	
Plalygobio gracillis	Flathead chub	N, lower	U	
Rhinichthys obtusus	Western blacknose dace	N	U	
Rhinichthys cataractae	Longnose dace	N	U	
Semotilus atronaculatus	Creek chub	N	U	
Carpiodes cyprinus	Quillback	N	U	
Catostomus catostomus	Longnose Sucker	O	C	
Catostomus commersoni	White sucker	N	C	
Ictiobus cyprinellus	Bigmouth buffalo	N	U	
Moxostoma anisurum	Silver redhorse	N	C	
Moxostoma erytrurum	Golden redhorse	N	R	
Moxostoma macrolepidotum	Shorthead redhorse	N	C	
Ameiurus melas	Black bullhead	N	C	
Ameiurus nebulosus	Brown bullhead	N	C	

SCIENTIFIC NAME	COMMON NAME	SPECIES STATUS		LITERATURE
		KWS[1]	MC[2]	
Ictalurus punctatus	Channel catfish	N	C	
Noturus flavus	Stonecat	N	U	
Noturus gyrinnus	Tadpole madtom	N	C	
Esox lucius	Northern pike	N	C	
Umbra limi	Central mudminnow	N	C	
Osmerus mordax	Rainbow smelt	I, 1 record		
Coregonus artedii	Cisco	N, lower	C	
Coregonus clupeaformis	Lake whitefish	N, recent	UC	
Thymallus arcticus	Artic grayling	T		
Oncorhynchus mykiss	Rainbow trout	I		
Salmo trutta	Brown trout	I		
Salvelinus alpinus	Arctic char	I, escapees		
Salvelinus fontinalis	Brook trout	T		
Peropsis omiscomayus	Trout-perch	N	C	
Lota lota	Burbot	N	C	
Fundulus diaphanus	Banded Killfish	N, 1 record	U	
Culaea inconstans	Brook stickleback	N	C	
Pungitius pungitius	Ninespine stickleback	O	C	
Morone chrysops	White bass	I	C	
Ambloplites rupestris	Rock bass	N	C	
Lepomis gibbosus	Pumpkinseed	T		
Lepomis macrochirus	Bluegill	N, tributaries		
Micropterus dolomieu	Smallmouth bass	I, recent		
Micropterus salmoides	Largemouth bass	I		
Pomoxis annularis	White crappie	N, R		
Pomoxis nigromaculatus	Black crappie	N	C	
Etheostoma exile	Iowa darter	N, tributaries	C	
Etheostoma nigrum	Johnny darter	N	C	
Perca flavescens	Yellow perch	N	C	
Perina caprodes	Logperch	N	C	
Percina maculata	Blackside darter	N	U	
Percina shumardi	River darter	N	C	
Stizostedion canadense	Sauger	N	C	
Stizostedion vitreum	Walleye	N	C	
Aplodinotus grunniens	Freshwater drum	N	A	

Source: Stewart and Watkinson 2004, Manitoba Conservation 1992.

Notes:
1 Species status within the Red River according to Stewart and Watkinson 2004.
2 Species status within the Red River according to Manitoba Conservation 1992.
N Native; a species that occurs in that watershed in the absence of any evidence of introduction by humans, or has been known there since before any introductions were made.
I Introduced; a species whose occurrence in that watershed is the result of introduction, or which has dispersed into the watershed from an introduction in an adjacent area.
O Unknown for this watershed.
R Rare.
T Transplanted; a species native to Maniotba that has been transplanted outside its native range in that watershed.

ATTACHMENT B

PROPULSION MODES TABLE

Table B-1
Propulsion Modes of Fish Species Known or Expected to Reside in The Red River

Family	Scientific name	Common name	Body and Caudal Fin Propulsion Mode	Median and/or Paired Fin Propulsion Mode
Petromyzontidae	*Ichthyomyzon castanaeus*	Chestnut lamprey	Anguilliform	
Petromyzontidae	*Ichthyomyzon unicuspis*	Silver lamprey	Anguilliform	
Acipenseridae	*Acipenser fluvescens*	Lake sturgeon	Subcarangiform	
Hiodontidae	*Hiodon alsoides*	Goldeye	Subcarangiform	
Hiodontidae	*Hiodon tergisus*	Mooneye	Subcarangiform	
Cyprinidae	*Carassius auratus*	Goldfish	Subcarangiform	
Cyprinidae	*Couesius plumbeus*	Lake chub	Subcarangiform	
Cyprinidae	*Cypinella spiloptera*	Spotfin shiner	Subcarangiform	
Cyprinidae	*Cyprinus carpio*	Carp	Subcarangiform	
Cyprinidae	*Hybognathus hankinsoni*	Brassy Minnow	Subcarangiform	
Cyprinidae	*Luxilus comutus*	Common shiner	Subcarangiform	
Cyprinidae	*Macrhybopsis storeriana*	Silver chub*	Subcarangiform	
Cyprinidae	*Margariscus margarita*	Pearl dace	Subcarangiform	
Cyprinidae	*Nocomis biguttatus*	Hornyhead Chub	Subcarangiform	
Cyprinidae	*Notemigomus chrysoleucas*	Golden shiner	Subcarangiform	
Cyprinidae	*Notropis atherinoides*	Emerald shiner	Subcarangiform	
Cyprinidae	*Notropis blennius*	River shiner	Subcarangiform	
Cyprinidae	*Notropis dorsalis*	Bigmouth shiner	Subcarangiform	
Cyprinidae	*Notrpois heterodon*	Blackchin shiner	Subcarangiform	
Cyprinidae	*Notropis heterolepis*	Blacknose shiner	Subcarangiform	
Cyprinidae	*Notropis hudsonius*	Spottail shiner	Subcarangiform	
Cyprinidae	*Notropis rubellus*	Rosyface shiner	Subcarangiform	
Cyprinidae	*Notropis stramineus*	Sand shiner	Subcarangiform	
Cyprinidae	*Notropis volucellus*	Mimic shiner	Subcarangiform	
Cyprinidae	*Phoxinus eos*	Northern redbelly dace	Subcarangiform	
Cyprinidae	*Chrosomus neogaeus*	Finescale dace	Subcarangiform	
Cyprinidae	*Pimephales notatus*	Bluntnose minnow	Subcarangiform	
Cyprinidae	*Pimephales promelas*	Fathead minnow	Subcarangiform	
Cyprinidae	*Plalygobio gracillis*	Flathead chub	Subcarangiform	
Cyprinidae	*Rhinichthys atratulus*	Blacknose dace	Subcarangiform	
Cyprinidae	*Rhinichthys cataractae*	Longnose dace	Subcarangiform	
Cyprinidae	*Semotilus atronaculatus*	Creek chub	Subcarangiform	
Catostomidae	*Carpiodes cyprinus*	Quillback	Subcarangiform	
Catostomidae	*Catostomus catostomus*	Longnose Sucker	Subcarangiform	
Catostomidae	*Catostomus commersoni*	White sucker	Subcarangiform	
Catostomidae	*Ictiobus cyprinellus*	Bigmouth buffalo	Subcarangiform	
Catostomidae	*Moxostoma anisurum*	Silver redhorse	Subcarangiform	
Catostomidae	*Moxostoma erytrurum*	Golden redhorse	Subcarangiform	
Catostomidae	*Moxostoma macrolepidotum*	Shorthead redhorse	Subcarangiform	
Ictaluridae	*Ameiurus melas*	Black bullhead	Subcaranigform	
Ictaluridae	*Ameiurus nebulosus*	Brown bullhead	Carangiform	
Ictaluridae	*Ictalurus punctatus*	Channel catfish	Carangiform	
Ictaluridae	*Noturus flavus*	Stonecat	Carangiform	

Family	Scientific name	Common name	Body and Caudal Fin Propulsion Mode	Median and/or Paired Fin Propulsion Mode
Ictaluridae	*Noturus gyrinnus*	Tadpole madtom	Carangiform	
Esocidae	*Esox lucius*	Northern pike	Subcarangiform	
Umbridae	*Umbra limi*	Central mudminnow	Subcarangiform*	Labriform
Osmeridae	*Osmerus mordax*	Rainbow smelt	Subcarangiform	
Salmonidae	*Coregonus artedii*	Cisco	Subcarangiform	
Salmonidae	*Coregonus clupeaformis*	Lake whitefish	Subcarangiform	
Salmonidae	*Thymallus arcticus*	Artic graylling	Subcarangiform	
Salmonidae	*Oncorhynchus mykiss*	Rainbow trout	Subcarangiform	
Salmonidae	*Salmo trutta*	Brown trout	Subcarangiform	
Salmonidae	*Salvelinus alpinus*	Arctic char	Subcarangiform	
Salmonidae	*Salvelinus fontinalis*	Brook trout	Subcarangiform	
Percopsidae	*Peropsis omiscomayus*	Trout-perch	Subcarangiform*	
Gadidae	*Lota lota*	Burbot	Anguilliform	
Fundulidae	*Fundulus diaphanus*	Banded Killfish	Subcarangiform*	
Gasterosteidae	*Culaea inconstans*	Brook stickleback	Subcarangiform*	Labriform
Gasterosteidae	*Pungitius pungitius*	Ninespine stickleback	Subcarangiform*	Labriform
Moronide	*Morone chrysops*	White bass	Subcaranigform	
Centrarchidae	*Ambloplites rupestris*	Rock bass	Carangiform	Labriform
Centrarchidae	*Lepomis gibbosus*	Pumpkinseed	Carangiform	Labriform
Centrarchidae	*Lepomis macrochirus*	Bluegill	Carangiform	Labriform
Centrarchidae	*Micropterus salmoides*	Largemouth bass	Carangiform	Labriform
Centrarchidae	*Pomoxis annularis*	White crappie	Carangiform	Labriform
Centrarchidae	*Pomoxis nigromaculatus*	Black crappie	Carangiform	Labriform
Percidae	*Etheostoma exile*	Iowa darter	Subcaranigform	
Percidae	*Etheostoma nigrum*	Johnny darter	Subcaranigform	
Percidae	*Perca flavescens*	Yellow perch	Subcaranigform	
Percidae	*Percina caprodes*	Logperch	Subcaranigform	
Percidae	*Percina maculata*	Blackside darter	Subcaranigform	
Percidae	*Percina shumardi*	River darter	Subcaranigform	
Percidae	*Stizostedion canadense*	Sauger	Subcaranigform	
Percidae	*Stizostedion vitreum*	Walleye	Subcaranigform	
Sciaenidae	*Aplodinotus grunniens*	Freshwater drum		
SUMMARY				
	Total number of Represented Families	18		
	Total Number of Represented Genus	50		
	Total number of Represented Species	75		

Source: Lindsey 1978, DFO 1995

Note:
It should be noted that early life-stages of fish generally exhibit anguilliform mode even if the adult life-stage exhibits an alternate form.
* - body and caudal fin propulsion determined through body shape and body flexibility towards the tail as no specific references are available.

ATTACHMENT C

FISH SWIMMING PERFORMANCE TABLE

TABLE C-1

FISH SWIMMING PERFORMANCE OF SELECTED SPECIES KNOWN OR SUSPECTED TO RESIDE IN THE RED RIVER

SCIENTIFIC NAME	SPECIES	FLUME TYPE	AGE	FED	TEMP(°C)		D.O. (mg/L)	LENGTH RANGE (cm)	MODEL TARGET BODY LENGTH (m)	SIZE[9]	WEIGHT RANGE (g)	CRITICAL VELOCITY[1,2]					BURST SPEED[4]			PROLONGED SPEED[5]			SUSTAINED SPEED[6]			REFERENCE	AVERAGED VELOCITY CALCULATION REMARKS	REMARKS
					°C	°C (ave)						m/s[8]	bl[3]/s	time incr. (mins)	velocity incr. (m/s)	average[9]	m/sec[8]	bl/s	average[9]	m/sec	bl/s	average[9]	m/sec	bl/s	average[9]			
Acipenser fluvescens	lake sturgeon	laboratory flume			7			< 15	0.15	VS																Scruton, D.A. *et al.* 1998		
Acipenser fluvescens	lake sturgeon	laboratory flume			14			< 15	0.15	VS							0.5			.2			0.10			Scruton, D.A. *et al.* 1998		
Acipenser fluvescens	lake sturgeon	laboratory flume			21			< 15	0.15	VS																Scruton, D.A. *et al.* 1998		
Acipenser fluvescens	lake sturgeon	laboratory flume			7			23 - 55	0.39	S							0.9			0.45			0.24			Scruton, D.A. *et al.* 1998		
Acipenser fluvescens	lake sturgeon	laboratory flume			14			23 - 55	0.39	S							0.9			0.3			0.25			Scruton, D.A. *et al.* 1998		
Acipenser fluvescens	lake sturgeon	laboratory flume			21			23 - 55	0.39	S							0.9						0.40			Scruton, D.A. *et al.* 1998		
Acipenser fluvescens	lake sturgeon	laboratory flume			7			> 100	1.00	L																Scruton, D.A. *et al.* 1998		
Acipenser fluvescens	lake sturgeon	laboratory flume			14			> 100	1.00	L							1.8						0.90			Scruton, D.A. *et al.* 1998		
Acipenser fluvescens	lake sturgeon	laboratory flume			21			> 100	1.00	L																Scruton, D.A. *et al.* 1998		
Acipenser sp.	Sturgeon sp				20																		1.65	1.50	1.65	Malinin *et al.* 1971*		
Acipenser sp.	Sturgeon sp				20																		0.15	0.14	0.15	Malinin *et al.* 1971*		
Acipenser sp.	Sturgeon sp				20																		0.33	0.30	0.33	Malinin *et al.* 1971*		
Hiodon aolsoides	goldeye	closed-circuit respirometer, 0.089 m ID			12			22.5	0.23	S		0.60	2.7	10	0.1	0.60										Jones *et al.* 1974		
Hiodon aolsoides	goldeye	field apparatus outlilned						22.5	0.23	S		0.60		10	0.1	0.60										Jones 1973		
Carassius auratus	goldfish	angular trough			14			6.7 - 21.3	0.14	VS							0.74 - 2.00	9.4 - 11.0	1.37							Bainbridge 1960*		time period = 1 second
Carassius auratus	goldfish	angular trough			14			6.7 - 21.3	0.14	VS							0.42 - 0.80	3.8 - 6.3	0.61							Bainbridge 1960*		time period = 20 seconds
Carassius auratus	goldfish	swimming tunnel			< 10	10		9	0.09	VS							1.38	15.3								Baxter & Dickson 1959*		
Carassius auratus	goldfish				5 - 25	15					4.4									22.4 - 37.4						Fry & Hart 1948*		
Carassius auratus	goldfish				10	10					4.4									29.1						Fry & Hart 1948*		
Carassius auratus	goldfish				5 - 25	15					4.4									22.4 - 40.3						Fry & Hart 1948*		
Carassius auratus	goldfish				20	20					4.4									51						Fry & Hart 1948*		
Carassius auratus	goldfish				15 - 35	25					4.4									28 - 51						Fry & Hart 1948*		
Carassius auratus	goldfish				30	30					4.4									50						Fry & Hart 1948*		
Carassius auratus	goldfish				20 - 38	29					4.4									15.3 - 38.8						Fry & Hart 1948*		
Carassius auratus	goldfish				20	20	0.8 - 1.9	18.2	0.18	S										15 - 85	1.0 - 3.2					Kutty 1968*		
Carassius auratus	goldfish				15 - 30	22.5		15 - 17	0.16	S										60 - 126	3.8 - 8.4					Smit *et al.* 1971*		
Carassius auratus gibelio	goldfish (spp)							23	0.23	S							2.26	9.8								Komarov 1971*		distance covered by 1 tailbeat; time period = < 1 second
Cyprinus carpio	common carp							13.5	0.14	S										170	12.6					Gray 1953**		
Cyprinus carpio	common carp							35.0	0.35	S							2.36	8.2								Komarov 1971*		distance covered by 1 tailbeat; time period = < 1 second
Cyprinus carpio	common carp	angular trough																5.2								Regnard 1893*		
Notropis atherinoides	emerald shiner	closed-circuit respirometer, 0.089 m ID			12			6.5	0.07	VS		0.59	9.1	10	0.1	0.59										Jones *et al.* 1974		fork length and critical velocity are means as sample size was too small for regression analysis
Pimephalus promelas	fathead minnow				15			4.8	0.05	VS										19.6	4.1					McLeod 1967*		
Playlgobio gracillis	flathead chub	closed-circuit respirometer, 0.089 m ID			12 - 19			17 - 30	0.24	S	40 - 300	0.43 - 0.63	2.1 - 2.5	10	0.1	0.53										Jones *et al.* 1974	average Ucrit calculated from averaging data provided	
Catostomus catostomus	longnose sucker	closed-circuit respirometer, 0.089 m ID and field measurements			7 - 19			4 - 53	0.29	S	0.5 - 2200	0.23 - 0.91	1.7 - 5.8	10	0.1	0.57										Jones *et al.* 1974	average Ucrit calculated from averaging data provided	
Catostomus commersoni	white sucker	closed-circuit respirometer, 0.089 m ID			12 - 19			17 - 37	0.27	S	50 - 550	0.48 - 0.73	2.0 - 2.8	10	0.1	0.60										Jones *et al.* 1974	average Ucrit calculated from averaging data provided	
Esox lucius	northern pike							16.5	0.17	VS										210	12.7					Gray 1953**		
Esox lucius	northern pike	closed-circuit respirometer, 0.089 m ID and field measurements			12 (lab)			12 - 62	0.37	S	7 - 1800	0.19 - 0.47	0.8 - 1.6	10	0.1	0.33										Jones *et al.* 1974		
Esox lucius	northern pike							37.8	0.38	S										148	3.9					Magnan 1929**		
Esox lucius	northern pike				.5			80	0.80	L													0.06	0.07		Poddubny et al. 1970*		swimming speed is respresented by calculated mean
Esox lucius	northern pike																3.60 - 4.50		4.05							Stringham 1924*		
Esox sp																	5.90 - 13.70		9.80							Lane 1941*		
Coregonus autumnalis	Arctic cisco	closed-circuit respirometer, 0.089 m ID			12			42.1	0.42	S		0.80	1.9	10	0.1	0.80										Jones et al. 1974		
Coregonus clupeaformis	lake whitefish	closed-circuit respirometer, 0.089 m ID			7 - 19			6 - 51	0.29	S	2 - 1500	0.34 - 0.72	1.4 - 5.7	10	0.1	0.53										Jones *et al.* 1974		
Coregonus clupeaformis	lake whitefish	laboratory			5						364	0.63				0.63										Bernatchez and Dodson 1985		
Coregonus clupeaformis	lake whitefish	laboratory			12						364	0.75				0.75										Bernatchez and Dodson 1985		
Coregonus clupeaformis	lake whitefish	laboratory			17						364	0.67				0.67										Bernatchez and Dodson 1985		
Coregonus sardinella	least cisco	closed-circuit respirometer, 0.089 m ID			12			29.5	0.30	S		0.60	2	10	0.1	0.60										Jones *et al.* 1974		while not a considered a resident of MB (Stewart 2004) has similar body shape (Scott & Crossman 1973) therefore swimming capacity is assumed relavent
Peropsis omiscomayus	trout-perch	closed-circuit respirometer, 0.089 m ID						7.2	0.07	VS	-	0.55		10	0.1	0.55										Jones *et al.* 1974		
Lota lota	burbot	closed-circuit respirometer, 0.089 m ID and field measurements			7 - 12			12 -62	0.37	S	7 - 1100	0.36 - 0.41	0.7 - 3.0	10	0.1	0.39										Jones *et al.* 1974		
Lota lota	burbot							50	0.50	S													0.00			Malinin 1971 *		swimming speed is respresented by calculated mean
Morone chrysops	white bass							26 - 38	0.32	S													0.13	0.4		Hasler *et al.* 1969 *		
Lepomis gibbosus	pumpkinseed				20			12.7	0.13	VS	44.9	0.37	3			0.37										Brett & Sutherland 1965*		
Lepomis macrochirus	blue gill				21		6.5	4.5 - 5.7	0.05	VS	1.9 - 3.7									22.5	4.0 - 5.0					Oseid & Smith 1972*		
Lepomis macrochirus	blue gill				21		6.5	5.1 - 5.4	0.05	VS	2.9 - 3.4									28	5.2 - 5.5					Oseid & Smith 1972*		
Micropterus salmoides	largemouth bass				20			5.7	0.06	VS										18.8 - 30.7						Beamish 1970*		
Micropterus salmoides	largemouth bass				10			15 - 27	0.21	S	45 - 270									24 - 55						Beamish 1970*		
Micropterus salmoides	largemouth bass				15			15 - 27	0.21	S	45 - 270									33 - 58						Beamish 1970*		
Micropterus salmoides	largemouth bass				20			15 - 27	0.21	S	45 - 270									45 - 63						Beamish 1970*		
Micropterus salmoides	largemouth bass				25			15 - 27	0.21	S	45 - 270									47 - 64						Beamish 1970*		
Micropterus salmoides	largemouth bass				30			15 - 27	0.21	S	45 - 270									48 - 66						Beamish 1970*		

SCIENTIFIC NAME	SPECIES	FLUME TYPE	AGE	FED	TEMP(°C)		D.O. (mg/L)	LENGTH RANGE (cm)	MODEL TARGET BODY LENGTH (m)	SIZE[9]	WEIGHT RANGE (g)	CRITICAL VELOCITY[1,2]					BURST SPEED[4]			PROLONGED SPEED[5]			SUSTAINED SPEED[6]			REFERENCE	AVERAGED VELOCITY CALCULATION REMARKS	REMARKS
					°C	°C (ave)						m/s[8]	bl[3]/s	time incr. (mins)	velocity incr. (m/s)	average[9]	m/sec[8]	bl/s	average[9]	m/sec	bl/s	average[9]	m/sec	bl/s	average[9]			
Micropterus salmoides	largemouth bass				34			15 - 27	0.21	S	45 - 270									40 - 60						Beamish 1970*		
Micropterus salmoides	largemouth bass	field	juvenile	Y	5			9.3 - 12.8	0.11	VS		0.24	2.2	20	0.055	0.24										Kolok 1991		ambient light (average fork length was used to determine critical swimming speed in m/s)
Micropterus salmoides	largemouth bass	laboratory	juvenile	Y	5			9.3 - 12.8	0.11	VS		0.24	2.2	20	0.055	0.24										Kolok 1991		testing effect of photo period in cold water - 9 hrs light/15 hrs dark (average fork length was used to determine critical swimming speed in m/s)
Micropterus salmoides	largemouth bass	laboratory	juvenile	Y	5			9.3 - 12.8	0.11	VS		0.17	1.5	20	0.055	0.17										Kolok 1991		testing effect of photo period in cold water - 12 hrs light/12 hrs dark (average fork length was used to determine critical swimming speed in m/s)
Micropterus salmoides	largemouth bass	field	juvenile	Y	10			9.3 - 12.8	0.11	VS		0.32	2.9	20	0.055	0.32										Kolok 1991		ambient light (average fork length was used to determine critical swimming speed in m/s)
Micropterus salmoides	largemouth bass	laboratory	juvenile	Y	10			9.3 - 12.8	0.11	VS		0.31	2.8	20	0.055	0.31										Kolok 1991		testing effect of photo period in cold water - 9 hrs light/15 hrs dark (average fork length was used to determine critical swimming speed in m/s)
Micropterus salmoides	largemouth bass	laboratory	juvenile	Y	10			9.3 - 12.8	0.11	VS		0.25	2.3	20	0.055	0.25										Kolok 1991		testing effect of photo period in cold water - 12 hrs light/12 hrs dark (average fork length was used to determine critical swimming speed in m/s)
Micropterus salmoides	largemouth bass	laboratory	juvenile	Y	15			9.3 - 12.8	0.11	VS		0.39	3.5	20	0.055	0.39										Kolok 1991		testing effect of photo period in cold water - 9 hrs light/15 hrs dark (average fork length was used to determine critical swimming speed in m/s)
Micropterus salmoides	largemouth bass	laboratory	juvenile	Y	15			9.3 - 12.8	0.11	VS		0.64	5.8	20	0.055	0.64										Kolok 1991		testing effect of photo period in cold water - 12 hrs light/12 hrs dark (average fork length was used to determine critical swimming speed in m/s)
Micropterus salmoides	largemouth bass	field	juvenile	Y	17			9.3 - 12.8	0.11	VS		0.39	3.5	20	0.055	0.39										Kolok 1991		ambient light (average fork length was used to determine critical swimming speed in m/s)
Micropterus salmoides	largemouth bass	laboratory	juvenile	Y	19			9.3 - 12.8	0.11	VS		0.39	3.5	20	0.055	0.39										Kolok 1991		testing effect of photo period in cold water - 9 hrs light/15 hrs dark (average fork length was used to determine critical swimming speed in m/s)
Micropterus salmoides	largemouth bass	laboratory	juvenile	Y	19			9.3 - 12.8	0.11	VS		0.42	3.8	20	0.055	0.42										Kolok 1991		testing effect of photo period in cold water - 12 hrs light/12 hrs dark (average fork length was used to determine critical swimming speed in m/s)
Micropterus salmoides	largemouth bass				25		1 - 24	8.0 - 8.5	0.08	VS	4.8 - 6.4									20 - 41						Dahlberg *et al.* 1968*		
Micropterus salmoides	largemouth bass				25		1.2 - 8.1	8.0 - 8.6	0.08	VS	5.6 - 7.4									24 - 43						Dahlberg *et al.* 1968*		
Micropterus salmoides	largemouth bass				25			10.2	0.10	VS		0.46	4.5			0.46										Farlinger & Beamish 1977*		
Micropterus salmoides	largemouth bass				25			10.0	0.10	VS		0.35	3.5			0.35										Farlinger & Beamish 1977*		
Micropterus salmoides	largemouth bass				15 - 35			5.2 - 6.4	0.06	VS		0.31 - 0.50	5.2 - 8.1			0.40										Hocutt 1973*		
Micropterus salmoides	largemouth bass				5 - 20			2.0 - 2.2	0.02	VS										4.8 - 14.6						Larimore & Duever 1968*		
Micropterus salmoides	largemouth bass				5 - 25			2.0 - 2.2	0.02	VS										5.2 - 16.8						Larimore & Duever 1968*		
Micropterus salmoides	largemouth bass				10 - 30			2.0 - 2.2	0.02	VS										7.2 - 23.9						Larimore & Duever 1968*		
Micropterus salmoides	largemouth bass				10 - 30			2.0 - 2.2	0.02	VS										11.1 - 27.0						Larimore & Duever 1968*		
Micropterus salmoides	largemouth bass				10 - 30			2.0 - 2.2	0.02	VS										8.5 - 29.2						Larimore & Duever 1968*		
Micropterus salmoides	largemouth bass				20 - 30			2.0 - 2.2	0.02	VS										17.7 - 31.2						Larimore & Duever 1968*		
Micropterus salmoides	largemouth bass				20			5.7	0.57	VS										18.8 - 30.7						MacLeod 1967*		
Micropterus salmoides	largemouth bass							21.3	0.21	VS										88						Magnan 1929*		
Pomoxis annularis	white crappie	swim tunnel with propeller-driven flow, described by Brett 1964	juvenile		5			6.38 - 8.01	0.07	VS	5.42 - 7.90	0.02 - 0.14		60	0.1	0.08										Smiley & Parsons 1997		range of values for critical swimming speeds signifigantly affected by photoperiod
Pomoxis annularis	white crappie	swim tunnel with propeller-driven flow, described by Brett 1964	juvenile		15			7.04 - 8.1	0.08	VS	5.18 - 8.88	0.12 - 0.18		60	0.1	0.15										Smiley & Parsons 1997		
Pomoxis annularis	white crappie	swim tunnel with propeller-driven flow, described by Brett 1964	juvenile		25			8.05 - 9.58	0.09	VS	9.33 - 17.3	0.098 - 0.25		60	0.1	0.17										Smiley & Parsons 1997		
Pomoxis annularis	white crappie	laboratory flume		Y	25			17	0.17	S	89 - 96	0.26 - 0.45														Parsons and Sylvester 1992		
Perca fluviatilis	yellow perch				13			0.6 - 1.4	0.01	VS										0.6 - 4.6	1.0 - 3.3					Houde 1969**		
Perca fluviatilis	yellow perch				-			11.5	0.12	VS							1.45	12.6								Komarov 1971*		distance covered by 1 tailbeat; time period = < 1 second
Perca fluviatilis	yellow perch				10			9.5	0.10	VS		0.016 - 2.10	1.6 - 2.2													Otto & Rice 1974*		
Perca fluviatilis	yellow perch				10			9.5	0.10	VS		0.16	1.6													Otto & Rice 1974*		
Perca fluviatilis	yellow perch				20			9.5	0.10	VS		0.25 - 0.33	2.7 - 3.5													Otto & Rice 1974*		
Perca fluviatilis	yellow perch				20			9.5	0.10	VS		0.34	3.5													Otto & Rice 1974*		
Stizostedion vitreum	walleye				13			0.7 - 1.5	0.01	VS										0.5 - 5.0	0.7 - 3.3					Houde 1969**		
Stizostedion vitreum	walleye	200L - Blazka respirometer			6			18 - 67	0.43	S		0.38		10	0.1	0.38										Peake *et al.* 2000	Ucrit calculation based on given eqn's & model target body length	
Stizostedion vitreum	walleye	200L - Blazka respirometer			12			19 - 67	0.43	S		0.45		10	0.1	0.45										Peake *et al.* 2000	Ucrit calculation based on given eqn's & average fork length	
Stizostedion vitreum	walleye	200L - Blazka respirometer			20			20 - 67	0.43	S		0.55		10	0.1	0.55										Peake *et al.* 2000	Ucrit calculation based on given eqn's & average fork length	
Stizostedion vitreum	walleye	200L - Blazka respirometer			6			21 - 67	0.43	S		0.32		60	0.1	0.32										Peake *et al.* 2000	Ucrit calculation based on given eqn's & average fork length	
Stizostedion vitreum	walleye	200L - Blazka respirometer			12			22 - 67	0.43	S		0.35		60	0.1	0.35										Peake *et al.* 2000	Ucrit calculation based on given eqn's & average fork length	
Stizostedion vitreum	walleye	200L - Blazka respirometer			20			23 - 67	0.43	S		0.40		60	0.1	0.40										Peake *et al.* 2000	Ucrit calculation based on given eqn's & average fork length	
Stizostedion vitreum	walleye	closed-circuit respirometer, 0.089 m ID and field measurements			19			8 - 38	0.23	S	4 - 500	0.38 - 0.84	2.2 - 4.7	10	0.1	0.61										Jones *et al.* 1974		

Notes:

1 - determined utilizing equation: $V = KL^e$ where V = critical velocity, K = constant, L = body length, e= exponent

2 - culvert of 100m length over a time period of 10 minutes

3 - body length

4 - Burst Speed - very high speed maintained for less than 15 seconds (Manitoba Natural Resources 1984).

5 - Critical Swimming Speed - an operational term use to compare the swimming speeds of differenct fish. It is measured by subjecting fish to stepwise increases in swimming speed until the fish fatigues - the maximum speed achieved before fatigue is the critical swimming speed (Manitoba Natural Resources 1984).

6 - Prolonged Swimming Speed - intermediate level of swimming performance which fish can maintain for periods of 15 s to 20 mins (Manitoba Natural Resources 1984).

7 - Sustained Swimming Speed - range of swimming activities that can be maintained for an indefinite period (i.e., longer than 200 mins; Manitoba Natural Resources 1984)

8 - in instances when velocity is given as bl/sec only, m/s was derived by multiplying bl/sec by average body length

9 - Size classifications: VS = <15 cm; S = 15 - 5- cm, M = 51 - 75 cm, L = >75 cm

* as referenced in Beamish 1978

** as referenced in Manitoba Natural Resources 1984

*** BL per second at which 50% of the fish were fatigued; MINNOW species

APPENDIX B

RED RIVER ACOUSTIC TELEMETRY STUDY – PR0GRESS REPORT – SEPTEMBER/OCTOBER 2004

NORTH/SOUTH CONSULTANTS INC.
RED RIVER ACOUSTIC TELEMETRY STUDY – PROGRESS REPORT
SEPTEMBER/OCTOBER 2004

- From Sept. 14 to Oct. 5, North/South Consultants Inc. biologists surgically implanted 49 acoustic transmitters into three species of fish on the Red River. Transmitters were placed in 34 fish captured just downstream of the floodway inlet gates (in the vicinity of the La Salle River), including: 13 channel catfish; 10 northern pike; and 11 walleye. Transmitters were placed in a total of 15 fish captured upstream of the floodway inlet gates, near the mouth of the Seine River Diversion, including: eight channel catfish; three northern pike; and four walleye.

- A total of eight acoustic receivers were deployed in the Red and Assiniboine rivers to track fish movements. The following table outlines the locations of the receivers:

Number	Location	Date Deployed
1	~2 km downstream St. Adolphe	Sept. 19/2004
2	~500m upstream of floodway inlet gates	Sept. 14/2004
3	~500m downstream of floodway inlet gates	Sept. 14/2004
4	~2 km downstream of floodway inlet gates	Sept. 14/2004
5	~ 2 km up the mouth of the Assiniboine	Sept. 18/2004
6	~3 km upstream from the Lockport Dam	Sept. 18/2004
7	~5 km downstream of the Lockport Dam	Sept. 18/2004
8	End of Main/Netley Marsh area	Sept. 18/2004

- Receivers 1 thru 5 were ‘downloaded’ on Sept 28. A cursory examination of the data indicated that at least five channel catfish moved upstream (through the floodway inlet gates) upstream to St. Adolphe. Another channel catfish moved downstream, and into the Assiniboine River. At least four walleye and three northern pike, tagged just downstream of the floodway inlet gates, moved past receiver 4 (a distance of at least 2 km).
- Red River water levels were drawn down on October 15. All eight receivers were downloaded and repositioned on October 22 and 24. These data have not been reviewed to date.
- All eight receivers will be removed from the river just prior to freeze-up (some time during November). The receivers will be put back in the river once ice conditions become stable (toward the end of December) and downloaded on a monthly basis thereafter.
- The project is proceeding as scheduled and on budget.

APPENDIX C

THE FLOODWAY CONTROL STRUCTURE AND CHANNEL CATFISH

Don Harron

From: "Marlene Gifford" <mgifford@tetres.ca>
To: <dharron@tetres.ca>; <dharron@skyweb.ca>
Sent: Monday, November 08, 2004 2:59 PM
Attach: Liz's 90cm master angler cat July 11 04-2.JPG
Subject: (Fwd) The Floodway Control Structure And Channel Catfish

------- Forwarded message follows -------
Date sent: Wed, 14 Jul 2004 12:59:35 -0500
From: Ken Stewart <kwstewart3@shaw.ca>
Subject: The Floodway Control Structure And Channel Catfish
To: Marlene Gifford <mgifford@tetres.ca>
Send reply to: kwstewart3@shaw.ca

Marlene,

For your info. I went fishing below the St Norbert Red River Floodway Control Structure on July 11 and 13. The control gates were still raised (maybe about a metre). This was not high enough to spill water into the Floodway, so the flow over the gates was a run-of-the-river flow. Probably not surprisingly, there was a large number of channel catfish concentrated in the 200-300m reach of the river downstream of the gates. From returns on my echo sounder, and the catch rate we experienced angling, plus the numbers of fish seen surfacing that could be unequivocally identified as channel catfish, there were at least hundreds, and possibly, thousands of catfish there. Again, judging from the intensity of sounder echoes and fish actually seen (caught and released and breaking the surface) the vast majority were mature adults. The size of the adults measured (about 14 fish) ranged from 75cm to 90 cm. Both males and females were present, and a few of the males were emaciated and very dark coloured, suggesting they were in spawning condition (see attached photo), although I could not express any milt from them. In addition, lesions caused by Columnaris infection were present to varying degrees on most fish we brought to the boat while angling. (Again, see attached photo of the emaciated male, and note lesions on caudal peduncle, the right side of the snout, just behind the posterior nostril, and the anterior surface of the base of the right maxillary barbel). I suspect that it's already too late for successful spawning by most of those fish. If they continue upstream after the control gates are lowered, it will still take time for them to reach known upstream spawning areas (St. Agathe, Aubigny, St Jean Baptiste), and then it will ceratinly be too late. Because of the delay in lowering the control gates, they may no longer be in good enough condition to reach the spawning areas upstream. The 90cm male we caught was notably emaciated already. Even if these fish do spawn, there may not be enough time for the young-of-the-year to get enough reserves to survive the winter. These fish have been holding for a long time in a faster-than-normal flow, and have been losing condition and subject to increasing Columnaris infection as time goes by, how will their survival rate compare with that of unimpeded upstream migrant spawners? The only thing going for them is that they apparently don't stop feeding, so they are taking in at least some energy the whole time. From what we saw, however, I suggest that the food intake is not sufficient to maintain the condition of these fish over the length of time their migration has been blocked. I think the lesson to be drawn from this is that summer operation of the floodway during the mid June-early July period can have a potentially devastating effect on channel catfish spawning upstream of the Red River Floodway Control Structure. Blocking these fish on their upstream migration may result in some or all of: (1) complete loss of reproductive effort in a year, (2) possible loss of young-of-the-year due to subsequent overwinter mortality, should spawning occur, and (3) possible loss of the mature fish which become trapped in the river downstream of the control structure, due to depletion of body reserves, leading to emaciation (despite continued feeding) and Columnaris infection. I should add that tagging studies done by Redmond Clarke (Fisheries and Oceans Canada), Don MacDonald, and Lionel Robert (Manitoba Fisheries Branch) demonstrate that Channel catfish migrate between Lake Winnipeg and the Red River at least as far upstream as Grafton, ND. The fish trapped by the late operation of the floodway constitute a significant portion of the spawning effort of the Lake Winnipeg/Red River channel catfish stock. These fish require ten years to become sexually mature, and live to at least 27 years. Mature fish do not spawn annually. Even a short-term reduction in reproductive effort or survival of mature fish could take decades for the stock to recover from, if recovery was possible. I realize that the Floodway will have to operate if Winnipeg is threatened by high water. I offer the above as a strong argument that there should not be summer operation for the purpose of keeping facilities like the River Walk, the boat docks at The Forks, or boat launch ramps within Winnipeg above water, or maintaining water in the Floodway channel for purposes other than flood control. Provision of fish passage around the Control Structure would have to be thoroughly researched and planned. Modification of the Floodway channel outlet to make the entire channel passable to fish would not work because the Red River between the Floodway and the St Norbert Control Structure would then become a cul de sac that would still trap many or most of the upstream migrants. Avoiding that by making the St Andrews Dam impassable would require that the boat lock be permanently blocked, and would lead to further loss in abundance and diversity fishes in the reach of the river between the St Andrews Dam and Ste Agathe than has already occurred due to the backup of water behind the St Andrews Dam, and the consequent sediment deposition and loss of habitat diversity that has already occurred there.

That would leave the creation of effective fish passage at the St Norbert control structure, which would have to operate at water levels ranging from bankfull and higher flood flows to summer low water levels, if the control structure were to be used during the summer and the effects on fish mitigated. Loss of the fish breeding above the Floodway control structure may be an unrecoverable setback for the Lake Winnipeg/Red River channel catfish stock as a whole, which would result in the loss of one of the two most significant recreational fisheries in Manitoba, and with it, the money brought into the area by resident and tourist anglers. Sorry this rambles so much. It's the first time i've tried to put all of my thoughts on this together. I hope it's useful.

Ken

------- End of forwarded message -------

Marlene Gifford, M. Sc.
Biologist
TetrES Consultants Inc.
603-386 Broadway
Ph. (204)942-2505
fax. (204)942-2548
Winnipeg, Manitoba, Canada
R3C 3R6
mgifford@tetres.ca

APPENDIX D

FLOODWAY INLET CONTROL STRUCTURE THREE-DIMENSIONAL FLOW ANALYSIS

KGS • ACRES • UMA

3rd FLOOR - 865 WAVERLEY STREET
WINNIPEG, MANITOBA R3T 5P4
PH. 896-1209 FAX 896-0754

MEMORANDUM

TO:	**Rick Carson, P.Eng.**
FROM:	**Joe Groeneveld, P.Eng.** **David Fuchs, P. Eng.**
DATE:	**September 23, 2004**
FILE NO:	**15450.00.07** **(03-1100-01.45)**
RE:	**Floodway Inlet Control Structure** **Three Dimensional Flow Analysis**

1 Introduction

During times of high flow on the Red River, velocities through the Floodway Inlet Control Structure increase significantly. If these velocities become too high, they can create a barrier to migrating fish species. To better understand the complexities of flow through the inlet structure, a three dimensional numerical model was set up and utilized to simulate various operating conditions. Initially, the model was set up to replicate a past physical model study test, and to simulate flow conditions experienced and monitored this spring at the structure. The objective of these initial calibration tests was to confirm the model's ability to simulate the complex hydraulic conditions associated with its operation. Following these successful calibration runs, the model was used to simulate flow conditions for a variety of operating scenarios. The objective of these production runs was to identify potential "low flow corridors" downstream of and through the structure, with velocities that are low enough to be traversed by migrating fish. The results of the study are briefly summarized below.

2 Description of FLOW3D Model

The model selected for use in this assignment is the state-of-the-art Computational Fluid Dynamics (CFD) numerical model – FLOW3D. The FLOW3D model is developed and distributed by Flow Science Incorporated out of Sante Fe, New Mexico. This advanced CFD model is capable of simulating the dynamic and steady state behaviour of liquids and gases, in one, two, or three dimensions through a solution of the complete Navier Stokes equations of fluid dynamics. The model is capable of simulating free surface flows, and can handle transitions between subcritical and super critical flow within a single model setup. These capabilities make it well suited for simulating the varied and complex flow conditions that occur through the Floodway Inlet Control Structure.

3 Model Setup

The numerical model developed for this assignment included the full inlet control structure, a 100 m portion of the upstream approach channel, and a 100 m portion of the downstream tailrace channel. Care was taken in selecting the upstream and downstream boundaries of the model to ensure that hydraulic conditions were being reasonably simulated, and that the selected boundaries were far enough away from the structure so as not to unduly influence simulation results.

The geometry for the model was based on data gathered from a number of sources and drawings, including:

- available construction drawings
- the original 1963 physical model study report
- available bathymetric surveys of the tailrace area taken after the 1997 flood event
- available river cross sections

The physical representation of inlet control structure was initially "constructed" within Autocad, and then imported into the numerical model. Figure 1 illustrates a three dimensional image of the structure. The upstream and downstream boundaries for the model were set as a prescribed elevation boundary. Flows through the structure were then automatically calculated by the model based on the prescribed boundaries and the structure geometry

4 Model Verification

Following its set up, the numerical model was used to simulate two flow conditions for which actual data exists on prototype performance. By comparing model results with this actual data, it is possible to verify the model's ability to simulate the relatively complex flow conditions associated with this structure. The two test cases selected include:

- Replication of a past physical model study test performed as a part of the original structure design
- Replication of flow conditions observed this past spring during Tetres' fish monitoring program

3rd FLOOR - 865 WAVERLEY STREET
WINNIPEG, MANITOBA R3T 5P4
PH. 896-1209 FAX 896-0754

Each test is described in more detail below.

4.1 Simulation of Physical Model Study Test

Physical model study tests were undertaken as a part of design studies for the original Floodway Inlet control Structure. These tests were performed by H.G.Acres & Company and the results of these tests are presented in a report entitled "Hydraulic Model Tests of the Submersible Gates and the Inlet Control Structure", March 1963. Of the various tests presented in this report, the test selected for this "verification" case represents operation of the control structure under it's design condition. This was considered to be the most severe test of the program's ability to simulate hydraulic conditions through the structure. Specific conditions associated with this run included:

- Gates are fully raised, to give a gate lip elevation of 762.8 ft (232.5 m).
- Headwater level of El. 778.0 ft (237.15 m)
- Tailwater level of El. 761.2 ft (232.0 m)

The results of the simulation are summarized in Figure 2. This figure provides a longitudinal cross section through one of the bays, showing both the final water surface profile, and anticipated velocity magnitudes.

The calculated discharge for this structure configuration and upstream/downstream water level combination was 56,100 cfs (1590m^3/s). This matches very closely the capacity of 55800 cfs recorded in the original physical model study report, confirming the overall performance of the numerical model.

4.2 Simulation of April 28th, 2004 Flow Conditions

As a second test of the model's ability to replicate prototype flow conditions, it was set up to simulate flow conditions experienced during the passage of the 2004 spring freshet. Near the end of the freshet, ultrasonic equipment had been installed by TetrES Consultants to monitor the movement of fish through the structure. It was found that fish migrating through the structure tended to remain very near to the east and west abutments, implying the existence of low velocity fish corridors near the abutments. Velocities in these corridors were estimated by TetrES to be approximately 0.8-0.9 m/s in magnitude. In addition, it was noted that migrating fish tended to "rest" in a submerged intake water passage entrance located just downstream of the nose of the abutment prior to completing their traverse. This implies that velocities around the nose are locally higher, and that fish tend to "burst" through this locally high velocity area.

3rd FLOOR - 865 WAVERLEY STREET
WINNIPEG, MANITOBA R3T 5P4
PH. 896-1209 FAX 896-0754

The numerical model was set up to replicate these flow conditions. Flows through the structure were adjusted to 15,550 cfs (440 m^3/s), and the tailwater level was set to El. 738.76 ft (225.17m). The gates were assumed to be fully lowered. The results of this simulation are shown in Figures 3 and 4. Figure 3 illustrates a longitudinal cut taken through the center of the west bay, whereas Figure 4 illustrates a plan view of calculated velocities cut along a plane located approximately 1.0 m above the channel invert. As shown, the results closely corroborate the earlier fish movement observations. The results show low velocity zones along both abutment walls that are consistent in velocity magnitude with observations. Also shown in Figure 4 are narrow higher velocity zones located near the nose of the abutments. These higher velocity zones are the likely reason migrating fish tend to rest in the submerged intake of each abutment prior to completing their navigation of the structure.

5 Production Runs

Following the successful verification of the model, it was modified and used to simulate a series of possible operating scenarios. The scenarios to be tested were developed in consultation with MFEA, and deviate slightly from those presented in our original proposal. Scenarios tested are summarized in Table 1. Figures associated with each run are also identified in Table 1.

The results for each of these runs are briefly discussed below.

5.1 Case 1: Moderate Flow – All Gates Lowered

This initial run was set up to help identify possible fish migration corridors during the passage of moderate flood events. For this case, it is assumed that the gates would remain fully lowered, with flows through the structure of approximately 600 m^3/s. Based on an assumed tailwater level of El 226 m downstream of the structure, the upstream level necessary to pass this discharge was calculated by the model to be El. 226.2 m.

Figures 5 to 6 summarize flow conditions for this case. Figure 5 illustrates a longitudinal section view cut through the west bay of the structure. Figure 6 illustrates a plan view of velocity magnitudes, cut through a plain located approximately 1 m above the floor of the structure.

In reviewing these figures, the following observations can be made:

- Velocities in the low flow corridors previously identified along the east and west abutments are approximately 1.1 m/s. This is higher than observed during the fish monitoring operations carried out this spring, a time when river flows were approximately 440 m^3/s, but

Table 1

Three Dimensional Modelling of Floodway Inlet Control Structure

Summary of Operating Scenarios Tested

Run No.	Scenario	Total Discharge (m^3/s)	Headwater Level (m)	Tailwater Level (m)	Objective	Figures
1	Both gates in fully down position	600	226.2	226	To estimate velocities within the water passages to determine whether there may be areas that can be traversed by migrating fish.	5, 6
2	Both gates in fully down position	1000	227.95	227.7	To estimate velocities within the water passages to determine whether there may be areas that can be traversed by migrating fish.	7, 8
3	1 gate fully down 1 gate raised to elv. 224.7 m to provide fish passage capability	1000	228.2	227.7	To assess whether it may be possible to develop an environment in which fish may be able to traverse over the gate during periods when flows are high	9 , 10, 11
4	1 gate fully down 1 gate raised to elv. 226.86 m to provide fish passage capability	1000	228.6	227.7	To assess whether it may be possible to develop an environment in which fish may be able to traverse over the gate during periods when flows are high	12, 13, 14
5	Both gates raised to El 232.3 m at gate tip	1682	237.13	231.7	Estimate water surface profile, discharge, and pressures on upstream skinplate of the gate for comparison with SNC model results - Case R1	15, 16

potentially traversable by migrating fish species.
- Velocities along the nose of each abutment are also relatively high, at 2.2 m/s.
- Velocities through the center of the bay are relatively high, at 2.6 m/s.

5.2 Case 2: High Flow – All Gates Lowered

This second case was run to help evaluate flow conditions through the structure for a slightly higher flow of 1 000 m^3/s. For this case, it is also assumed that the gates would remain fully lowered. Based on an assumed tailwater level of El 227.7 m downstream of the structure, the upstream level necessary to pass this discharge was calculated by the model to be El. 227.95 m.

Figures 7 to 8 summarize flow conditions for this case. Figure 7 illustrates a longitudinal section view cut through the west bay of the structure. Figure 8 illustrates a plan view of velocity magnitudes, cut through a plain located approximately 1 m above the floor of the structure.

In reviewing these figures, it is clear that velocities in the low flow corridors previously identified along the east and west abutments have increased significantly, with magnitudes approaching 1.8 m/s. Velocities along the nose of each abutment are also relatively high, at just over 3.0 m/s. These high velocities will likely preclude fish movement through the structure.

5.3 Case 3: High Flow – One Gate Raised (a)

This run was undertaken to assess whether it would be possible to develop an environment by which fish may be able to more easily traverse through the structure during periods of high flow. This would be done by utilizing an asymmetric operation of the gates – one gate would be completely lowered and the other partially raised to try to limit flows through one side of the structure. For this run, Red River flows were assumed to be 1 000 m^3/s, tailwater levels were set to El. 227.7 m, the east gate was assumed to be fully lowered, and the west gate was raised to give a lip elevation of 224.7 m. The upstream level necessary to pass this discharge was calculated by the model to be El. 228.2 m, giving a 0.5 m loss across the structure.

Figures 9 to 11 summarize flow conditions for this case. Figure 9 illustrates a longitudinal section view cut through the west bay of the structure, while Figure 10 illustrates a similar view through the east bay. Figure 11 illustrates a plan view of velocity magnitudes, cut through a plain located approximately 1 m above the floor of the structure.

In reviewing these figures, the following observations can be made:

- Velocities through the east bay are very high, as the majority of the river flow is forced to pass through this bay of the structure. These velocities approach 3.5 m/s, precluding fish movement through this bay. Velocities along the east abutment of the structure are also relatively high, at 2.2 m/s.
- Velocities through the west bay are relatively low over most of the structure, except for the locally high velocities reached over the gate lip. Velocities as high as 3.4 m/s are reached directly over the elevated lip of the gate. Migrating fish would quite easily be able to navigate to the backside of the gate, but would require a considerable burst speed to overcome the flow stream passing over the gate lip.
- The total drop in head across the elevated gate lip would be approximately 0.5 m. This is considerably higher than the limit of 0.3 m per drop adopted in the design of most standard fish ladders. It is possible that this operation could be made to produce acceptable conditions at a total flow less than 1 000 m^3/s.

5.4 Case 4: High Flow – One Gate Raised (b)

A second run was undertaken to assess whether it would be possible to develop an environment by which fish may be able to more easily traverse over the gate during periods of high flow. For this case, Red River flows were again assumed to be 1 000 m^3/s, tailwater levels were set to El. 227.7 m. The east gate was assumed to be fully lowered, and the west gate was raised to give a lip elevation of 226.86 m, approximately 2.2 m higher than for Case 3 above. The upstream level necessary to pass this discharge was calculated by the model to be El. 228.6 m, giving a total head loss over the structure of 0.9 m.

Figures 12 to 14 summarize flow conditions for this case. Figure 12 illustrates a longitudinal section view cut through the west bay of the structure, while Figure 13 illustrates a similar view through the east bay. Figure 14 illustrates a plan view of velocity magnitudes, cut through a plane located approximately 1 m above the floor of the structure.

In reviewing these figures, the following observations can be made:

- Velocities in the east bay are very high, as the majority of the river flow is forced to pass through this bay of the structure. For this more severe case, flows through the East Bay reach velocities of 4.6 m/s. Velocities in the narrow corridor along the east abutment of the structure are also quite high, at 2.7 m/s.
- As shown in Figure 13, velocities through the west bay are relatively low over most of the structure, but they do reach a high of 3.6 m/s directly over the elevated lip of the gate. This high local velocity may preclude fish movement through the structure.

3rd FLOOR - 865 WAVERLEY STREET
WINNIPEG, MANITOBA R3T 5P4
PH. 896-1209 FAX 896-0754

- The total drop in head across the elevated gate lip would be approximately 0.9 m. Again, this is approximately three times larger than the limit of 0.3 m per drop adopted in the design of most standard fish ladders.

5.5 Case 5: Replication of SNC Physical Model Study Test

As a final test case, the model was also set up to replicate one of the more recent physical model tests undertaken earlier this year at the University of Manitoba laboratory by SNC Lavalin. The objective of this test was to provide verification, or confirmation of the discharge coefficient for the gates under a non-submerged tailwater condition. The test would also provide additional data on the nature of the pressure distribution across the upstream skinplate of the gates. The test originally selected for comparison was test R1 as documented in Section 5.7.5 of the draft SNC report.

It should be noted that although this initial test case does not appear in the final SNC report, the results of a similar test are presented in Table 5-2 of the final report (Test Case 1C). Table 2 below summarizes the comparison between the FLOW3D results for test case R1, the SNC model study test 1C, and the original design condition as tested in the 1963 Acres model study tests.

Table 2
Comparison of Discharge Coefficients

Test	Headwater Level (m)	Gate Lip Elevation (m)	Tailwater Level (m)	Total Discharge/Bay (m^3/s)	Discharge Coefficient C (metric) (Imperial)
FLOW3D	237.13	232.33	231.65	841	2.31 (4.17)
SNC Test 1C	237.41	232.49	232.44	875	2.27 (4.11)
1963 Model Study	237.15	232.49	232.47	790	2.30 (4.16)

As shown, although there are slight variations in the total estimated discharge released by the structure owing to the small differences in headwater level and gate lip elevation, the estimated discharge coefficient for all cases is very similar.

Finally, Figures 15 and 16 summarize the results of the FLOW3D simulation of test case R1.

Figure 15 provides a plot of velocity contours over the gate crest, while Figure 16 provides a plot of pressures over the upstream skin plate for a similar plane. Of particular interest are the relatively high negative pressures evident on the gate immediately at and downstream of the gate lip.

6 Summary

The three dimensional numerical model, FLOW3D, has been set up and used to test various operating strategies for the Floodway Inlet Control Structure during the passage of moderate to high flood events. Model performance was initially verified by comparing the numerical results to available observations and data gathered during earlier physical model study tests. Subsequently the model was used to test various operating strategies associated with the control structure, in a search for “low velocity” corridors that could be utilized by migrating fish species.

An initial review of the results indicates that under lower flows (i.e. 440 m^3/s), distinct low velocity corridors form along the east and west abutments of the structure through which migrating fish can pass. However, other flow conditions tested result in higher velocities that could limit fish migration. For example, at more moderate flows of 600 m^3/s, velocities in these “abutment corridors” rise to approximately 1.1m/s. Given the length of travel for fish at these higher velocities, weaker species may have some difficulty in sustaining a sufficient swimming speed. At a flow of 1 000 m^3/s, these corridor velocities are clearly too high too for fish to negotiate.

Asymmetric operation of the inlet gates was also tested, and found to offer some advantages for migrating fish. By raising one gate, while fully lowering the other, the majority of flow is directed through the lowered bay, and this significantly reduces velocities in the adjacent bay. The resulting flow patterns indicate a large “dead zone” is created immediately downstream of the raised gate, allowing fish to easily migrate to the downstream face of that gate. However, the simulation results also indicate that, at a total flow of 1 000 m^3/s, velocities over the lip of the raised gate would remain relatively high, albeit over a shorter length. Again, weaker species of fish would likely be unable to burst through this locally high velocity at this river flow. The operation may be acceptable at lower flows, and additional runs would be necessary to identify the limit.

In assessing these results, it must also be remembered that they represent only a limited combination of operating strategies, for a small number of flows. Ideally other combinations of flow and gate lip elevation should be considered to identify an optimum operating strategy for fish migration. It is recommended that consideration be given to testing a select number of other operating conditions to assess this potential.

KGS • ACRES • UMA

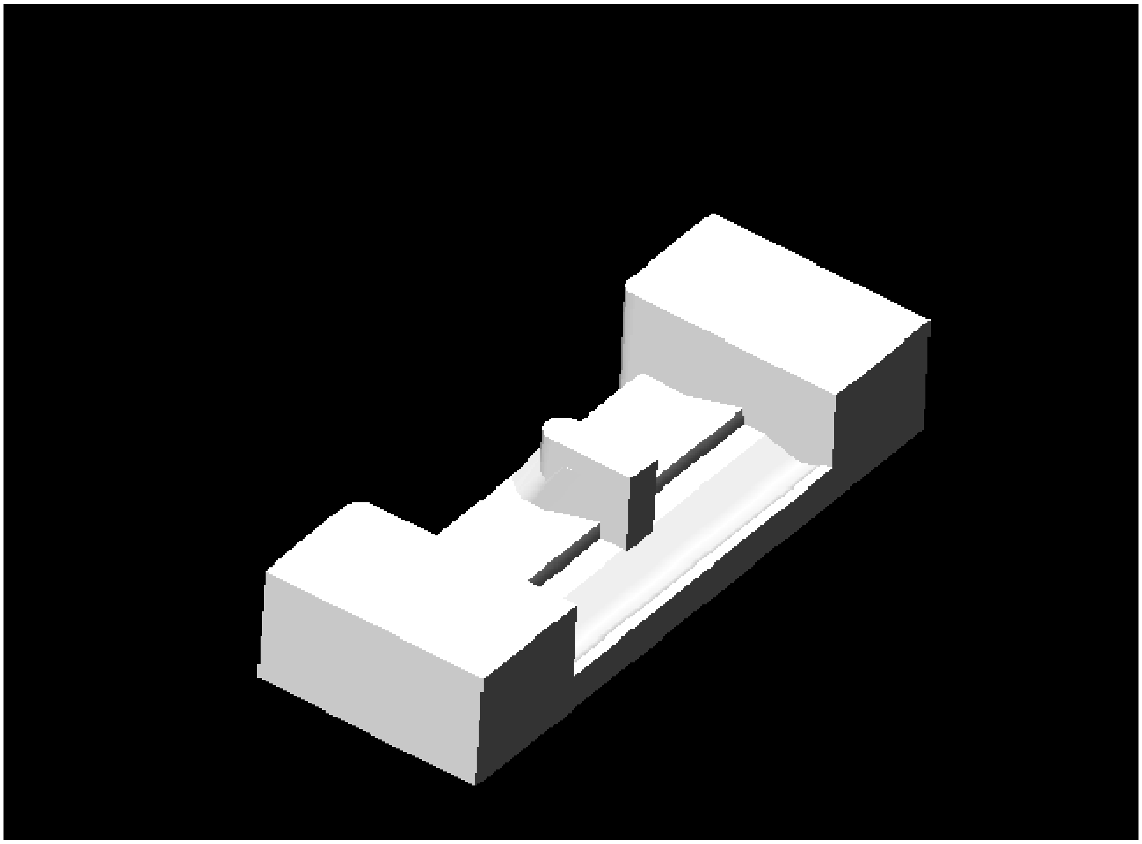
3rd FLOOR - 865 WAVERLEY STREET
WINNIPEG, MANITOBA R3T 5P4
PH. 896-1209 FAX 896-0754

JLG:sep
Attach

Joe Groeneveld, P.Eng.

David Fuchs, P.Eng.

cc. Warren Gendzelevich, Acres



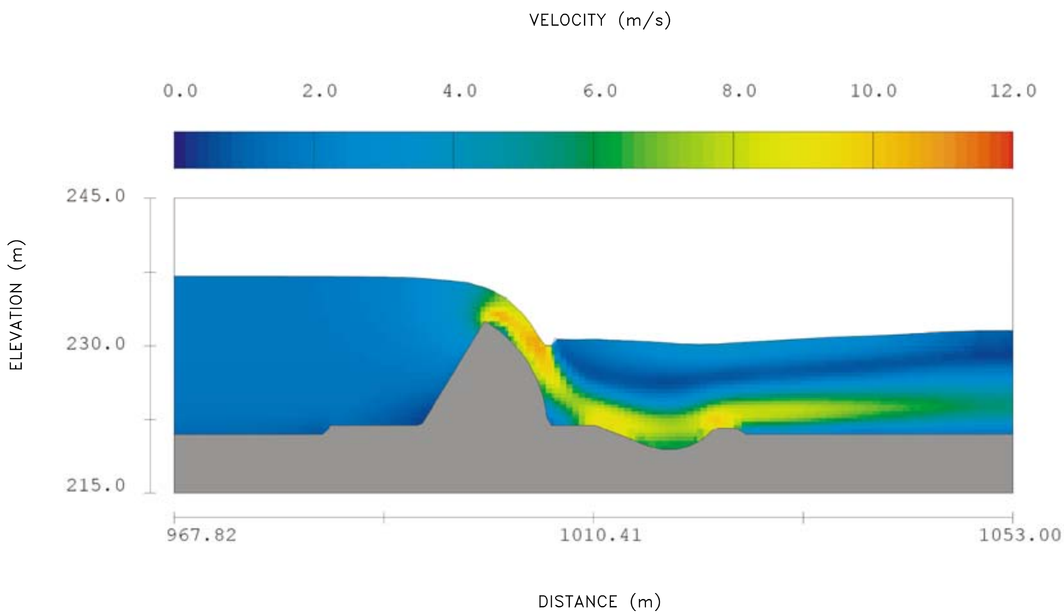
KGS • ACRES • UMA

MANITOBA FLOODWAY
EXPANSION AUTHORITY

FLOODWAY INLET CONTROL STRUCTURE – FLOW ANALYSIS

INLET CONTROL STRUCTURE
IMAGE OF THREE DIMENSIONAL
MODEL

DATE 04-09-02	FIGURE 1
PROJECT NO. 03-1100-01	



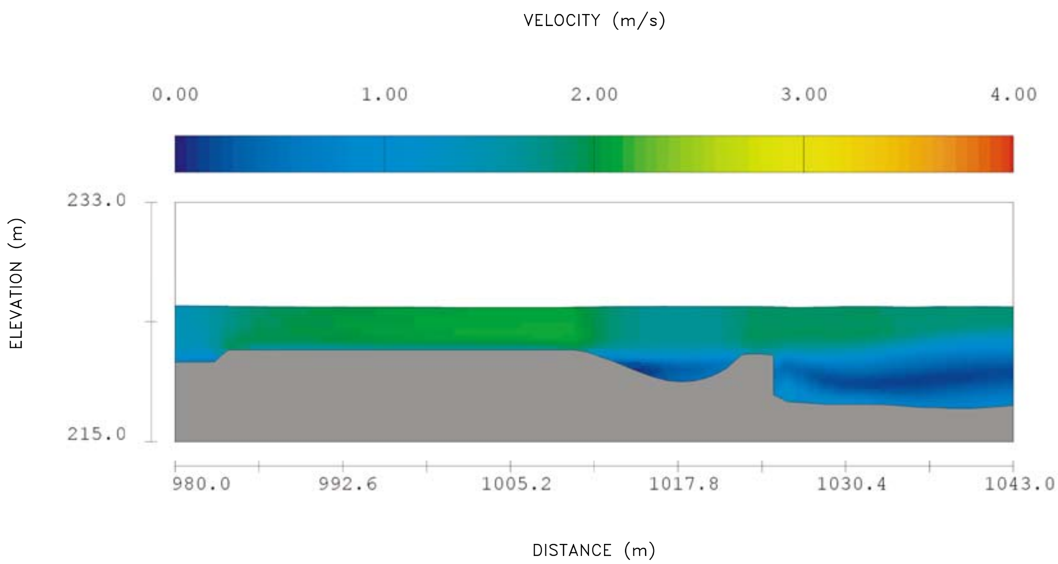
KGS • ACRES • UMA

MANITOBA FLOODWAY
EXPANSION AUTHORITY

FLOODWAY INLET CONTROL STRUCTURE – FLOW ANALYSIS

1963 MODEL STUDY TEST
VELOCITY PROFILE

DATE 04–09–02	FIGURE 2
PROJECT NO. 03–1100–01	



KGS • ACRES • UMA

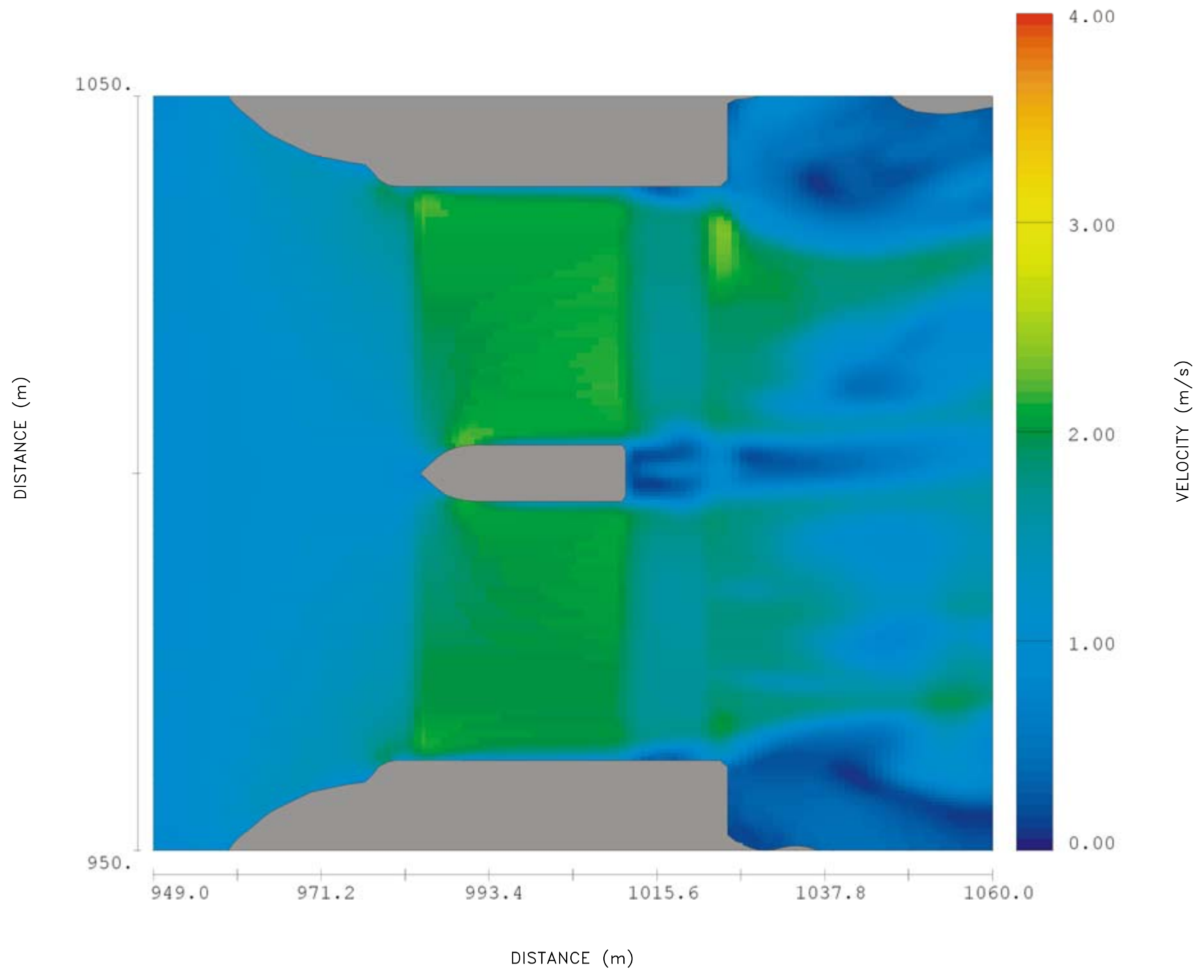
MANITOBA FLOODWAY
EXPANSION AUTHORITY

FLOODWAY INLET CONTROL STRUCTURE – FLOW ANALYSIS

APRIL 28TH FLOW CONDITIONS
VELOCITY PROFILE THROUGH
CENTER OF WEST BAY

DATE 04-09-02
PROJECT NO. 03-1100-01

FIGURE 3



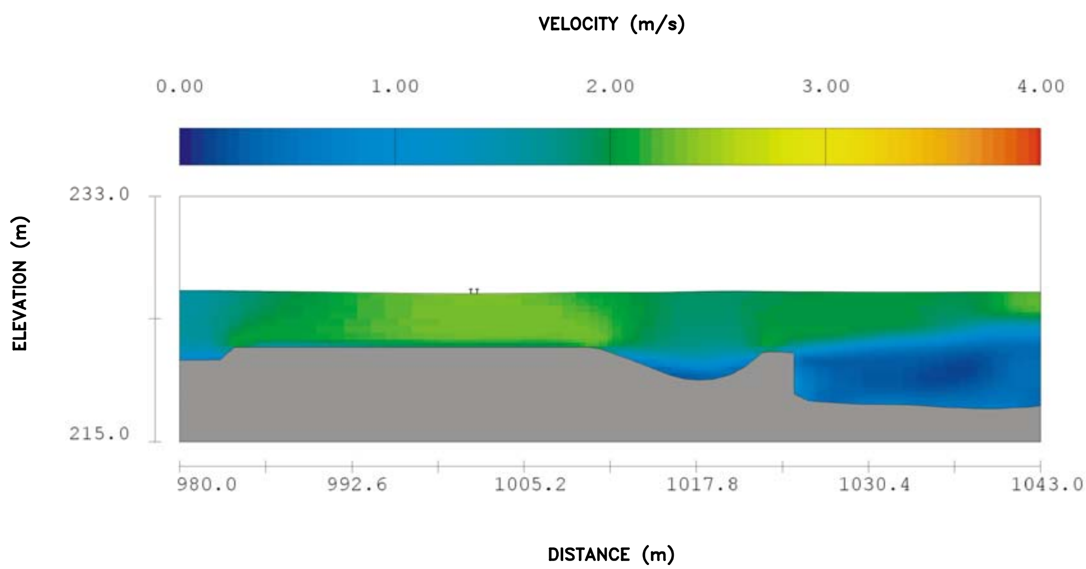
KGS • ACRES • UMA

MANITOBA FLOODWAY
EXPANSION AUTHORITY

FLOODWAY INLET CONTROL STRUCTURE – FLOW ANALYSIS

APRIL 28TH FLOW CONDITIONS
PLAN VIEW OF VELOCITIES

DATE 04-09-02	FIGURE 4
PROJECT NO. 03-1100-01	



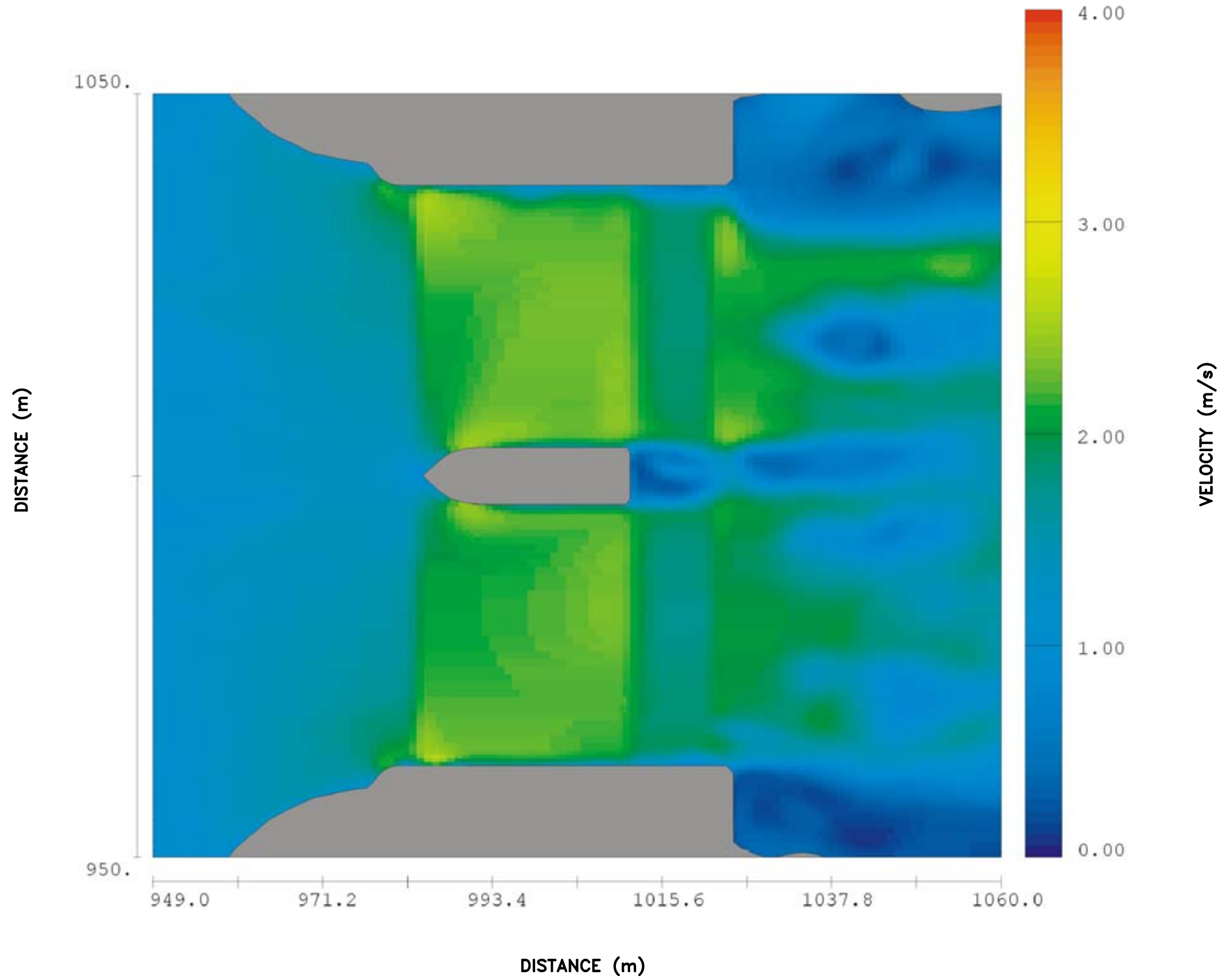
KGS • ACRES • UMA

MANITOBA FLOODWAY
EXPANSION AUTHORITY

FLOODWAY INLET CONTROL STRUCTURE - FLOW ANALYSIS

CASE 1
VELOCITY PROFILE THROUGH
CENTER OF WEST BAY
Q=600 m^3/s

DATE 04-09-22	FIGURE 5
PROJECT NO. 03-1100-01	



KGS • ACRES • UMA

MANITOBA FLOODWAY
EXPANSION AUTHORITY

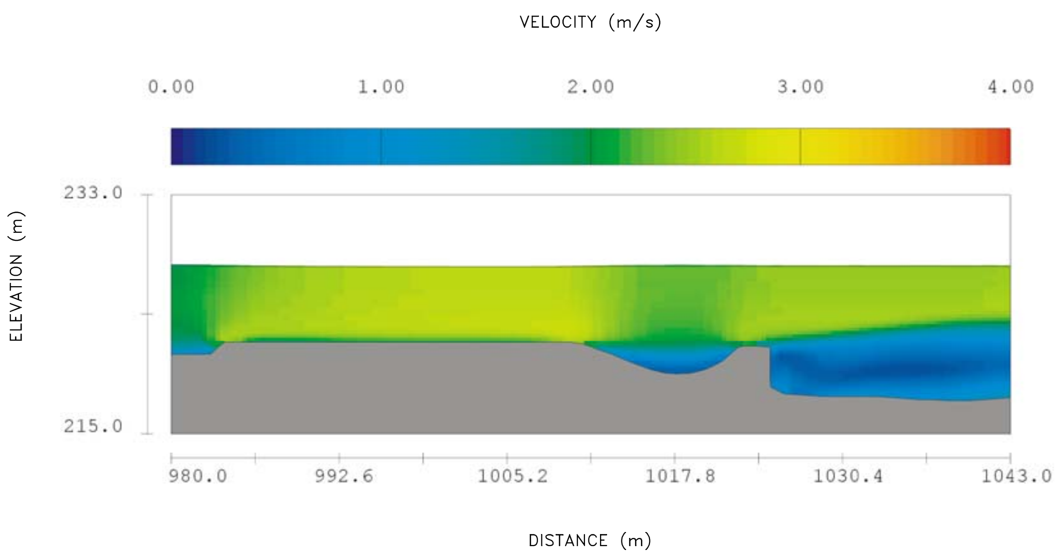
FLOODWAY INLET CONTROL STRUCTURE - FLOW ANALYSIS

CASE 1
PLAN VIEW OF VELOCITIES
Q=600 m^3/s

DATE 04-09-22

PROJECT NO. 03-1100-01

FIGURE 6



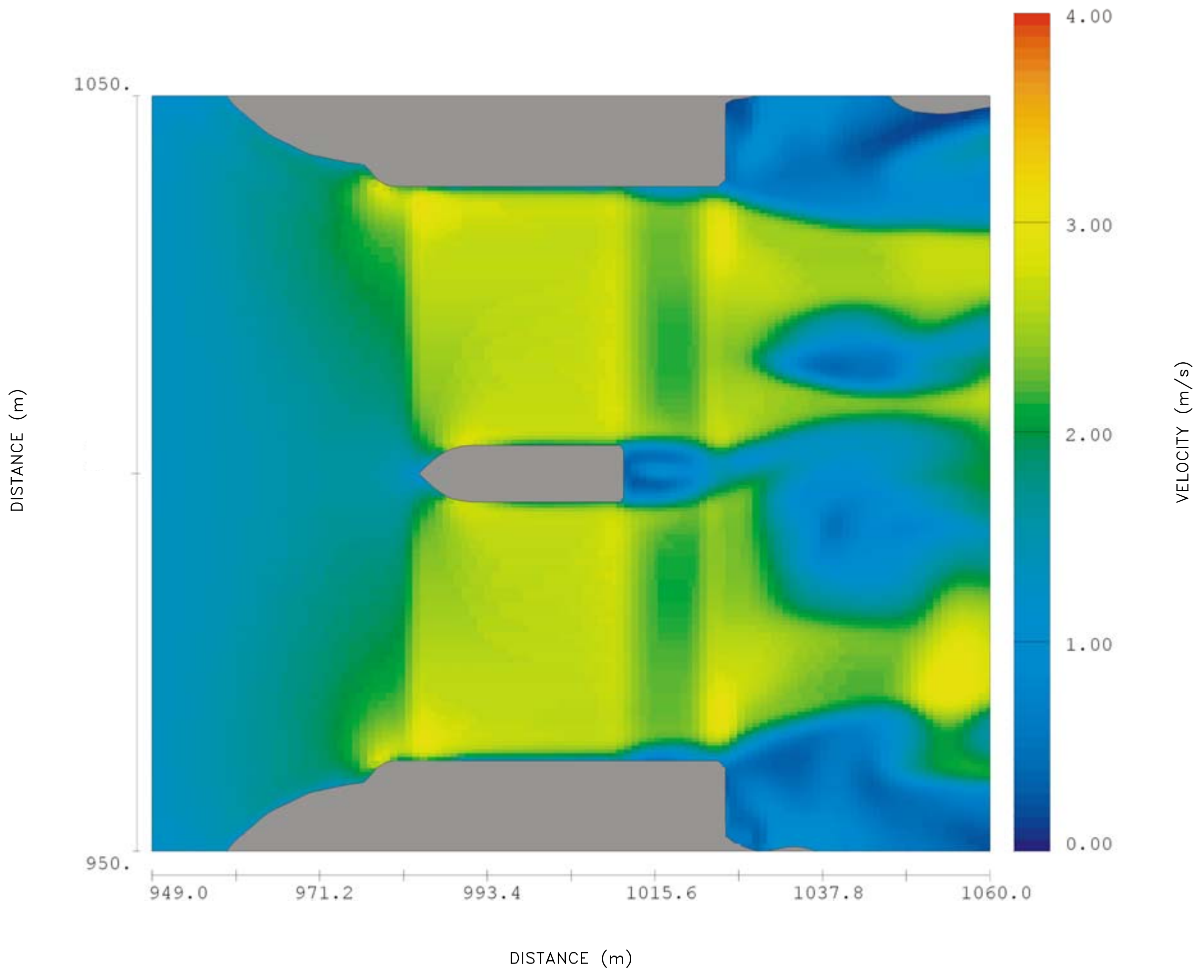
KGS • ACRES • UMA

MANITOBA FLOODWAY EXPANSION AUTHORITY

FLOODWAY INLET CONTROL STRUCTURE – FLOW ANALYSIS

CASE 2
VELOCITY PROFILE THROUGH CENTER OF WEST BAY
$Q=1000\ m^3/s$

DATE 04-09-02	FIGURE 7
PROJECT NO. 03-1100-01	



KGS • ACRES • UMA

MANITOBA FLOODWAY
EXPANSION AUTHORITY

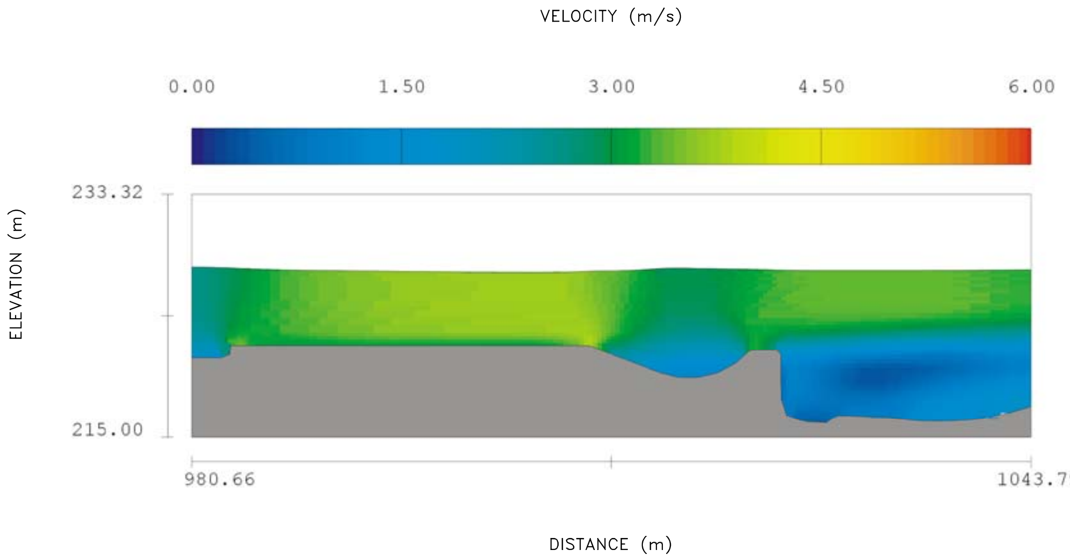
FLOODWAY INLET CONTROL STRUCTURE – FLOW ANALYSIS

CASE 2
PLAN VIEW OF VELOCITIES
$Q=1000\ m^3/s$

DATE 04-09-02

PROJECT NO. 03-1100-01

FIGURE 8



KGS • ACRES • UMA

MANITOBA FLOODWAY
EXPANSION AUTHORITY

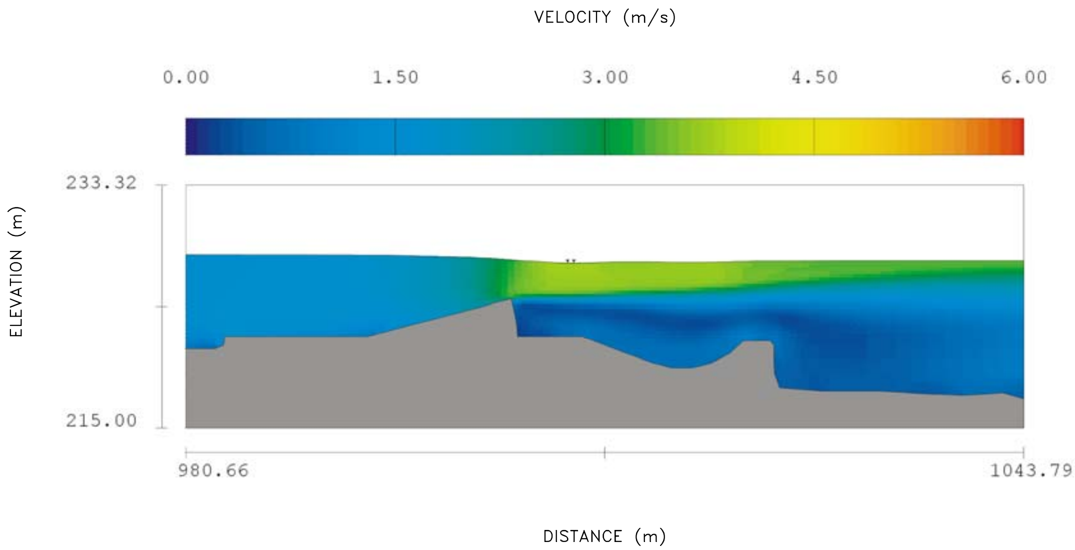
FLOODWAY INLET CONTROL STRUCTURE – FLOW ANALYSIS

CASE 3
VELOCITY PROFILE THROUGH
CENTER OF EAST BAY
Q=1000 m^3/s

DATE 04-09-02

PROJECT NO. 03-1100-01

FIGURE 9



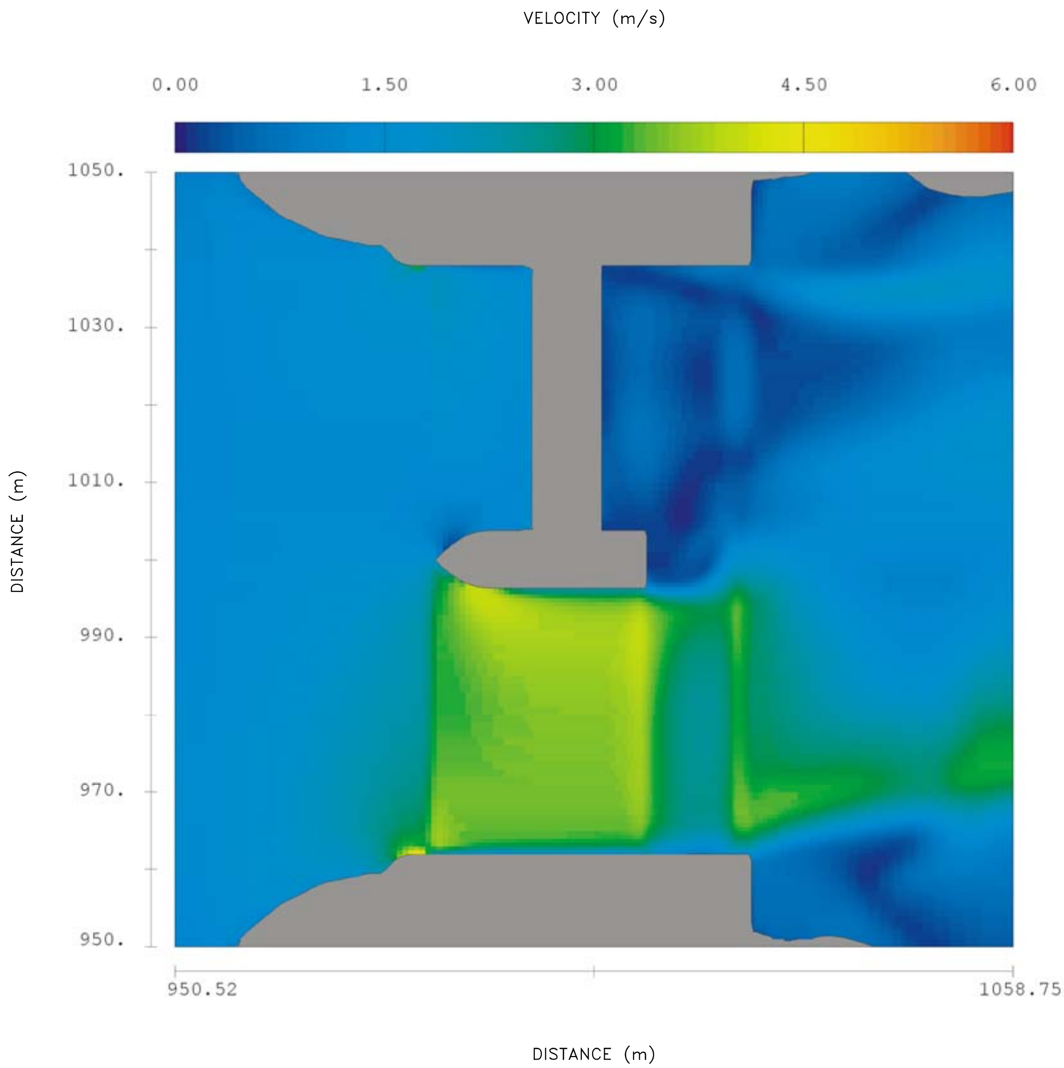
KGS • ACRES • UMA

MANITOBA FLOODWAY EXPANSION AUTHORITY

FLOODWAY INLET CONTROL STRUCTURE – FLOW ANALYSIS

CASE 3
VELOCITY PROFILE THROUGH CENTER OF WEST BAY
$Q=1000\ m^3/s$

DATE 04-09-02	FIGURE 10
PROJECT NO. 03-1100-01	



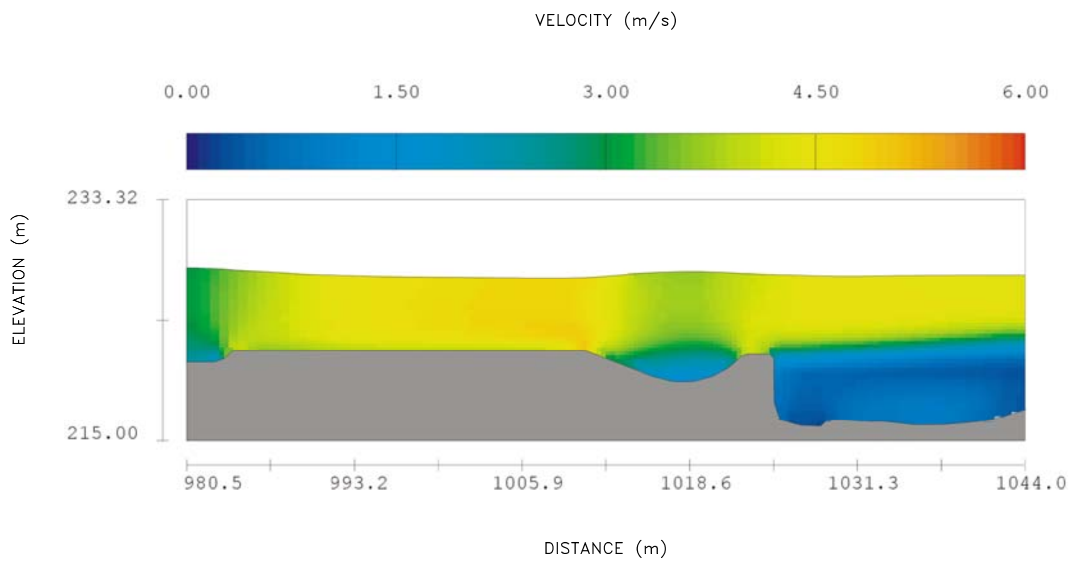
KGS • ACRES • UMA

MANITOBA FLOODWAY
EXPANSION AUTHORITY

FLOODWAY INLET CONTROL STRUCTURE – FLOW ANALYSIS

CASE 3
PLAN VIEW OF VELOCITIES
Q=1000 m^3/s

DATE 04-09-02	FIGURE 11
PROJECT NO. 03-1100-01	



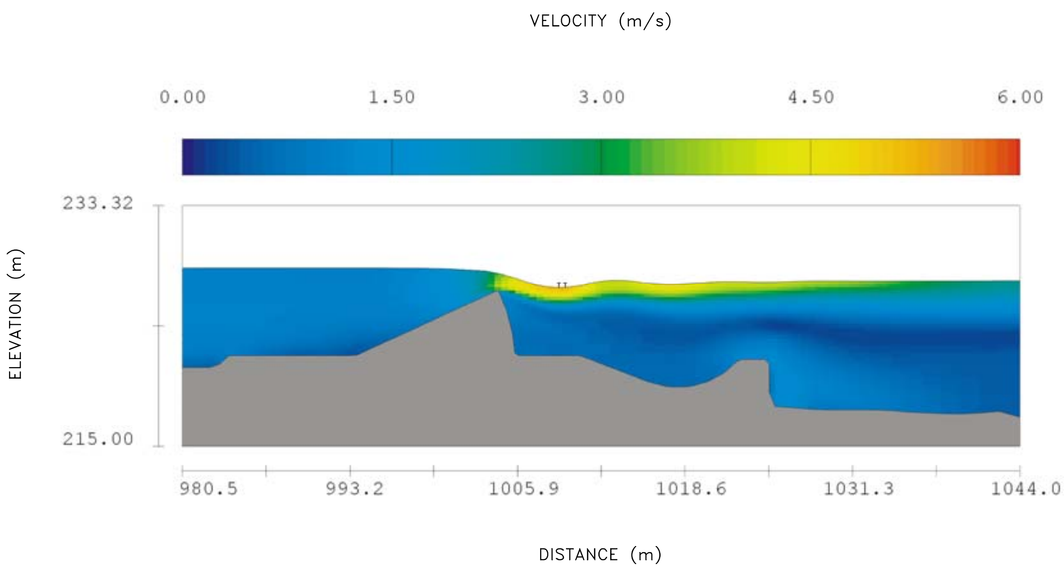
KGS • ACRES • UMA

MANITOBA FLOODWAY EXPANSION AUTHORITY

FLOODWAY INLET CONTROL STRUCTURE – FLOW ANALYSIS

CASE 4
VELOCITY PROFILE THROUGH CENTER OF EAST BAY
$Q=1000\ m^3/s$

DATE 04-09-02	FIGURE 12
PROJECT NO. 03-1100-01	



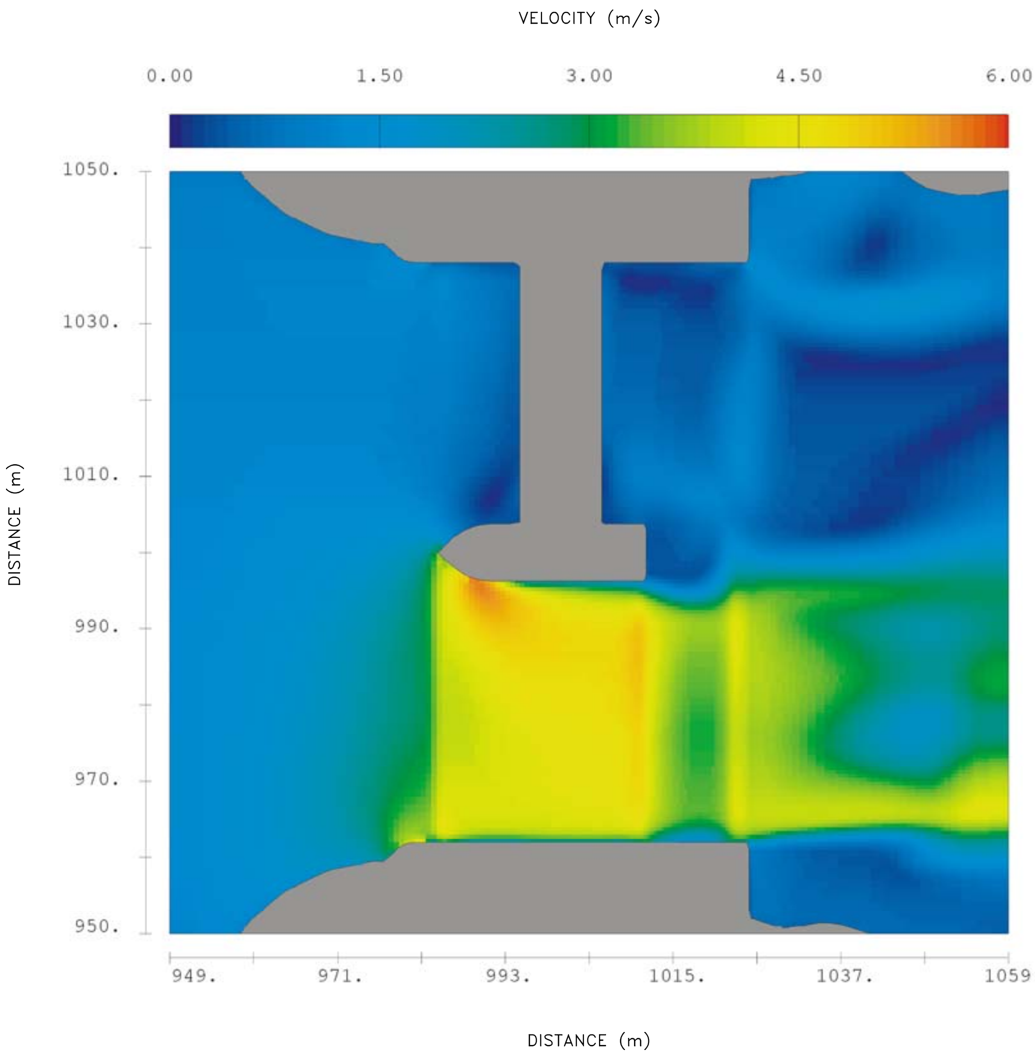
KGS • ACRES • UMA

MANITOBA FLOODWAY EXPANSION AUTHORITY

FLOODWAY INLET CONTROL STRUCTURE – FLOW ANALYSIS

CASE 4
VELOCITY PROFILE THROUGH CENTER OF WEST BAY
Q=1000 m^3/s

DATE 04-09-02	FIGURE 13
PROJECT NO. 03-1100-01	



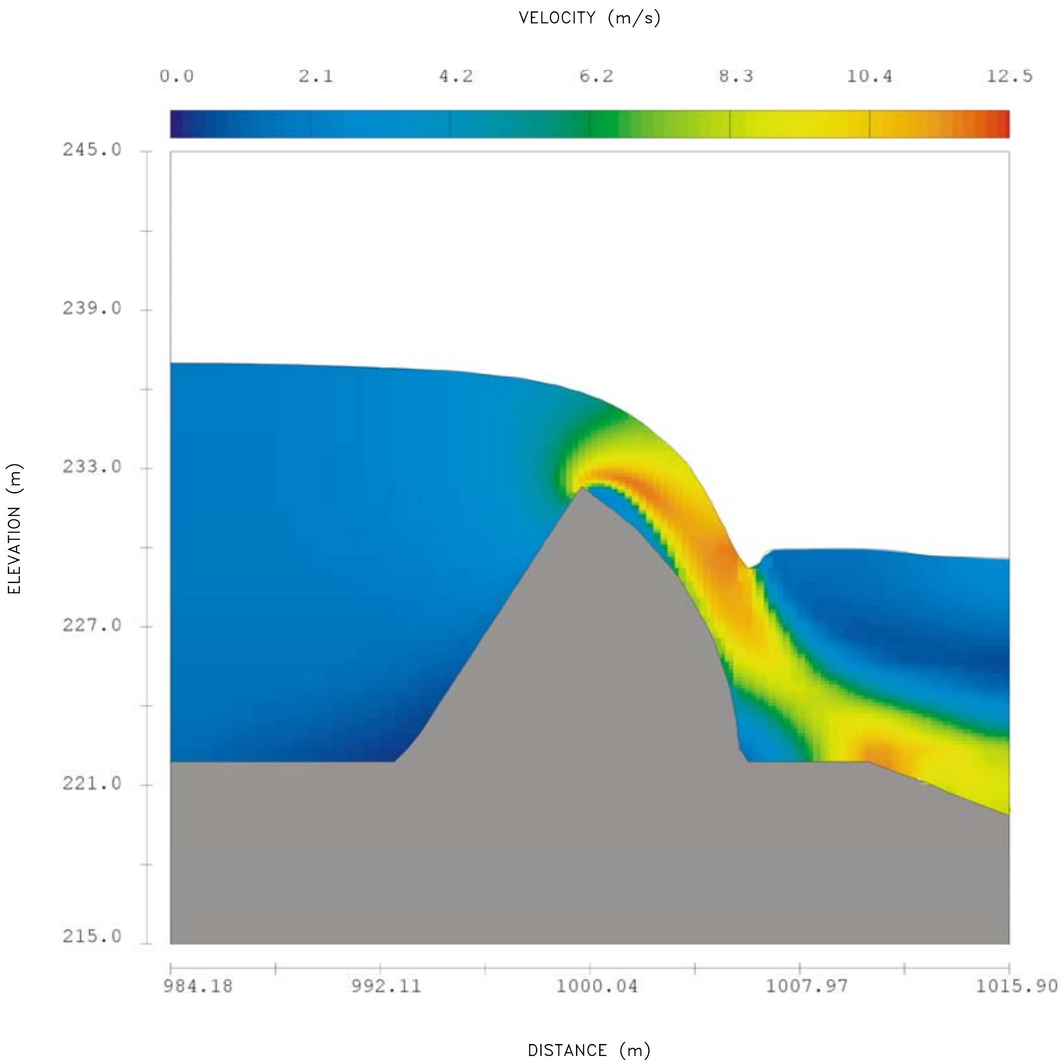
KGS • ACRES • UMA

MANITOBA FLOODWAY
EXPANSION AUTHORITY

FLOODWAY INLET CONTROL STRUCTURE – FLOW ANALYSIS

CASE 4
PLAN VIEW OF VELOCITIES
Q=1000 m^3/s

DATE 04-09-02	FIGURE 14
PROJECT NO. 03-1100-01	



KGS • ACRES • UMA

MANITOBA FLOODWAY EXPANSION AUTHORITY

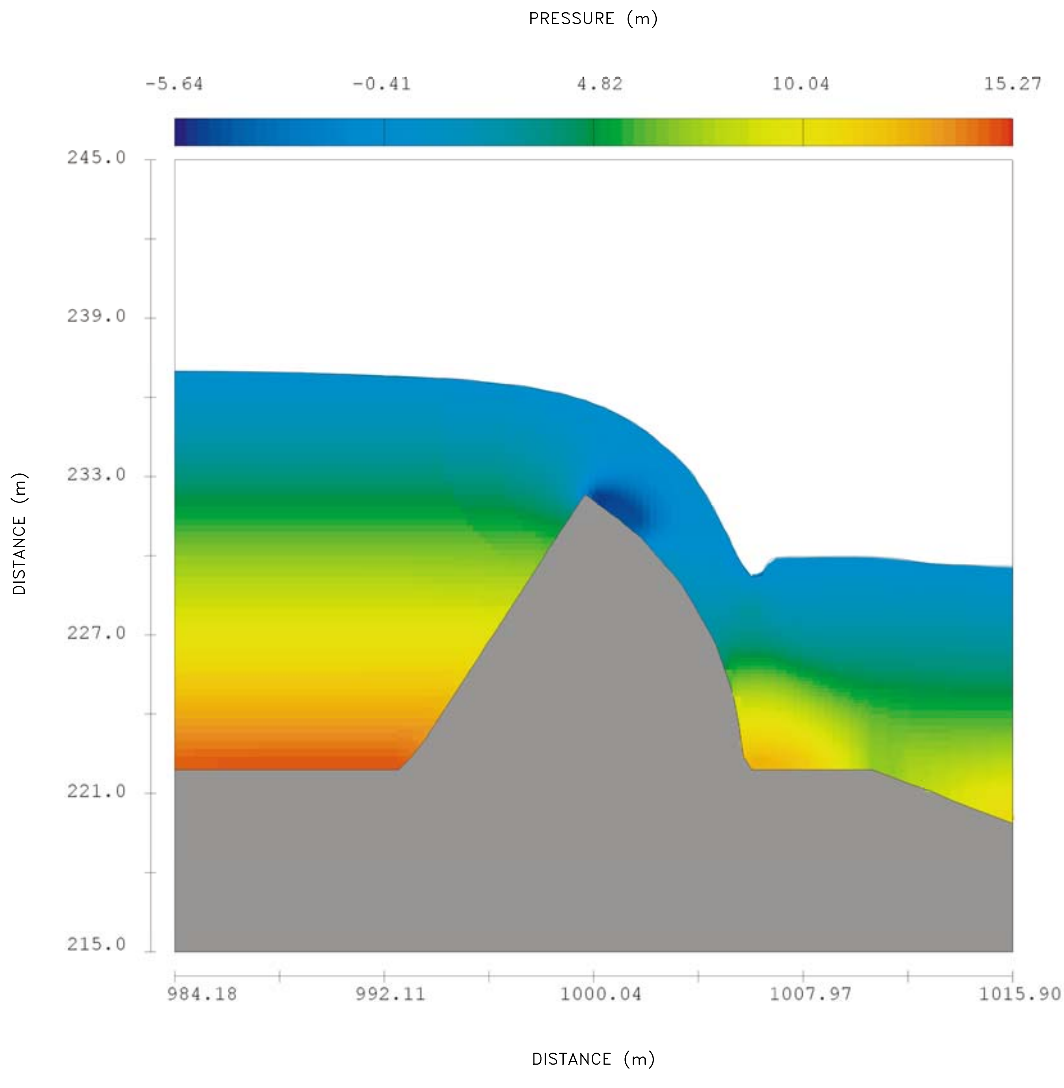
FLOODWAY INLET CONTROL STRUCTURE – FLOW ANALYSIS

CASE 5
VELOCITY PROFILE THROUGH
CENTER OF WEST BAY
Q=1714 m^3/s

DATE 04-09-02

PROJECT NO. 03-1100-01

FIGURE 15



KGS • ACRES • UMA

MANITOBA FLOODWAY EXPANSION AUTHORITY

FLOODWAY INLET CONTROL STRUCTURE – FLOW ANALYSIS

CASE 5
PRESSURES ON GATE SKINPLATE
$Q=1714\ m^3/s$

DATE 04-09-02

PROJECT NO. 03-1100-01

FIGURE 16

APPENDIX E

SUMMARY OF DIDSON FISH PASSAGE OBSERVATIONS IN THE INLET CONTROL STRUCTURE

TABLE E-1

RESULTS OF DIDSON UNDERWATER ACOUSTIC CAMERA SURVELANCE OF THE FLOODWAY INLET CONTROL STRUCTURE EAST GATE (APRIL 30, 2004)

Time	Fish Size				Total Number of Fish Observed	Fish Speed Past Gate[a]				Number of Fish that Swam Past Gate[b]	Fish Location[c]		Number of Fish that Failed in Attempts to Swim Past Gate[d]	Species[d]	Concentration of Fish (proximity to each other)[e]	Comments
	Very Small (< .15m)	Small (.15 to .5m)	Medium (.51m-.75m)	Large (>.75m)		very fast	fast	slow	Multiple Attempts		<.25m from East Wall	>.25m from East Wall				
9:59:58					**0**											
10:00:00		1			**1**											
10:02:00		1			**1**											
10:04:00		2			**2**				1s	**1**						
10:06:00		3			**3**										l	
10:08:00		4			**4**				1s	**1**					l	
10:10:00		3			**3**				1s	**1**					l	
10:12:00		3	1		**4**											
10:14:00		2	1		**3**											
10:16:00		2	2		**4**				1m/f 1sm/sl	**2**					l	sm fishes swam through tucked up by wall, med. fish swam through centre
10:18:00		4	1		**5**				1m/sl	**1**					m	4-5 sm fish approach image area & schooled, med wide head/body fish went through
10:20:00		1	2		**3**								**1s**	NOPI	l	med. fish had 1 failed attempt, then got through but thrown back after 20sec
10:22:00		1	2		**3**				1m/sl	**1**				CHCA	l	
10:24:00			2		**2**											
10:26:00			2		**2**											
10:28:00			2		**2**											
10:30:00			3		**3**				1m/sl	**1**					m	
10:32:00			3		**3**				1m/very fast	**1**					l	med. fish comes from ouside image area and swims (very quickly) through near side/edge (drum/carp?)
10:34:00			2		**2**											
10:36:00		1	2		**3**				1sm/f 1m/sl	**1**						med. fish (wide head and body); sm. fish cuts across centre to get to side and quickly swims through
10:38:00			1		**1**											poor quality image
10:40:00			2		**2**				1m/sl	**1**				NOPI		1-2 mins swims directly through near side
10:42:00			2		**2**											
10:44:00					**0**											

Time	Fish Size				Total Number of Fish Observed	Fish Speed Past Gate[a]				Number of Fish that Swam Past Gate[b]	Fish Location[c]		Number of Fish that Failed in Attempts to Swim Past Gate[d]	Species[d]	Concentration of Fish (proximity to each other)[e]	Comments
	Very Small (< .15m)	Small (.15 to .5m)	Medium (.51m-.75m)	Large (>.75m)		very fast	fast	slow	Multiple Attempts		<.25m from East Wall	>.25m from East Wall				
10:46:00			3		**3**										l	fish swimming at edge of image .5-1m from wall (no fish observed passing though image area but can assume some successful passage 1m away from wall)
10:48:00			3		**3**										l	
10:50:00	1		2		**3**			1vs		**1**						1 very small fish .15-.2m attemping passage along side; swims to centre and appears to go through
10:52:00			2		**2**			1m		**1**						
10:54:00			2		**2**											
10:56:00					**0**											only 12 sec.
10:58:00		1			**1**											only 1 fish appears at 59.00 well back of gate along wall
11:00:00		2	1		**3**		1s			**1**					l	sm. fish appears at 11.27 and swims 3.5m near wall to gate; is stopped and after 10sec swims through, other small fish still back & resting against wall
11:02:00		2	1		**3**											
11:04:00		1	3		**4**									1 med CHCA	l	wall
11:06:00		1	3		**4**		1m			**1**				NOPI	l	pike swims through with only 2 sec interruption at gate
11:08:00		1	2		**3**								**1**		l	sm. Fish from 10.58 swims to gate and flounders for 1min then is swept back out of image
11:10:00			2		**2**											mid -way back in and out of image
11:12:00			2		**2**											
11:14:00		2	1	1	**4**										l	1 sm. fish swims to gate and is held up, cd file stops at 11.15.06
11:16:00		1			**1**			1s		**1**						cd starts at 11.17.47
11:18:00			3		**3**								**1m**		l	2 fish swim/rest upstream of gate, 3rd attempted gate passage (mid. area) but 10sec later was swept way back.
11:20:00			3		**3**										l	
11:22:00			3		**3**										l	
11:24:00			2		**2**								**1m**	NOPI/CHCA		lrg pike swept way back
11:26:00			2		**2**											at edge of image .5-1m away from wall
11:28:00			3		**3**								**1m**		l	
11:30:00			4		**4**								**3m**		l	
11:32:00			5	1	**6**								**1m**	?	m	
11:34:00		3	5	1	**9**		2s	1lg		**3**					m	could large fish be white sucker, burbot?
11:36:00		2	5	1	**8**		1s			**1**			**1m**		m	gates

Time	Fish Size				Total Number of Fish Observed	Fish Speed Past Gate[a]				Number of Fish that Swam Past Gate[b]	Fish Location[c]		Number of Fish that Failed in Attempts to Swim Past Gate[d]	Species[d]	Concentration of Fish (proximity to each other)[e]	Comments
	Very Small (< .15m)	Small (.15 to .5m)	Medium (.51m-.75m)	Large (>.75m)		very fast	fast	slow	Multiple Attempts		<.25m from East Wall	>.25m from East Wall				
11:38:00		2	4	1	**7**		1lg			**1**			**1m**		m	large fish swept back finally and then swims right back through
11:40:00		3	1		**4**		1m			**1**					m	
11:42:00					**0**											no data
11:44:00					**0**											no data
11:46:00					**0**											no data
11:48:00		2			**2**											camera image area reduced downstream of gate, approx .5m wide triangled length 1m
11:50:00		2	1		**3**								**1m**		h	
11:52:00		2			**2**											
11:54:00		3			**3**										h	and gate, still no activity upstream of gates
11:56:00		3	1		**4**								**1m**		m	med. pike? shoots through at 57.59 and is thrown back at 58.02
11:58:00		3	1		**4**		1s 1m			**2**					m	small fish follows through quickly in med. fish wake, med. pike? goes back through successfully
12:00:00		2	1		**3**				1m	**1**			**1s, 1m**		l	successful
12:02:00			1		**1**											
12:04:00			1		**1**											
12:06:00					**0**											
12:08:00					**0**											no data
12:10:00					**0**											
12:12:00			1		**1**											
12:14:00	1				**1**		1vs			**1**						tucked up along wall
12:16:00		1			**1**											
12:18:00		2	1		**3**								**1s**	m/CHCA/ sucker?	l	
12:20:00	1	1	1		**3**		1vs			**1**		1	**1vs**	m/NOPI?		crosses away from wall and goes through at centre .5m off wall
12:22:00	2	1	1		**4**					**1**					l	
12:24:00		2	2		**4**		1s 1m			**2**	2			m/NOPI?	m	sm. through tucked up by wall, med. through .2m off wall
12:26:00		1	2		**3**											swimming near wall, very small triangular view area
12:28:00	1	1	2		**4**								**1vs, 1s, 1m**	m/NOPI	m	
12:30:00	1	1	3		**5**			1m		**1**			**1vs**	1m/CHCA/ 1m/NOPI?	m	1 v. small fish swept back. Never saw v. sm fish go through in last 8min of image data
12:32:00		2	5		**7**		1s	2m		**3**			**1m**	CHCA/NOPI	h	sm. fish passes through below others against wall, congestion at gate near wall

Time	Fish Size				Total Number of Fish Observed	Fish Speed Past Gate[a]				Number of Fish that Swam Past Gate[b]	Fish Location[c]		Number of Fish that Failed in Attempts to Swim Past Gate[d]	Species[d]	Concentration of Fish (proximity to each other)[e]	Comments
	Very Small (< .15m)	Small (.15 to .5m)	Medium (.51m-.75m)	Large (>.75m)		very fast	fast	slow	Multiple Attempts		<.25m from East Wall	>.25m from East Wall				
12:34:00	1	2	2		**5**								**1m**		m	med. fish swept back from upstream
12:36:00	1		3		**4**										h	camera moving
12:38:00	1		3		**4**		1m			**1**	1					camera moving
12:40:00		1	2		**3**		2m			**2**	2				m	
12:42:00		1	2		**3**		1s			**1**	1				m	camera shift, very small <1m image downstream of gate
12:44:00			2		**2**			1m		**1**	1			NOPI	m	very small image area
12:46:00			1		**1**									NOPI		very small image area
12:48:00			3		**3**			1m		**1**		1			l	fish crosses gate edge of image .5m off wall
12:50:00		2	2		**4**								**1m 1s**		m	very small image view
12:52:00		1	2		**3**									CHCA		
12:54:00		1	4		**5**		3m			**3**			**1m**	NOPI/CHCA	m	
12:56:00		1	3		**4**		1m						**1m**			med. fish swept back after 2min swimming upstream of gate
12:58:00	1	3	3		**7**		1vs 1s 1m	2s		**5**			**2s 1m**		m	1sm fish swept back (hit camera?) then swims back through close to wall
13:00:00			4		**4**		3m			**3**				NOPI?	m	
13:02:00			4		**4**		2m		1m	**3**				NOPI?	m	gate successfully with in sec. of each other
13:04:00			4		**4**		2m			**2**						Program crash
13:06:00		1	2		**3**								**1m**		l	med. fish thrown back & hits camera?
13:08:00		2	1		**3**		1s			**1**	1				l	
13:10:00			2		**2**		1m			**1**	1				l	camera shift, very small image downstream of camera; virtually no activity upstream of camera
13:12:00		1	3		**4**		1m			**1**	1		**1m**		m	med. fish thrown way back from uptream of image
13:14:00		1	4		**5**		1m			**1**				NOPI?	h	
13:16:00		2	5		**7**		1s 2m			**3**			**1sm**		h	
13:18:00			3		**3**		2m			**2**					l	med. fish thrown far back from uptream of image
13:20:00			2		**2**								**1m**		l	
13:22:00		1	2		**3**		1m	1s		**2**					l	
13:24:00		1	2		**3**			1m		**1**				NOPI?	m	
13:26:00			4	1	**5**		1lg			**1**		1			h	fish goes through off centre .5m
13:28:00		1	5		**6**		1s 1m	1m		**3**				NOPI and CHCA	h	
13:30:00			5		**5**		1m			**1**				NOPI?	h	

Time	Fish Size				Total Number of Fish Observed	Fish Speed Past Gate[a]				Number of Fish that Swam Past Gate[b]	Fish Location[c]		Number of Fish that Failed in Attempts to Swim Past Gate[d]	Species[d]	Concentration of Fish (proximity to each other)[e]	Comments
	Very Small (< .15m)	Small (.15 to .5m)	Medium (.51m-.75m)	Large (>.75m)		very fast	fast	slow	Multiple Attempts		<.25m from East Wall	>.25m from East Wall				
13:32:00		1	5		**6**		1s 1m			**2**					h	
13:34:00		2	5		**7**		2s			**2**			**2m**		m	
13:36:00	1	1	2		**4**		1s			**1**					m	looks like catfish downstream at gate
13:38:00		1	3	4	**8**		1m			**1**			**1m 1s**		m	
13:40:00			4		**4**		3m			**3**			**1m**		m	
13:42:00		1	1		**2**			1s		**1**					l	
13:44:00			2		**2**										l	
13:46:00			3		**3**		1m			**1**					l	
13:48:00			2		**2**											
13:50:00		2	5		**7**										m	camera adjusted; view MUCH better! although moving. 1m wide, 3m long downstream
13:52:00			3	2	**5**		1lg	1lg		**2**					m	first through was pike; view minimized again
13:54:00		1	5	3	**9**		2lg	1m		**3**	1	2	**1lg**	NOPI and CHCA	h	lrg. CHCA? swam quickly up to gate and pushed the med. fish through. CHCA? tried later and was successful. Both lrg. fish through at centre
13:56:00		2	3	1	**6**		2s			**2**			**2s**		h	
13:58:00			4		**4**		2m			**2**	2			NOPI and CHCA	l	second fish through (likely pike) goes under CHCA (?) along wall
14:00:00		2	2		**4**											
14:02:00		3	3		**6**		2s			**2**			**1m 1s**		m	
14:04:00			4		**4**											
14:06:00		1	4	1	**6**		1lg	1s		**2**			**1lg**	various	h	
14:08:00			5	1	**6**		1m			**1**			**1m**	various	h	
14:10:00			3		**3**											
14:12:00			4		**4**		2m			**2**			**2m**		m	
14:14:00		1	4		**5**		1s	1m		**2**					m	
14:16:00			6		**6**		1m			**1**			**1m**		h	
14:18:00			6		**6**		4m	1m		**5**			**3m**		h	fish that go through again in last 4 -6 mins
14:20:00			4		**4**											
14:22:00			3		**3**		1m			**1**			**1m**		m	
14:24:00			5	1	**6**		1lg	2m		**3**			**1m**		m	
14:26:00		1	2	1	**4**			1lg		**1**					m	no image >14.27.35-14.28.28
14:28:00		1	2		**3**		1m			**1**					m	
14:30:00		2	4		**6**		1m			**1**			**2s 1m**		m	
14:32:00		2	4		**6**			1m		**1**					h	

Time	Fish Size				Total Number of Fish Observed	Fish Speed Past Gate[a]				Number of Fish that Swam Past Gate[b]	Fish Location[c]		Number of Fish that Failed in Attempts to Swim Past Gate[d]	Species[d]	Concentration of Fish (proximity to each other)[e]	Comments
	Very Small (< .15m)	Small (.15 to .5m)	Medium (.51m-.75m)	Large (>.75m)		very fast	fast	slow	Multiple Attempts		<.25m from East Wall	>.25m from East Wall				
14:34:00		1	3		**4**											
14:36:00			4		**4**								**2m**		m	
14:38:00		2	4		**6**		2m	1s		**3**			**1m**	various	m	
14:40:00		1	3	1	**5**			1lg		**1**					h	
14:42:00		2	4		**6**			1m		**1**					m	
14:44:00		2	3	1	**6**			1m		**2**			**1lg**		m	med-large fish swept back at 14.45.47 dead?
14:46:00		1	4		**5**		1m	1m		**2**					m	very small image view
14:48:00			2		**2**											
14:50:00			2		**2**			1m		**1**					m	
14:52:00			4		**4**			2m		**2**					m	
14:54:00	1		2		**3**								**1vs**		l	v. sm. fish swept back from way up stream centre, low activity near gate
14:56:00	1	1	2		**4**			1m		**1**					l	
14:58:00			2		**2**		1m			**1**			**1m**	NOPI	l	
15:00:00			1	1	**2**									NOPI		
15:02:00			2	1	**3**		1lg			**1**					l	program (disc) unreadable at 15.02.59, shuts down no data
15:04:00					**0**											no data
15:06:00					**0**											no data
15:08:00					**0**											no data
15:10:00					**0**											no data
15:12:00					**0**											image is only of wall and shadows, no fish images discernable
15:14:00					**0**											image is only of wall and shadows, no fish images discernable, disc end 15.10
15:16:00					**0**											start disc at15.15.22
15:18:00					**0**											
15:20:00					**0**											
15:22:00					**0**											
15:24:00					**0**											
15:26:00					**0**											
15:28:00					**0**											
15:30:00					**0**											
15:32:00		1			**1**			1s		**1**	1					1sm. fish through along wall at 13.55
15:34:00					**0**											view 95% wall and shadow
15:36:00					**0**											
15:38:00					**0**											
15:40:00					**0**											

Time	Fish Size				Total Number of Fish Observed	Fish Speed Past Gate[a]				Number of Fish that Swam Past Gate[b]	Fish Location[c]		Number of Fish that Failed in Attempts to Swim Past Gate[d]	Species[d]	Concentration of Fish (proximity to each other)[e]	Comments
	Very Small (< .15m)	Small (.15 to .5m)	Medium (.51m-.75m)	Large (>.75m)		very fast	fast	slow	Multiple Attempts		<.25m from East Wall	>.25m from East Wall				
15:42:00					**0**											
15:44:00					**0**											
15:46:00					**0**											
15:48:00					**0**											
15:50:00					**0**											
15:52:00					**0**											
15:54:00					**0**											
15:56:00					**0**											
15:58:00					**0**											
16:00:00		3	2		**5**			2m		**2**	2		**1m**		m	view 95% upstrea, gate image small and blurry, med. fish struggled upstream,1 swept back
16:02:00	1	3	2		**6**		1vs 1s	2s 1m		**5**	3	2	**2s 1m**		l	same view
16:04:00			2		**2**			2m		**2**	1	1	**2s 1m**		l	
16:06:00	1		2		**3**	1vs	1m	1m		**3**	3		**1s 1m**		l	
16:08:00	1	2			**3**		1vs 2s			**3**	2	1			l	
16:10:00		1			**1**		1s			**1**	1		**1vs 1s**		l	
16:12:00		1			**1**		1s			**1**	1		**1s 1m**		l	
16:14:00		1	1		**2**		1s			**1**	1		**1s**		l	
16:16:00		1	2		**3**		1s 1m	1m		**3**	2	1			l	some fish struggle uptream after passing though gate, do not recount
16:18:00	1	2	2		**5**		1s	1vs 1s 2m		**5**	3	2	**2s 1m**		l	some fish struggle uptream after passing though gate, do not recount
16:20:00	1	2	1		**4**		1vs	2s 1m		**4**	1	3			l	some fish struggle uptream after passing though gate, do not recount
16:22:00		2	1		**3**			1m		**1**	1		**1m**		l	view 95% upstrea, gate image small and blurry, med. fish struggled upstream,1 swept back
16:24:00		3	1		**4**		1m	3s		**4**	1	3	**1m**		l	
16:26:00		3	1		**4**		1m	1s		**2**	1	1			l	
16:28:00	1	2			**3**			1vs 2s		**3**		3	**1vs 1m**		l	
16:30:00		3	1		**4**										l	clear image; visual upstream 3m x 1m and downstream of gate 1m x.75m
16:32:00					**0**											
16:34:00					**0**											
16:36:00					**0**											
16:38:00					**0**											
16:40:00					**0**											
16:42:00		4	2		**6**	1m	1m			**2**	2				l	

Time	Fish Size				Total Number of Fish Observed	Fish Speed Past Gate[a]				Number of Fish that Swam Past Gate[b]	Fish Location[c]		Number of Fish that Failed in Attempts to Swim Past Gate[d]	Species[d]	Concentration of Fish (proximity to each other)[e]	Comments
	Very Small (< .15m)	Small (.15 to .5m)	Medium (.51m-.75m)	Large (>.75m)		very fast	fast	slow	Multiple Attempts		<.25m from East Wall	>.25m from East Wall				
16:44:00		5	3		**8**			1s 2m		**3**	3		**1s 2m**		m	
16:46:00		5	4		**9**		2s 3m	1s 2m	1m	**7**	7		**1s 3m**		l	lots of ghost images off wall
16:48:00		5	3		**8**			2s 1m	1m	**4**	3	1	**2s 3m**		l	
16:50:00		3	3		**6**		2s 1m	2m		**5**	2	3	**2m**		l	
16:52:00		3	3		**6**			1vs 1m		**2**		2	**2s 1m**		l	image changes a lot and gate becomes obliterated
16:54:00		4	1		**5**										l	poor image, view zoomed and appears to be all upstream of gates 1.5m
16:56:00	1	4	3		**8**			2s 1m		**3**	3		**1m**		l	image change back able to see gate
16:58:00		5	2		**7**		1s	1m		**2**	1	1	**1m**		l	
17:00:00					**0**											
17:02:00					**0**											
17:04:00					**0**											
17:06:00					**0**											
17:08:00					**0**											
17:10:00					**0**											
17:12:00					**0**											
17:14:00		6	4		**10**			1s 2m		**3**	3		**2s 1m**		l	image includes gate and upstream
17:16:00		5	4		**9**			1s 1m		**2**	1	1	**1m**		l	
17:18:00					**0**											blurry image then read only and no data available
17:20:00		1	2		**3**			2m		**2**	2				l	image 95% upstream gate, blurry gate image
17:22:00		2			**2**										l	image 95% upstream gate, blurry gate image
17:24:00		2	1		**3**		1m	1s		**2**	2		**1m**		l	image 95% upstream gate, blurry gate image
17:26:00		3			**3**			1s		**1**		1	**1s**		l	image 95% upstream gate, blurry gate image
17:28:00		1	1		**2**			1s 1m		**2**		2			l	image 95% upstream gate, blurry gate image
17:30:00		4	1		**5**		1s 1m	1s		**3**	1	2	**1s 1m**		l	image 95% upstream gate, blurry gate image
17:32:00			1		**1**		1m			**1**	1		**1m**		l	image 95% upstream gate, blurry gate image
17:34:00			1		**1**				1m	**1**					l	image 95% upstream gate, blurry gate image
17:36:00	2				**2**		2vs			**2**		2	**1m**		l	image 95% upstream gate, blurry gate image
17:38:00		1			**1**										l	image 95% upstream gate, blurry gate image

Time	Fish Size				Total Number of Fish Observed	Fish Speed Past Gate[a]				Number of Fish that Swam Past Gate[b]	Fish Location[c]		Number of Fish that Failed in Attempts to Swim Past Gate[d]	Species[d]	Concentration of Fish (proximity to each other)[e]	Comments
	Very Small (< .15m)	Small (.15 to .5m)	Medium (.51m-.75m)	Large (>.75m)		very fast	fast	slow	Multiple Attempts		<.25m from East Wall	>.25m from East Wall				
17:40:00		3	3		**6**		2s 2m	1s 1m		**6**	3	3	**1m**		I	image 95% upstream gate, blurry gate image
17:42:00	1	2	2		**5**		1vs 1s 1m			**3**		3	**1vs 1s 1m**		I	image 95% upstream gate, blurry gate image
17:44:00		2	2		**4**	1s		1s 1m		**3**	1	2			I	image 95% upstream gate, blurry gate image
17:46:00		3	5		**8**		2s	1s 3m		**6**	1	5	**1m**		I	image 95% upstream gate, blurry gate image
17:48:00		3	3		**6**		1m	1s	1m	**3**	3		**1m**		I	image 95% upstream gate, blurry gate image
17:50:00	1	1	1		**3**			1vs 1s		**2**	2		**1m 1s**		I	image 95% upstream gate, blurry gate image
17:52:00		1	2		**3**			1s		**1**	1				I	1 med. fish swept back to gate then recovers and swims, struggling 3.5 m upstream and out of view
17:54:00		3	2		**5**	1s	2s	1m		**4**	2	2			I	image 95% upstream gate, blurry gate image
17:56:00		2	2		**4**		1s			**1**		1	**2s 1m**		I	image 95% upstream gate, blurry gate image
17:58:00	1	4	1		**6**		4s 1m			**5**	4	1	**1s 1m**		I	image 95% upstream gate, blurry gate image
18:00:00	1	2	1		**4**	1vs	1s	1s		**3**	2	1	**2s 1m**		I	image 95% upstream gate, blurry gate image
18:02:00		2	2		**4**		1s 2m			**3**	1	2			I	image 95% upstream gate, blurry gate image
18:04:00	1	2	2		**5**		1vs 1s	2m		**4**		4	**1s 1m**		I	image 95% upstream gate, blurry gate image
18:06:00		5	3		**8**	2s 2m	2s 1m			**7**	3	4	**3s**		I	image 95% upstream gate, blurry gate image
18:08:00		5			**5**		3s	1s		**4**	1	3	**1s 2m**		I	image 95% upstream gate, blurry gate image
18:10:00		5	1		**6**		1s	4s		**5**	5		**2s**		I	image 95% upstream gate, blurry gate image
18:12:00		1	2		**3**		1m	1s		**2**	1	1	**1s**		I	image 95% upstream gate, blurry gate image
18:14:00		3	4		**7**		1s 2m	1s 1m		**5**	2	3			I	image 95% upstream gate, blurry gate image
18:16:00		3	3		**6**		1s	1s 2m	1s	**5**	3	2	**1s**		I	image 95% upstream gate, blurry gate image
18:18:00		1	2		**3**	1s		1m		**2**	1	1	**2m**		I	still same image, lots of shadow images
18:20:00		2	1		**3**		2s			**2**	2		**1m**		I	still same image, lots of shadow images
18:22:00		1	2		**3**		1s	2m		**3**	1	2	**1m**		I	still same image, lots of shadow images
18:24:00		4			**4**		1s	3s		**4**	1	3			I	still same image, lots of shadow images
18:26:00		3			**3**			1s		**1**	1		**1s**		I	still same image, lots of shadow images
18:28:00		2	1		**3**			1s		**1**		1	**1s**		I	still same image, lots of shadow images

Time	Fish Size				Total Number of Fish Observed	Fish Speed Past Gate[a]				Number of Fish that Swam Past Gate[b]	Fish Location[c]		Number of Fish that Failed in Attempts to Swim Past Gate[d]	Species[d]	Concentration of Fish (proximity to each other)[e]	Comments
	Very Small (< .15m)	Small (.15 to .5m)	Medium (.51m-.75m)	Large (>.75m)		very fast	fast	slow	Multiple Attempts		<.25m from East Wall	>.25m from East Wall				
18:30:00		1	2		**3**		1m	1m		**2**	1	1	**1m**		l	
18:32:00		2	2		**4**			2s 1m		**3**	1	2	**1s 1m**		l	
18:34:00		4	1	1	**6**		4s	1m 1lg		**6**	1	5	**1lg**		m	all fish activity second during minute
18:36:00		3	3		**6**		1s 1m	1s 2m		**5**	3	2	**2s 2m**		m	still same image, lots of shadow images
18:38:00		3	1		**4**	1s	1s	1m		**3**	3		**2s 1m**		m	still same image, lots of shadow images
18:40:00		3	2		**5**		1s	2s 2m		**5**	2	3	**2s**		l	still same image, lots of shadow images
18:42:00		2			**2**			1s		**1**	1		**1m**		l	still same image, lots of shadow images
18:44:00		2			**2**			2s		**2**	1	1	**1s**		l	still same image, lots of shadow images
18:46:00			2		**2**		2m			**2**		2	**1m**		l	still same image, lots of shadow images
18:48:00		4	2		**6**		3s 1m			**4**	3	1	**1s 1m**		l	still same image, lots of shadow images
18:50:00		1	1		**2**		1m			**1**		1			l	still same image, lots of shadow images
18:52:00		4	1		**5**		3s	1s 1m		**5**	3	2	**2s**		l	still same image, lots of shadow images
18:54:00		1	1		**2**		1s 1m			**2**	2		**1m**		l	still same image, lots of shadow images
18:56:00		2	2		**4**		2s	1m		**3**	1	2	**1s**		l	still same image, lots of shadow images
18:58:00		2	2		**4**		2s 1m	1m		**4**	4		**1s 1m**		l	end disc 17a
19:00:00		2			**2**			1s		**1**	1		**1s 1m**		l	still same image, lots of shadow images
19:02:00		4	1		**5**		1s 1m			**2**	2		**1s**		l	still same image, lots of shadow images
19:04:00		2			**2**			1s		**1**	1		**1m**		l	still same image, lots of shadow images
19:06:00			1		**1**								**1s**		l	disc 17b quits at 19.06.45
Total	**28**	**334**	**487**	**25**	**874**	2vs, 5s, 3m	10vs, 77s, 86m, 6lg	5vs, 61s, 70m, 4lg	6s,13m	**356**	**139**	**103**	**7vs, 64s, 94m, 4lg**		112low, 49m, 18h	

[a]Fish speed past gate:

very fast (vf) = < 3sec without failed attempt at passing gate

fast (f) = 4 to 10sec without failed attempt at passing gate

slow (s) = >10sec without failed attempt at passing gate

multiple attempts = Pass through gate fall back >1 time

[b]Assumption based on observations of fish swimming past the field of view and not returning into the field of view

[c]Location of fish when observed swimming past the gate (note that camera field of view width from the wall was approximately 2 metres: field of view length approximately 5m)

[d]Most likely species based on discernable body form/features and swimming behaviour. Species code: NOPI = Northern Pike; CHCA = Channel Catfish

[e]Concentration of fish in proximity to each other:

High (h) = >80% of fish observed in 2 min. period were less than 10cm from each other

Medium (m) = >80% of fish observed in 2 min. period were between 10 and 20cm from each other

Time	Fish Size				Total Number of Fish Observed	Fish Speed Past Gate[a]				Number of Fish that Swam Past Gate[b]	Fish Location[c]		Number of Fish that Failed in Attempts to Swim Past Gate[d]	Species[d]	Concentration of Fish (proximity to each other)[e]	Comments
	Very Small (< .15m)	Small (.15 to .5m)	Medium (.51m-.75m)	Large (>.75m)		very fast	fast	slow	Multiple Attempts		<.25m from East Wall	>.25m from East Wall				

Low (l) = >80% of fish observed in 2 min. period were greater than 20cm from each other

P:\0211-MB Cons Fldway\08_BAseline\Inlet Structure Fish Passage\DIDSON Report\Didson data MG.xls

TABLE E-2

RESULTS OF DIDSON UNDERWATER ACOUSTIC CAMERA SURVELANCE OF THE FLOODWAY INLET CONTROL STRUCTURE WEST GATE (MAY 1, 2004)

Time	Fish Size				Total Number of Fish Observed	Fish Speed Past Gate[a]				Number of Fish that Swam Past Gate[b]	Fish Location[c]		Number of Fish that Failed in Attempts to Swim Past Gate[d]	Species[d]	Concentration of Fish (proximity to each other)[e]	Comments
	Very Small (< .15m)	Small (.15 to .5m)	Medium (.51m-.75m)	Large (>.75m)		very fast	fast	slow	Multiple Attempts		<.25m from East Wall	>.25m from East Wall				
11:15:00		6	1		**7**		2s			**2**			**2s**	unable to determine from image	m	excellent image: shows 2+m downstream gate approach and 1.5m upstream of gate
11:17:00		5	2		**7**		2s			**2**			**2s**	unable to determine from image	m	image is not as crisp therefore size is more difficult to discern because of shadowing
11:19:00		8	2		**10**		4s		1s	**5**				unable to determine from image	m	
11:21:00		9	1		**10**		5s			**5**			**1s**	unable to determine from image	m	
11:23:00	1	8	3		**12**		1vs 6s 2m			**9**				unable to determine from image	m	most fish observed 1m downstream of gate; brief rest before swimming through gate quickly
11:25:00		4	4		**8**		2s		1m	**3**			**2m**	unable to determine from image	m	
11:27:00		3	3		**6**				1s	**1**			**2s 1m**	unable to determine from image	m	
11:29:00		5	3		**8**		5s 2m			**6**			**1m**	unable to determine from image	m	
11:31:00		8	5		**13**		3s 2m		1m	**6**			**1m 2s**	unable to determine from image	m	
11:33:00		5			**5**		2s			**2**			**2s**	unable to determine from image	l	
11:35:00		3	3		**6**		1s 1m			**2**			**1s 1m**	unable to determine from image	l	
11:37:00	1	2	2		**5**	1vs				**1**			**1s**	unable to determine from image	l	no fish activity in view upstream of gate
11:39:00		5	4		**9**		4s 1m			**5**			**2s 1m**	unable to determine from image	m	
11:41:00		6	5		**11**		4s 3m	1s	1m	**9**			**2s 2m**	unable to determine from image	m	m. fish at .42.42 is fat, multi-attempts to get past gate

Time	Fish Size				Total Number of Fish Observed	Fish Speed Past Gate[a]				Number of Fish that Swam Past Gate[b]	Fish Location[c]		Number of Fish that Failed in Attempts to Swim Past Gate[d]	Species[d]	Concentration of Fish (proximity to each other)[e]	Comments
	Very Small (< .15m)	Small (.15 to .5m)	Medium (.51m-.75m)	Large (>.75m)		very fast	fast	slow	Multiple Attempts		<.25m from East Wall	>.25m from East Wall				
11:43:00		2	6		**8**		2s 2m		1m	**5**			**3m**	unable to determine from image	m	
11:45:00		3	5		**8**		1s 1m		1s	**3**			**1s 1m**	unable to determine from image	m	med. fish swam fast 1m off wall to centre
11:47:00		4	3		**7**		4s			**4**			**1s**	unable to determine from image	h	3 fish at wall, 1 at centre
11:49:00		3	4		**7**		2s 2m			**4**			**1m**	unable to determine from image	h	most fish take short rest along wall >1m back of gate then swim quickly through
11:51:00		6	3		**9**		4s	1s 1m	1m	**7**			**1m 2s**	unable to determine from image	h	
11:53:00		3	5		**8**		2s 1m		1s	**4**			**1s 1m**	unable to determine from image	h	
11:55:00		3	6		**9**		2s		1m	**3**			**3m**	unable to determine from image	h	
11:57:00		2	6		**8**		1s 2m			**3**			**1s**	unable to determine from image	h	
11:59:00		3	5		**8**		1m		2m	**3**			**3m**	unable to determine from image	h	most fish take short rest along wall >1m back of gate then swim quickly through
12:01:00		4	7		**11**		2m 2s		1m	**5**			**1m**	unable to determine from image	h	med fish at .22 and .49 through at centre
12:03:00		5	6	1	**12**		2s 3m			**5**				unable to determine from image	h	sm fish at 4.36 through at centre
12:05:00		2	5	2	**9**		1s 2m			**3**			**1s**	unable to determine from image	h	fish consistently rest/swim abreast 1m downstream of gate face
12:07:00		2	6	2	**10**		1s 2m	1s 1m		**5**			**2m**	unable to determine from image	h	
12:09:00		2	5	2	**9**		3m		1m	**4**				unable to determine from image	h	
12:11:00		2	4	1	**7**		1s	1lg		**2**			**1m**	unable to determine from image	m	
12:13:00		3	7		**10**		1m 3s	2m		**6**			**2m**		h	fish consistently rest/swim abreast 1m downstream of gate face

Time	Fish Size				Total Number of Fish Observed	Fish Speed Past Gate[a]				Number of Fish that Swam Past Gate[b]	Fish Location[c]		Number of Fish that Failed in Attempts to Swim Past Gate[d]	Species[d]	Concentration of Fish (proximity to each other)[e]	Comments
	Very Small (< .15m)	Small (.15 to .5m)	Medium (.51m-.75m)	Large (>.75m)		very fast	fast	slow	Multiple Attempts		<.25m from East Wall	>.25m from East Wall				
12:15:00		3	6		**9**		2s 1m	1s		**4**			**1s 2m**	CHCA?	h	fatheaded fish through at .41 and later swept back
12:17:00	1	2	6		**9**	1vs 1s	1m	2m		**5**			**1s**		h	
12:19:00	1	2	9		**12**	1vs	1s 3m	2m	1s	**8**			**1s 1m**		m	
12:21:00		7	9	1	**17**		4s 6m	3s 1m		**14**	10	4	**1m**		h	
12:23:00		1	5		**6**			1m		**1**	1	0	**1s**		m	fish are concentrated along wall and not spread across channel
12:25:00	1	3	3	1	**8**	1m	1vs 2s			**4**	3	1	**1m**		m	
12:27:00	1	6	7	1	**15**	2m	6s 2m 1vs	1lg		**12**	9	3		CHCA?	h	fatheaded sm. fish swimming upstream of gate
12:29:00		1	7		**8**		1s 1m		2m	**4**	4	0	**1m**		m	
12:31:00			10	1	**11**	1lg	4m	1m		**6**	5	1	**1m**		m	large fish through centre
12:33:00		4	5	1	**10**		2s 1m	2s 1m	1m	**7**	6	1			h	fish are concentrated along wall and not spread across channel
12:35:00		6	2	1	**9**		5s 2m	1s		**8**	8	0	**1m**		h	
12:37:00	1	1	12	1	**15**	1lg	1vs 1s 2m	1m		**6**	4	2	**1s**		h	fish along wall and across channel
12:39:00	1	1	10		**12**		1vs 1s 2m	3m		**7**	7	0	**1m**		h	fish along wall and across channel
12:41:00		3	9		**12**		2s 1m	4m		**7**	5	2				
12:43:00		2	8	1	**11**	1m	1s	2m		**4**	3	1			m	
12:45:00		5	10	2	**17**		3s 1m 1lg	2s 5m 1lg		**13**	12	1	**3m**		h	
12:47:00		1	4		**5**		1m	1s 2m		**4**	3	1	**1m**		h	read only after 12.47.45
12:49:00					**0**											
12:51:00					**0**											
12:53:00		1	4	1	**6**		3m	1s 1m 1lg		**6**	4	2	**1m**		m	1m fish through fast then held up a bit at upstrm edge of gate
12:55:00		2	10		**12**		1s 1m	1s 2m		**5**	4	1	**1s**			
12:57:00	1	1	3	1	**6**	1vs	1m	1s		**3**	1	2	**1lg**		l	
12:59:00		2	6		**8**		1s 2m	2m		**5**		5	**1s**		l	end disc
13:01:00		2	11	2	**15**		1s	3s 7m 1lg		**12**	8	4	**2m**		h	
13:03:00		3	11		**14**		2s	2s 3m		**7**	6	1			h	fish are concentrated along wall and not spread across channel
13:05:00		5	11		**16**		3s 3m	1s 2m		**9**	3	6	**1m**		h	image still very good
13:07:00		6	10	2	**18**		5s 4m	1s 4m		**14**	3	11			h	12 fish through in 1 min , only 2 fish second minute
13:09:00	1	1	4	2	**8**		1vs	2m 1lg		**4**	3	1			h	large fish through centre quickly and then falters and retries at upstream edge of gate
13:11:00			12	4	**16**		1m	6m 2lg	1m 1lg	**11**	5	6	**3m 1lg**		h	

Time	Fish Size				Total Number of Fish Observed	Fish Speed Past Gate[a]				Number of Fish that Swam Past Gate[b]	Fish Location[c]		Number of Fish that Failed in Attempts to Swim Past Gate[d]	Species[d]	Concentration of Fish (proximity to each other)[e]	Comments
	Very Small (< .15m)	Small (.15 to .5m)	Medium (.51m-.75m)	Large (>.75m)		very fast	fast	slow	Multiple Attempts		<.25m from East Wall	>.25m from East Wall				
13:13:00		3	9	4	**16**	1m	1m 1lg	2s 4m 3lg		**12**	8	4	**1m**		m	
13:15:00		1	6	2	**9**		1m 2lg	3m	1m	**7**	5	2	**1m**		m	
13:17:00			5		**5**			1m		**1**	1		**1m**		m	only 40 sec of footage, disc start at 18:19
13:19:00		1	8	1	**10**			1s 3m		**4**	4		**1m 1lg**		h	
13:21:00		1	11		**12**	1m	4m	1s	2m	**8**	5	3	**1m**		m	1m fatheaded athrough at .22.33
13:23:00		1	8		**9**		1s	3m	1m	**5**	5		**6m**		m	image scope still excellent
13:25:00		3	13		**16**		2s	2s 5m		**9**	7	2	**2m 1s**		m	see fish bunching up along wall .5 metres upstream after passing through gate
13:27:00		2	10		**12**		1s	4m		**5**	5		**3m 1lg**		m	
13:29:00		10	7	2	**19**		7s 3m 2lg	1s 2m		**15**	10	5	**1sm**		h	12 fish through in less than 1 min, 8 were small fish
13:31:00		3	5		**8**		1s 1m	2s 1m		**5**	4	1	**1m**		m	
13:33:00		3	3	1	**7**		2s		1m	**3**	2	1	**2m**		m	lrg fish bursts forward to gate is stopped but causes 2 sm fish to pass over gate successfully
13:35:00		2	8	1	**11**			1m	2s 5m	**8**	6	2	**1m 1lg**		h	
13:37:00			9		**9**			1m	2m	**3**	2	1			m	
13:39:00			19		**19**			3m	8m	**11**	7	3	**1m**		h	a few fish struggling upstream of gates after successful passgae
13:41:00		2	14	2	**18**		1s 1m 1lg	1s 9m 1lg		**14**	9	5	**3m**		m	
13:43:00			14	1	**15**	1m	2m 2s	1m 1lg		**5**	3	2	**2m**		h	
13:45:00			14	1	**15**		3m	7m		**10**	6	4	**2m**		h	
13:47:00		3	12		**15**		1s	5m	2m	**9**	7	2	**1m**		h	
13:49:00			16	2	**18**		5m	8m 1lg		**14**	10	4	**2m**		h	
13:51:00			13	2	**15**	1lg	3m	4m 1lg		**9**	6	3	**1m**		h	
13:53:00		2	13	1	**16**		2m	2s 2m 1lg	1m	**8**	6	2	**6m**		h	excellent image: shows 2+m downstream of gate approach and 1.5m upstream of
13:55:00		6	10		**16**	1s	1s	2s 4m		**8**	6	2	**1m**		h	image is not as crisp therefore size is more difficult to discern because of shadowing
13:57:00		2	9		**11**		2s	3m		**5**	4	1	**1m**		h	
13:59:00					**0**			6s 3m		**9**	8	1			h	
14:01:00					**0**											
14:03:00					**0**											
14:05:00					**0**											
14:07:00					**0**											
14:09:00					**0**											
14:11:00					**0**											
14:13:00					**0**											

Time	Fish Size				Total Number of Fish Observed	Fish Speed Past Gate[a]				Number of Fish that Swam Past Gate[b]	Fish Location[c]		Number of Fish that Failed in Attempts to Swim Past Gate[d]	Species[d]	Concentration of Fish (proximity to each other)[e]	Comments
	Very Small (< .15m)	Small (.15 to .5m)	Medium (.51m-.75m)	Large (>.75m)		very fast	fast	slow	Multiple Attempts		<.25m from East Wall	>.25m from East Wall				
14:15:00					**0**											
14:17:00					**0**											
14:19:00					**0**											
14:21:00					**0**											
14:23:00					**0**											
14:25:00		3	4		**7**		1s			**1**	1				m	Disc 6a starts at 14.26 and image is reduced; <1m upstream of gates leading edge and >1m across from wall is visible
14:27:00		9	6		**15**			7s 2m		**9**	4	5	**1s**		h	This image is better for sizing and identifying fish type
14:29:00		9	2		**11**			1s 1m		**2**	1	1			h	
14:31:00		5	7		**12**		1m	1s 2m		**4**	1	3			h	image changes 3 times zooming in and out
14:33:00		6	4		**10**			2m		**2**	2				h	
14:35:00		9	14	2	**25**		1s 2m	3s 6m 2lg		**14**	10	4	**1m**		h	first minute 11 fish through gate, very high concentration of fish
14:37:00					**0**			6s 3m		**9**	5	4	**4m**		h	very visible pectoral fins on one of the m. fish swept back across gate
14:39:00		18	5		**23**		3s	7s 1m		**11**	8	3	**2s 1m**		h	
14:41:00		20	4		**24**			7s 4m		**11**	7	4			h	
14:43:00		12	5	1	**18**	1lg		7s 3m		**11**	8	3	**1m**	CHCA?	h	small fish passing at 43.45 more visibly fat/ID?
14:45:00		6	11		**17**			3s 8m		**11**	9	2	**1m**		h	limited view upstream cannot record movements
14:47:00		4	9		**13**		3m	2s 1m		**6**	3	3			m	1st minute only 5 fish and non through, medium fish swim up and push through
14:49:00		8	8		**16**	1s	1s 2m	2s 4m		**10**	8	2			m	fish swims very fast up to gate and is stopped then quickly crosses gate successfully at 50.29
14:51:00		8	3		**11**		1s	4s 2m		**7**	5	2	**2s**		m	
14:53:00		16			**16**		3s	6s		**9**	7	2	**1s**		h	
14:55:00		12	3		**15**		1m	7s		**8**	7	1	**1m**		h	
14:57:00		3	6		**9**	2m	2s 2m			**6**	4	2	**1s**	NOPI? Carp?	m	image discerns very narrow and wide fatheaded fish
14:59:00		5	4		**9**		1s	3s		**4**	4				m	
15:01:00		8	5	2	**15**		1s	5s 2m 2lg		**10**	7	3			h	
15:03:00			7	2l	**7**		1m	2m 1lg	1lg	**5**	1	4	**1lg**		h	camera hit
15:05:00		1	10	1	**12**		1m	1s 3m 1lg		**6**	4	2			m	camera hit again
15:07:00		6	4		**10**			2s 3m		**5**	2	3			m	fish struggling upstream gates
15:09:00		5	6	1	**12**		1s 1m	1s 2m 1lg		**6**	3	3			h	fish struggling

Time	Fish Size				Total Number of Fish Observed	Fish Speed Past Gate[a]				Number of Fish that Swam Past Gate[b]	Fish Location[c]		Number of Fish that Failed in Attempts to Swim Past Gate[d]	Species[d]	Concentration of Fish (proximity to each other)[e]	Comments
	Very Small (< .15m)	Small (.15 to .5m)	Medium (.51m-.75m)	Large (>.75m)		very fast	fast	slow	Multiple Attempts		<.25m from East Wall	>.25m from East Wall				
15:11:00		4	5	1	**10**			2s 2m 1lg		**5**	1	4			m	fish struggling uptream
15:13:00		6	3		**9**			3s 1m	1m	**5**		5	**1s**		m	fish struggling uptream
15:15:00		8	10		**18**			3s 4m		**7**	3	4			h	fish struggling uptream
15:17:00		9	13		**22**			4s 8m	1m	**14**	4	10	**1s 3m 1lg**		h	fish struggling uptream
15:19:00		11	8		**19**			5s 5m		**10**	7	4	**1m**		h	fish struggling uptream
15:21:00		6	8		**14**			2s 4m		**6**	4	2	**1s 4m**		h	
15:23:00		9	10		**19**		2s	5s 6m	1m	**14**	7	7	**3m**		h	fish struggling uptream
15:25:00		6	7		**13**		1s	3m		**4**	3	1	**1s 1m**		h	fish struggling uptream
15:27:00		7	8		**15**		1m	5s 2m		**8**	5	3				
15:29:00		6	8		**14**			1s 5m		**6**	5	1	**1s**			disc 7 ends at 15.29.58
15:31:00		6	10		**16**		1s	1s 6m		**8**	5	3			h	disc 8 starts at 15.30.00
15:33:00		6	7		**13**		2s 1m		2m	**5**	2	3	**1m**		h	same image as disc 7
15:35:00		4	11		**15**			1s 7m		**8**	3	5	**1m**		h	
15:37:00		5	7		**12**		1s	3m		**4**	3	1	**2m**	CHCA?	m	1 med fatheaded fish struggling upstream swept back
15:39:00		4	8		**12**		1s 1m	1s 4m		**7**	3	4			m	fish struggling upstream
15:41:00		6	6	1	**13**			3s 2m 1lg		**6**	3	3	**2m**	CHCA?	m	1 med. Fatheaded fishat 42.38
15:43:00		7	9		**16**		1s 1m	2s 3m		**7**	5	2	**2m**		h	fish struggling upstream of gate
15:45:00		13	2		**15**			8m 2lg		**10**	5	5	**2m**		m	fish struggling upstream of gate
15:47:00	4	8	5		**17**		1vs	1vs 3s 2m		**7**	4	3	**1vs 1m**	CHCA?	h	1m fatheaded fish passes gate
15:49:00		6	12		**18**			1s 7m		**8**	4	4	**1s 4m**		h	lots of activity
15:51:00		1	13	1	**15**			1s 8m 1lg		**10**	6	4	**1m**	2-3 NOPI?	h	2-3 very narrow fish (pike)
15:53:00		3	3		**6**			1s 1m		**2**	2		**2s**		l	
15:55:00		3	4		**7**			1s	1s	**2**	2				m	
15:57:00	1	7	9		**17**			1vs 4s 3m		**9**	6	3	**1s 3m**		h	
15:59:00		8	6		**14**		1s1m	3m		**5**	3	2			h	disc ends at 15.59.58
16:01:00	1	8	9	1	**19**		1s	2s 4m 1lg		**8**	5	3	**1vs**		m	
16:03:00		7	4		**11**		2s	1s 1m		**4**	4		**1s 1m**		m	
16:05:00		5	4		**9**		1s	2s 2m		**5**	5		**1m**		m	
16:07:00		3			**3**			2s		**2**	2		**1s**			
16:09:00		3			**3**					**0**					l	
16:11:00		6			**6**			2s		**2**	2				l	
16:13:00		4	2		**6**		1s			**1**	1				l	

Time	Fish Size				Total Number of Fish Observed	Fish Speed Past Gate[a]				Number of Fish that Swam Past Gate[b]	Fish Location[c]		Number of Fish that Failed in Attempts to Swim Past Gate[d]	Species[d]	Concentration of Fish (proximity to each other)[e]	Comments
	Very Small (< .15m)	Small (.15 to .5m)	Medium (.51m-.75m)	Large (>.75m)		very fast	fast	slow	Multiple Attempts		<.25m from East Wall	>.25m from East Wall				
16:15:00		4	5		**9**			2s 2m		**4**	3	1	**1s**		l	
16:17:00		3	4	1	**8**					**0**					l	large and few med fish swim to centre and could have swam through but not visible in image
16:19:00	1	6	7		**14**			1s 1m		**2**	2				h	
16:21:00		4	7		**11**			1s 3m		**4**	3	1	**2m**		m	
16:23:00		5	9		**14**			1s 3m		**4**		4	**1s**		h	
16:25:00		3	10		**13**			1s 4m		**5**	2	3	**1m**		m	fish struggling upstrem
16:27:00	1		7		**8**		1m	4m		**5**	2	3	**1**		l	
16:29:00		3	5		**8**		1s	1m		**2**	1	1				
16:31:00		2	8		**10**		2s	3m		**5**	4	1	**1m**		m	
16:33:00	2	3	4		**9**		1s	1vs 3m		**5**	2	3			m	
16:35:00		4	6		**10**		1s	1m		**2**		2			l	
16:37:00		3	8		**11**			1m		**1**		1			h	
16:39:00		4	12		**16**		1m	1s 9m		**11**	5	3	**2m**		m	
16:41:00		6	8		**14**		1s	3s 3m		**7**	5	2		fat and thin	h	
16:43:00	1	3	4		**8**			2m		**2**		2		fat and thin	l	
16:45:00		3	3		**6**		4s	1m		**4**	3	1	**1s**	fat and thin		
16:47:00		3	5		**8**			1s 2m		**3**	2	1	**1m**			
16:49:00		5	5		**10**		1m	3s 1m		**5**	3	2			m	
16:51:00		2	5		**7**		1s	1m		**2**	1	1	**2m**		l	
16:53:00		7	4		**11**			2s 1m		**3**	2	1			m	
16:55:00		3	6		**9**		1s 1m	1s 3m		**6**	4	2			m	image same for disc 7,8,9,10
16:57:00		1	2		**3**			1m		**1**		1				camera shaking a lot, image changed to include 1m upsream of gate
16:59:00			4		**4**			1m		**1**	1					image shows rectangular grate? approx 15cmx50cm on gate
17:01:00		2	5		**7**			1s 1m		**2**	2		**1s**		m	image shows rectangular grate? approx 15cmx50cm on gate
17:03:00		4	7		**11**					**0**					m	
17:05:00		5	5		**10**			3s 1m		**4**	3	1			h	
17:07:00		8	3		**11**			1s		**1**	1				h	fish swimming 7 abreast along leading edge gate 17.08
17:09:00		11	3		**14**			5s		**5**	5		**3s**		h	fish struggle swimming upstream of gate
17:11:00		12	8		**20**			8s 6m		**14**	9	5	**1s 2m**		h	lots of fish
17:13:00		3	6		**9**			1s		**1**	1		**2s**		h	
17:15:00		10	6		**16**			6s 3m		**9**	6	3	**2s 2m**	NOPI?	h	very narrow fish at 16.19
17:17:00		4	5		**9**			1s 4m		**5**	1	4	**1s 3m**		h	struggle to swim upstream of gate
17:19:00		5	4		**9**			3s 1m		**4**	1	3	**2s**		h	same view with rectangular shape

Time	Fish Size				Total Number of Fish Observed	Fish Speed Past Gate[a]				Number of Fish that Swam Past Gate[b]	Fish Location[c]		Number of Fish that Failed in Attempts to Swim Past Gate[d]	Species[d]	Concentration of Fish (proximity to each other)[e]	Comments
	Very Small (< .15m)	Small (.15 to .5m)	Medium (.51m-.75m)	Large (>.75m)		very fast	fast	slow	Multiple Attempts		<.25m from East Wall	>.25m from East Wall				
17:21:00		11	7		**18**			10s 2m		**12**	6	6	**2s**		h	struggle to swim upstream of gate
17:23:00		4	5		**9**			1s 3m		**4**	2	2	**2s 2m**		h	struggle to swim upstream of gate
17:25:00		4	5		**9**			2m		**2**		2	**4s**		m	
17:27:00	1	7	4		**12**			1vs 4s 1m		**6**	2	4	**2s 3m**	NOPI?	h	very narrow fish 26.44
17:29:00		8	5	1	**14**		1s	4s 2m 1lg		**9**	6	3	**3s 3m**		h	
17:31:00		5	3		**8**			1s 1m		**2**	2		**1s**		m	end disc 11a
17:33:00					**0**											same view closer
17:35:00					**0**											
17:37:00	1	4	3		**8**			1s 3m		**4**	1	3	**2s 1m**		m	view zoomed in and out a few times
17:39:00		6	7		**13**	1s	1m	3s 5m		**10**	6	4	**2s 3m**		m	fish stuggling to swim upstream of gate
17:41:00		2	3		**5**			1m		**1**		1	**1m**		l	
17:41:59					**0**											
Total	**23**	**802**	**1131**	**63**	**2019**	3vs, 4s, 9m, 4lg	7vs, 174s, 122m, 6lg	4vs, 247s,372m,30lg	8s, 42m, 2lg	**1046**	577	325	**2vs, 84s, 160m, 7lg**		16low, 65m, 88h	

[a]Fish speed past gate:

very fast (vf) = < 3sec without failed attempt at passing gate

fast (f) = 4 to 10sec without failed attempt at passing gate

slow (s) = >10sec without failed attempt at passing gate

multiple attempts = Pass through gate fall back >1 time

[b]Assumption based on observations of fish swimming past the field of view and not returning into the field of view

[c]Location of fish when observed swimming past the gate (note that camera field of view width from the wall was approximately 2 metres: field of view length approximately 5m)

[d]Most likely species based on discernable body form/features and swimming behaviour. Species code: NOPI = Northern Pike; CHCA = Channel Catfish

[e]Concentration of fish in proximity to each other:

High (h) = >80% of fish oberved in 2 min. period were less than 10cm from each other

Medium (m) = >80% of fish oberved in 2 min. period were between 10 and 20cm from each other

Low (l) = >80% of fish oberved in 2 min. period were greater than 20cm from each other

P:\0211-MB Cons Fldway\08_BAseline\Inlet Structure Fish Passage\DIDSON Report\Didson data MG.xls

APPENDIX F

COMPACT DISC WITH REPORT IN ADOBE ACROBAT FORMAT WITH MOVIE FILES