5.0 FISH HABITAT INSTREAM FLOW NEEDS

5.1 General Process

This section of the report provides an overview of the process used to make instream flow needs (IFN) determinations based on fish habitat modelling. A considerable amount of fish habitat modelling data already existed in the SSRB from previous PHABSIM studies (**P**hysical **HAB**itat **SIM**ulation system developed by the U.S. Fish and Wildlife Service). It was decided to review this information with the purpose of determining whether it met current habitat modelling criteria, standards, protocols, and objectives for the SSRB study. This was considered to be the most cost efficient approach for ensuring existing data were up to current standards and were in the most suitable format for the SSRB evaluation. Collecting new PHABSIM data at locations for which data did not exist required considerably more resources than were available for this study.

It should be noted that the PHABSIM group of models are widely used, and often, equally widely criticized. The criticisms usually cite:

- The representativeness of transects used to calculate habitat (Williams 1996);
- The underlying assumptions about the interpretation of weighted useable area (WUA) curves for fish species (EPRI 2000, Railsback et al. *in press*); and
- The explicit narrowness of the modelled biological responses. The pros and cons of PHABSIM are widely discussed in the scientific literature (Wesche and Rechard 1980, EPRI 1986, Annear et al. 2002).

Notwithstanding these criticisms, the use of the PHABSIM models, as presented in this report, is believed to be reasonable and to adequately describe the flow requirements for fish for the appropriate time of year and range of flows. As with the use of any model, extreme care and caution must be used and the true test is to monitor the response of the fish populations to the flow regime that is ultimately selected.

The PHABSIM models were used to develop fish habitat versus flow relationships, or WUA curves for each reach of each river where site-specific data were available. Where site-specific data were not available, office based techniques were used. The WUA curves were used to conduct time-series analysis for evaluating different flow regimes, created as constant-percent flow reductions from natural, to produce IFN determinations for fish habitat. The fish habitat-derived flow determinations were subsequently integrated with the flow recommendations for the other aquatic ecosystem components (i.e., channel maintenance, riparian vegetation and water quality,) to form one integrated instream flow need recommendation.

The primary objective for the fish habitat-modelling component was to develop a science based IFN determination using the available field data, current modelling techniques, and the best available evaluation protocols. This effort was focused on the use of physical habitat modelling as a central element.

5.1.1 Physical Habitat Modelling

In habitat modelling, a hydraulic model is used to determine characteristics of the stream, in terms of depth and velocity, as a function of discharge. This information is integrated with habitat suitability criteria curves to produce a measurement for available habitat as a function of discharge.

The general assumption underlying habitat modelling is that aquatic species will react to changes in the hydraulic environment. This assumption is rooted in ecological principles and has been demonstrated to be valid in applied research (Jowett 1992, Jager et al. 1993, Nehring and Anderson 1993, Railsback et al. 1993, Bovee et al. 1994, Stalnaker et al. 1995, Studley et al. 1995). These changes in hydraulic properties are simulated for each computational cell within each cross section, throughout the study reach. The stream reach simulation takes the form of a multi-dimensional matrix of the calculated surface areas of a stream, having different combinations of hydraulic parameters (i.e., depth, velocity, and channel index), as illustrated in Figure 5.1. This figure shows the generalized representation of a segment of river for a series of transects that define a grid of habitat cells with their associated attributes of depth, velocity, and channel index (i.e., substrate and cover). These cells represent the basic computational elements used by the habitat programs to derive relevant indices of available habitat. Depth and velocity attributes for each computational cell vary with simulated changes in discharge. These variations in discharge can result in changes in the amount and quality of available habitat.

Habitat Suitability Criteria (HSC) are used to describe the adequacy of various combinations of depth, velocity and channel index conditions in each habitat computational cell to produce an estimate of the quantity and/or quality of habitat in terms of surface area. This measure is referred to as the weighted usable area (WUA) and is expressed in terms of units of area per linear length of stream (traditionally square feet per 1000 linear feet of stream). WUA is computed within the reach, at a specific discharge, by the following equation:

$$WUA = \frac{\sum_{i=1}^{n} A_i C_i}{\text{Reach Length (1000's feet)}}$$

Equation 5.1

Where:

Ai = Surface area of cell i,

Ci = Combined suitability of cell i (i.e., composite of individual depth, velocity and channel index suitabilities).

The combined or composite suitability of the cell is derived from the aggregation of the individual suitabilities for depth, velocity, and channel index based on the simulated depth, velocity and channel index attributes within a habitat computational cell. The individual suitabilities for depth, velocity and channel index are obtained from the corresponding species and life stage HSC. This is illustrated in Figure 5.2.

Composite suitabilities can be computed by a number of methods. The most common are the multiplicative, geometric mean, or limiting value approaches. The specific habitat modelling approaches used in these studies are detailed in the following sections.

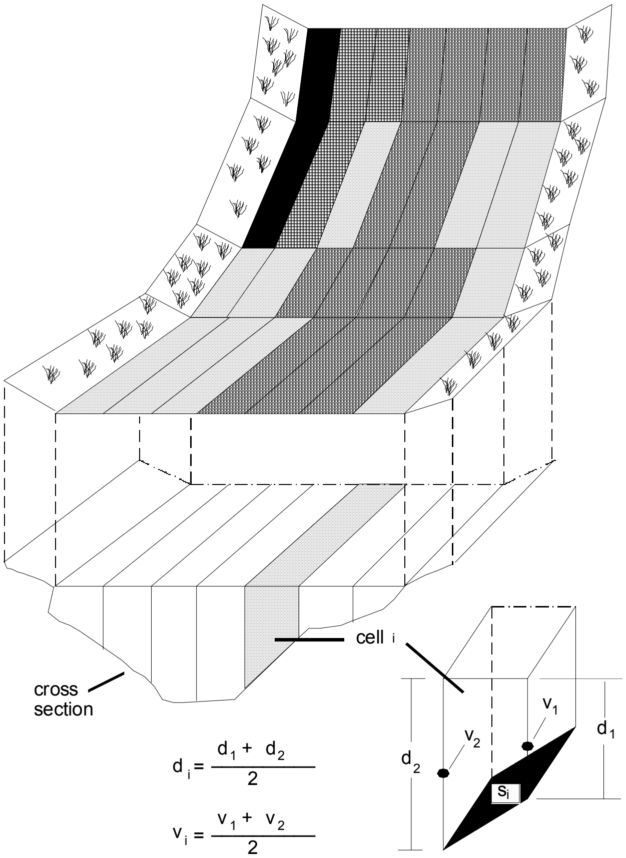


Figure 5.1. Conceptual representation of a stream reach by computational cells, with attributes of depth, velocity, and channel index, used in habitat modelling (from Hardy and Addley 2001).

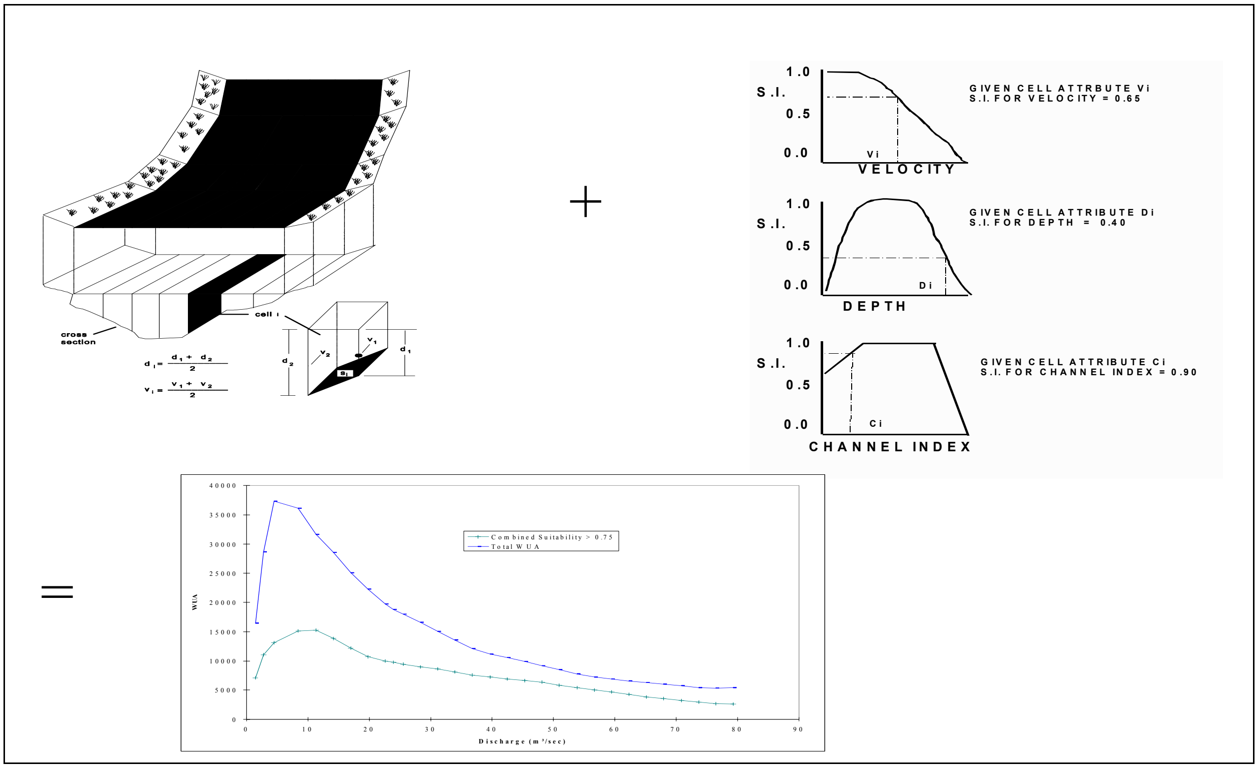


Figure 5.2. Calculation of component suitability index values for the depth, velocity and channel index that generates the WUA versus discharge function for a species and life stage (from Hardy and Addley 2001)

5.2 Site-specific Fish Habitat IFN Data for the SSRB

5.2.1 River Reach Delineation

River reaches had been defined for the Red Deer, Bow, Oldman, Belly, Waterton, and St. Mary rivers from previous IFN studies. The rivers were delineated according to the standard procedures outlined by the US Fish and Wildlife Service (Bovee 1982). Details of the specific procedures that were used are found in the reports that describe the original instream flow needs studies carried out on the Red Deer, Bow, Oldman, Waterton, Belly and St. Mary rivers (Fernet et al. 1990, EMA 1994, Golder & WER 1994, Golder 1999). The decision process for delineating the river into reaches was reviewed by the Technical Team, in consultation with fisheries biologists in Alberta Sustainable Resource Development (SRD). Based on this review, the original reach delineation was deemed acceptable.

The final river reaches selected for the SSRB review were based largely on the reaches defined by previous fish habitat IFN studies (Figure 3.2). Some minor modifications were made to the original reach delineations, to better accommodate the reach boundaries defined for the other ecosystem components and the reaches defined for the Water Resource Management Model (WRMM). Since the IFN values will be incorporated into the WRMM, it was decided by the Technical Team to try to accommodate the WRMM reaches as much as possible. Additional reach breaks were identified for the Red Deer River, particularly in the downstream reaches. The original fish habitat IFN here identified two reaches, whereas the WRMM uses four reaches. In these situations, the single PHABSIM site was used to calculate a single set of WUA curves that were then evaluated using the reach specific hydrology data.

Several reaches were also adjusted on the Oldman River to overlap the WRMM reach breaks. One major change to the Oldman reaches involved moving the reach boundary to start at the confluence of Pincher Creek and Willow Creek (see Reaches OM7 And OM5 in Figure 3.2). The St. Mary River was originally divided into four different reaches for the fish habitat IFN study. However, because only two study sites were measured, and there are only two different gauging stations, it was decided to reduce the number of reaches to two. The downstream reach boundary remained unchanged and the upper three reaches were combined into a single reach for the purpose of this review process.

5.2.2 Study Site Selection

Discussions on study site selection procedures for the original studies are found in the detailed IFN reports for each river (Fernet et al. 1990, EMA 1994, Golder & WER 1994, Golder 1999). Every PHABSIM study site defined within the SSRB applies the representative reach method, in which all the variability in habitat types present in the larger reach is represented within the selected study site (Bovee et al. 1998). Members of the Technical Team, in consultation with fisheries biologists of SRD, reviewed the study site selection process for these studies. Based on this review, the original selection of study sites was deemed acceptable for this study.

A total of 19 PHABSIM study sites were available from previous studies within the SSRB WMP study boundaries. These included:

- 4 study sites on the Red Deer River,
- 3 study sites on the Bow River,

- 6 study sites on the Oldman River, and
- 2 study sites on each of the St. Mary, Belly, and Waterton rivers.

The location of the study sites can be found in the original study reports (Fernet et al. 1990, EMA 1994, Golder & WER 1994, Golder 1999).

5.2.3 Hydraulic Modelling

All the original data collection and hydraulic modelling procedures were done according to standard PHABSIM protocols (Bovee 1982, Milhous et al. 1989) and are presented in the original IFN reports for each river (Fernet et al. 1990, EMA 1994, Golder & WER 1994, Golder 1999). The original calibration data files and model production data files were all available electronically as output files from the DOS-based PHABSIM computer models.

The original hydraulic data were sent to Utah State University (USU) for evaluation. This was done as a check on whether there were any errors in the original data decks and to use the latest hydraulic modelling techniques, procedures and practices to improve the calibration if and where necessary. The hydraulic data from the original IFN studies, which was a DOS-based format, were converted into the USU Windows version of PHABSIM, for ease of use in subsequent model runs. The Windows-based software allows the user to conduct the water surface elevation, velocity, and habitat modelling within the same interface and have the data stored in a single Microsoft® Access® database file. The software provides quicker model calibration, allows for graphical evaluations of the model outputs, and simplifies the data management requirements of PHABSIM modelling. The specific model calibration procedures are detailed below.

Water Surface Modelling

The determination of the relationship between the water surface (stage) and the discharge is the first step in hydraulic calibration and simulation phases of PHABSIM. The stage is used in the simulations to derive depth distributions for each cross section and to identify the location of the free surface to establish boundaries (i.e. wetted cell locations) for some of the equations that describe velocity distributions. If stage and bed elevation are known, depth may be determined at any location on the cross section by subtracting the bed elevation from the stage.

Several approaches may be used in the prediction of stage-discharge relationships. In PHABSIM this includes:

- linear regression techniques based on multiple measurements of stage and discharge (Stage-Q or IFG4);
- use of Manning's equation (MANSQ); and
- calculation of water surface profiles (WSP) using standard step backwater computations.

These three approaches represent the three main hydraulic modelling options within PHABSIM for water surface predictions.

Water surface modelling at each study site followed recognized guidelines for calibration and simulation of water surface elevations for the application of PHABSIM, as outlined in Bovee et al. (1998) and Hardy (2000b). In general, the calibration and simulation of water surface elevations for specific cross sections employed one or more of the following three models:

Stage-Q The Stage-Q model uses a stage-discharge relationship (rating curve) to calculate water surface elevations at each cross section. Implicit in this approach is analyzing each cross section independently of all others in the study reach. The basic computational procedure is conducted by performing a log-linear regression between observed stage and discharge pairs at each cross section. The resulting regression equation is then utilized to simulate water surface elevations at all flows of interest.

MANSQ The MANSQ program uses Manning's equation to calculate water surface elevations on a cross-section by cross-section basis. It therefore treats each cross-section independently. Model calibration is accomplished by a trial and error procedure to select a β coefficient that minimizes the error between observed and simulated water surface elevations at all measured discharge and water surface elevation pairs.

WSP The Water Surface Profile (WSP) program uses a standard step backwater method to determine water surface elevations at each cross section. The WSP program requires that all cross sections being analyzed in a given model run be dependent. That is, each cross section's hydraulic characteristics in terms of bed geometry and water surface elevations are measured from a common survey datum (bench mark). The model is initially calibrated to a measured longitudinal profile of the water surface elevations by adjusting Manning's roughness at each cross section, such that predicted and observed water surface elevations are acceptable. The model is then further calibrated by adjustment of roughness modifiers used within the model to other observed longitudinal profiles associated with other calibration discharges.

The specific equations for each of these models and their application to water surface modelling in PHABSIM can be found in Bovee et al. (1998) and Hardy (2000b).

The selection of a particular model(s) (i.e., Stage-Q, MANSQ, or WSP) for specific cross sections for specific flow ranges at each study site was based on a comparative evaluation of calibration and simulation results among the three models. This evaluation included a comparison of simulated and observed water surface elevations at each calibration flow and the behaviour of simulated water surface elevations at all simulated discharges to ensure that model outputs were rational (i.e., water flowed downhill between successive cross sections within the hydraulic modelling study site).

Calibration and simulation results for water surface elevations at each study site for each cross section were considered to meet acceptable standards of practice for the application of PHABSIM (see, Bovee et al. 1998, Hardy 2000b). The final water surface model definitions and calibration results for water surface elevations are reported in Hardy (2003) and are provided in Appendix C.

Velocity Modelling

The second major step in hydraulic modelling within PHABSIM involves the determination of velocity profiles at each cross section within the river. PHABSIM models velocities at one cross section at a time and, as such, treats the cross sections independently regardless of the model employed to generate the water surface elevations. Within PHABSIM, the IFG4 model is used for all velocity predictions. These are subsequently used in the habitat modelling components of the system. The specific equations and different approaches for velocity modelling and their application to simulation of velocity profiles in PHABSIM can be found in Bovee et al. (1998), and Hardy (2000b).

Velocity modelling at each study site followed recognized guidelines for calibration and simulation of PHABSIM data sets as outlined in Bovee et al. (1998), and Hardy (2000b). The specific IFG4 computational options (velocity calibration sets, use of cell specific Manning's n, Manning's n minimum/maximums) for individual cross sections for specific flow ranges was based on model predictions compared with calibration data. It also included reviews of the simulated model results of velocity predictions for the full range of simulated discharges.

The calibrations involved a comparison of simulated and observed velocities at each vertical for all cross sections, at all calibration flows. This included use of single and multiple velocity calibration sets (different velocity models) for each cross section. The calibrations used adjustments to individual cell Manning's n values, where poor simulation results at specific locations within a cross section were initially obtained. Once an adequate fit between observed and simulated velocity profiles at the calibration flows was obtained, the behaviour of the model predictions for the full range of simulated discharges was examined. The behaviour of the velocities in each cell of each cross section, for all simulated ranges of discharges, were examined to ensure model outputs were rational (i.e. velocity magnitudes in edge cells were within realistic ranges for computed cell depths).

Calibration and simulation results for velocities at each study site for each cross section were considered to meet acceptable standards of practice for the application of PHABSIM (Bovee et al. 1998, Hardy 2000b). Calibration and simulation results for velocities are reported in Hardy (2003) and are provided in Appendix C.

5.2.4 Selection of Target Species and Life Stages

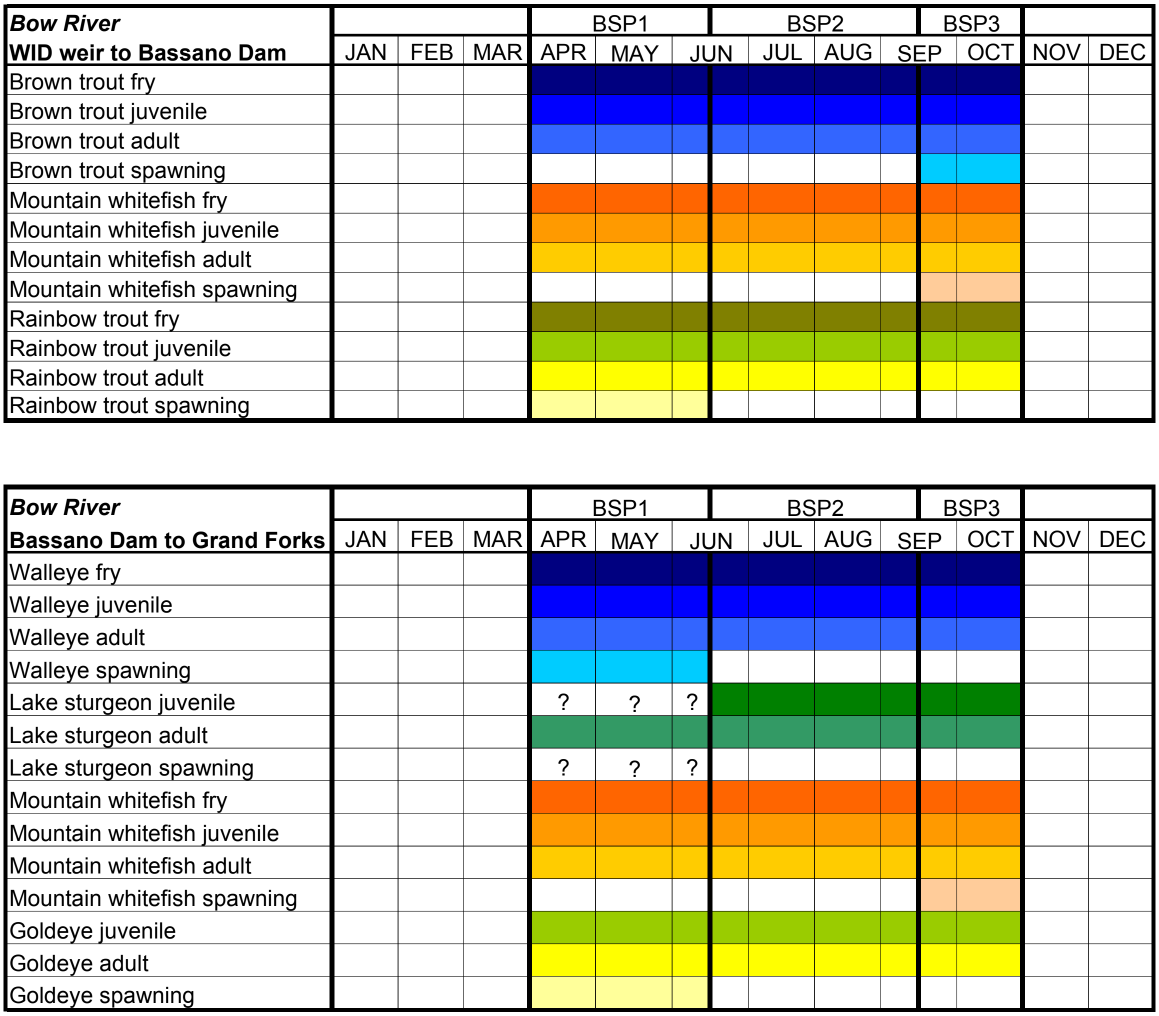
For the original studies, the list of species and life stages were derived from existing knowledge and through extensive discussions with regional fisheries biologists (Fernet et al. 1990, EMA 1994, Golder & WER 1994, Golder 1999). The selection of species for this study was based on the information contained in the previous reports and through examination of more recent knowledge and current discussions with regional fisheries staff.

Selecting a few sport fish species and life stages to represent all aquatic species is a concern with using these types of habitat models. Given quantification of the selected management species and life stages, consideration of other species and life stage life history needs, and professional judgment, it is assumed that flow protection for non-modelled species and life stages (e.g., sturgeon in the case of the South Saskatchewan and Oldman rivers, and other sport fish and non-sport fish species) will be met. This assumption has frequently been employed under similar circumstances in applied instream flow assessments, where specific species and life stages are used to represent indicator species or guilds for multi-species aquatic communities (Hardy 2000a).

This assumption is particularly problematic for sturgeon, since it is a much larger fish, with unique habitat requirements compared with the largest species for which data were collected such as rainbow trout. Without the ability to collect data on sturgeon, we simply had to rely on a much broader assumption that the integrated IFN would meet the life history requirements of the species. In the future, the specific habitat suitability criteria data for this species should be collected and directly factored into the fish habitat IFN requirement component.

5.2.5 Species and Life Stage Periodicities

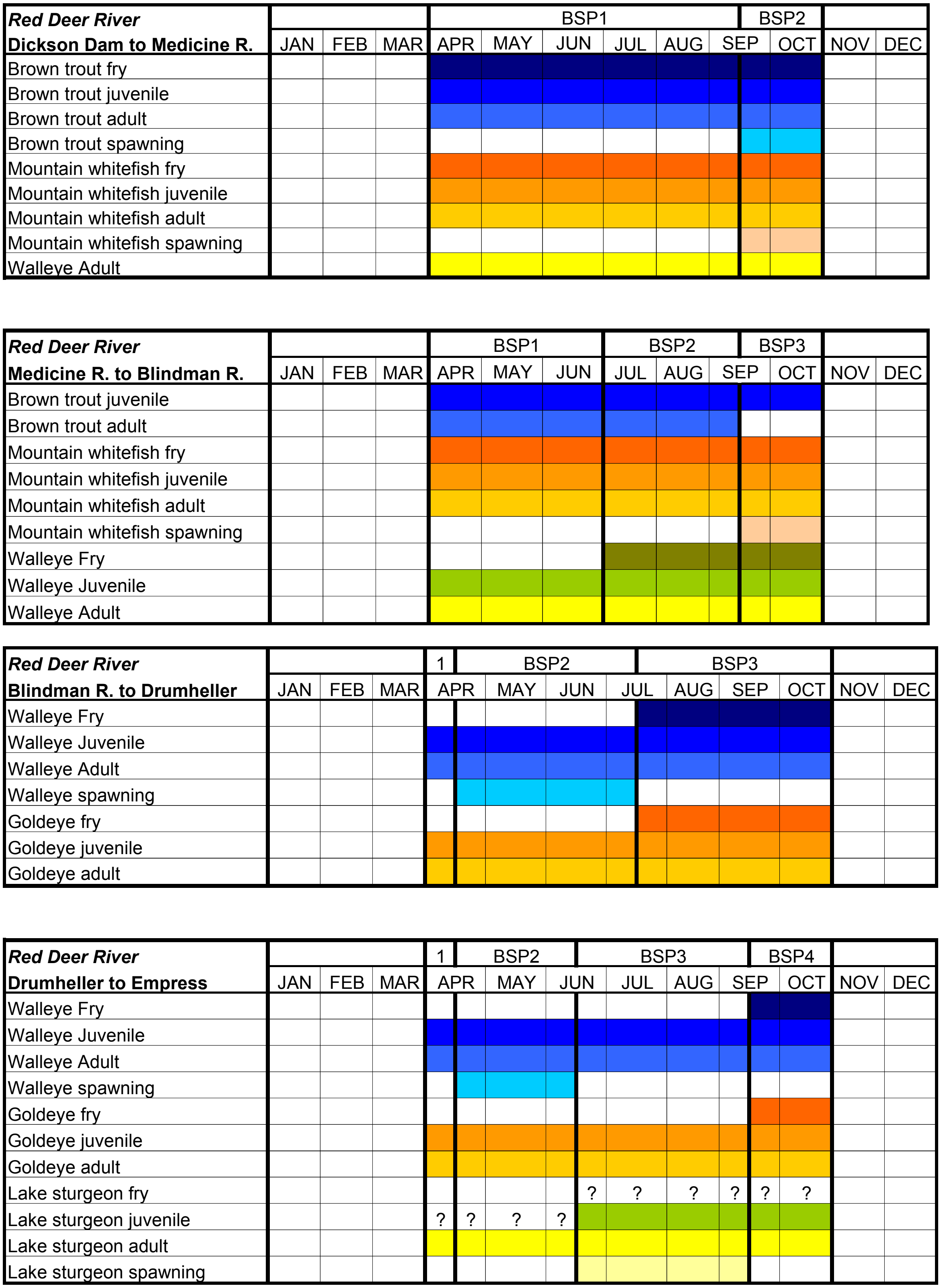
Species and life stage periodicity for the fish species within the South Saskatchewan River Basin were discussed with regional fisheries biologists at the time of the original studies and again for this study. All available existing fisheries data from the South Saskatchewan River Basin and additional literature on known species distributions and life stage periodicities were reviewed. The review included consideration of potential longitudinal and seasonal variation within the mainstem rivers in the South Saskatchewan River Basin. The species and life stage periodicity used in the assessment of instream flows is provided in Figures 5.3 through 5.6. A time period that has a common set of life stages present is referred to as a Biologically Significant Period (BSP) (Geer 1983). Winter or ice-covered months were not included in the analysis in any of the original IFN studies. As a result, the species periodicity tables only represent the open-water period. This in no way implies that some species and life stages are not present or do not over-winter in any of the reaches. It is, however, a reflection on the lack of a suitable tool to evaluate ice-covered conditions using standard IFN hydraulic modelling tools and a lack of under-ice habitat suitability data. As no new data were collected for the current evaluation, the ice-covered period was once again not included in the fish habitat portion of the analysis. For this study, as is the case with many other PHABSIM studies, only the sport fish of concern were modelled. Implicit in this is the assumption that sport fish serve as a surrogate for all fish species, including forage fish. In the future, data should be collected to verify this assumption.



Bow River				BSP1			BSP2				BSP3			
WID weir to Bassano Dam	JAN	FEB	MAR	APR	MAY	JUN		JUL	AUG	SEP		OCT	NOV	DEC
Brown trout fry				■	■	■	■	■	■	■	■	■		
Brown trout juvenile				■	■	■	■	■	■	■	■	■		
Brown trout adult				■	■	■	■	■	■	■	■	■		
Brown trout spawning											■	■		
Mountain whitefish fry				■	■	■	■	■	■	■	■	■		
Mountain whitefish juvenile				■	■	■	■	■	■	■	■	■		
Mountain whitefish adult				■	■	■	■	■	■	■	■	■		
Mountain whitefish spawning											■	■		
Rainbow trout fry				■	■	■	■	■	■	■	■	■		
Rainbow trout juvenile				■	■	■	■	■	■	■	■	■		
Rainbow trout adult				■	■	■	■	■	■	■	■	■		
Rainbow trout spawning				■	■	■								

Bow River				BSP1			BSP2				BSP3			
Bassano Dam to Grand Forks	JAN	FEB	MAR	APR	MAY	JUN		JUL	AUG	SEP		OCT	NOV	DEC
Walleye fry				■	■	■	■	■	■	■	■	■		
Walleye juvenile				■	■	■	■	■	■	■	■	■		
Walleye adult				■	■	■	■	■	■	■	■	■		
Walleye spawning				■	■	■								
Lake sturgeon juvenile				?	?	?	■	■	■	■	■	■		
Lake sturgeon adult				■	■	■	■	■	■	■	■	■		
Lake sturgeon spawning				?	?	?								
Mountain whitefish fry				■	■	■	■	■	■	■	■	■		
Mountain whitefish juvenile				■	■	■	■	■	■	■	■	■		
Mountain whitefish adult				■	■	■	■	■	■	■	■	■		
Mountain whitefish spawning											■	■		
Goldeye juvenile				■	■	■	■	■	■	■	■	■		
Goldeye adult				■	■	■	■	■	■	■	■	■		
Goldeye spawning				■	■	■								

Figure 5.3. Species periodicity charts for the Bow River. *Note: "?" identifies a data gap.*



Red Deer River				BSP1						BSP2			
Dickson Dam to Medicine R.	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP		OCT	NOV	DEC
Brown trout fry				■	■	■	■	■	■	■	■		
Brown trout juvenile				■	■	■	■	■	■	■	■		
Brown trout adult				■	■	■	■	■	■	■	■		
Brown trout spawning										■	■		
Mountain whitefish fry				■	■	■	■	■	■	■	■		
Mountain whitefish juvenile				■	■	■	■	■	■	■	■		
Mountain whitefish adult				■	■	■	■	■	■	■	■		
Mountain whitefish spawning										■	■		
Walleye Adult				■	■	■	■	■	■	■	■		

Red Deer River				BSP1			BSP2			BSP3			
Medicine R. to Blindman R.	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP		OCT	NOV	DEC
Brown trout juvenile				■	■	■	■	■	■	■	■		
Brown trout adult				■	■	■	■	■	■				
Mountain whitefish fry				■	■	■	■	■	■	■	■		
Mountain whitefish juvenile				■	■	■	■	■	■	■	■		
Mountain whitefish adult				■	■	■	■	■	■	■	■		
Mountain whitefish spawning										■	■		
Walleye Fry							■	■	■	■	■		
Walleye Juvenile				■	■	■	■	■	■	■	■		
Walleye Adult				■	■	■	■	■	■	■	■		

Red Deer River				1	BSP2				BSP3					
Blindman R. to Drumheller	JAN	FEB	MAR	APR		MAY	JUN	JUL		AUG	SEP	OCT	NOV	DEC
Walleye Fry									■	■	■	■		
Walleye Juvenile				■	■	■	■	■	■	■	■	■		
Walleye Adult				■	■	■	■	■	■	■	■	■		
Walleye spawning					■	■	■	■						
Goldeye fry									■	■	■	■		
Goldeye juvenile				■	■	■	■	■	■	■	■	■		
Goldeye adult				■	■	■	■	■	■	■	■	■		

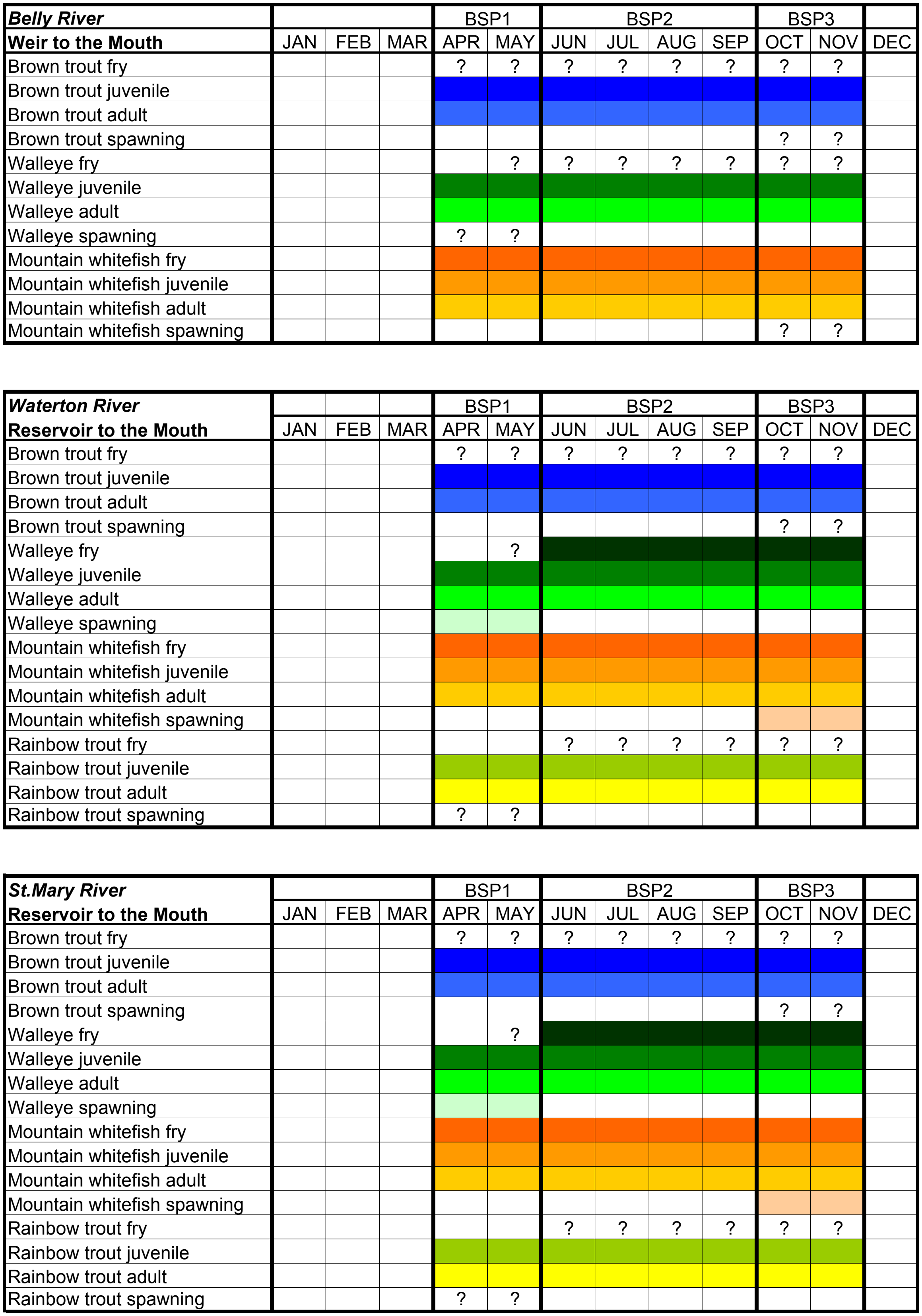
Red Deer River				1	BSP2			BSP3				BSP4			
Drumheller to Empress	JAN	FEB	MAR	APR		MAY	JUN		JUL	AUG	SEP		OCT	NOV	DEC
Walleye Fry												■	■		
Walleye Juvenile				■	■	■	■	■	■	■	■	■	■		
Walleye Adult				■	■	■	■	■	■	■	■	■	■		
Walleye spawning					■	■	■								
Goldeye fry												■	■		
Goldeye juvenile				■	■	■	■	■	■	■	■	■	■		
Goldeye adult				■	■	■	■	■	■	■	■	■	■		
Lake sturgeon fry								?	?	?	?	?	?		
Lake sturgeon juvenile				?	?	?	?	■	■	■	■	■	■		
Lake sturgeon adult				■	■	■	■	■	■	■	■	■	■		
Lake sturgeon spawning								■	■	■	■				

Figure 5.4. Species periodicity charts for the Red Deer River. *Note: "?" identifies a data gap.*

Oldman River				BSP1		BSP2				BSP3		
Oldman Dam to Willow Creek	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Brown trout fry				🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	
Brown trout juvenile				🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	
Brown trout adult				🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	
Brown trout spawning										🟦	🟦	
Mountain whitefish fry				🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	
Mountain whitefish juvenile				🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	
Mountain whitefish adult				🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	
Mountain whitefish spawning										🟧	🟧	
Rainbow trout fry						🟫	🟫	🟫	🟫	🟫	🟫	
Rainbow trout juvenile				🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	
Rainbow trout adult				🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	
Rainbow trout spawning				🟨	🟨							

Oldman River				BSP1		BSP2				BSP3		
Willow Creek to Grand Forks	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Brown trout fry				🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	
Brown trout juvenile				🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	
Brown trout adult				🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	
Brown trout spawning										🟦	🟦	
Walleye/ Sauger fry					?	🟩	🟩	🟩	🟩	🟩	🟩	
Walleye/ Sauger juvenile				🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	
Walleye/ Sauger adult				🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	
Walleye/ Sauger spawning				🟩	🟩							
Mountain whitefish fry				🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	
Mountain whitefish juvenile				🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	
Mountain whitefish adult				🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	
Mountain whitefish spawning										🟧	🟧	
Lake sturgeon juvenile				?	?	🟩	🟩	🟩	🟩	🟩	🟩	
Lake sturgeon adult				🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	
Lake sturgeon spawning						?	?	?	?			

Figure 5.5. Species periodicity charts for the Oldman River. *Note: “?” identifies a data gap.*



Belly River				BSP1		BSP2				BSP3		
Weir to the Mouth	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Brown trout fry				?	?	?	?	?	?	?	?	
Brown trout juvenile				🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	
Brown trout adult				🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	
Brown trout spawning										?	?	
Walleye fry					?	?	?	?	?	?	?	
Walleye juvenile				🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	
Walleye adult				🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	
Walleye spawning				?	?							
Mountain whitefish fry				🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	
Mountain whitefish juvenile				🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	
Mountain whitefish adult				🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	
Mountain whitefish spawning										?	?	

Waterton River				BSP1		BSP2				BSP3		
Reservoir to the Mouth	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Brown trout fry				?	?	?	?	?	?	?	?	
Brown trout juvenile				🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	
Brown trout adult				🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	
Brown trout spawning										?	?	
Walleye fry					?	🟩	🟩	🟩	🟩	🟩	🟩	
Walleye juvenile				🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	
Walleye adult				🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	
Walleye spawning				🟩	🟩							
Mountain whitefish fry				🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	
Mountain whitefish juvenile				🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	
Mountain whitefish adult				🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	
Mountain whitefish spawning										🟧	🟧	
Rainbow trout fry						?	?	?	?	?	?	
Rainbow trout juvenile				🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	
Rainbow trout adult				🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	
Rainbow trout spawning				?	?							

St.Mary River				BSP1		BSP2				BSP3		
Reservoir to the Mouth	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Brown trout fry				?	?	?	?	?	?	?	?	
Brown trout juvenile				🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	
Brown trout adult				🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	
Brown trout spawning										?	?	
Walleye fry					?	🟩	🟩	🟩	🟩	🟩	🟩	
Walleye juvenile				🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	
Walleye adult				🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	
Walleye spawning				🟩	🟩							
Mountain whitefish fry				🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	
Mountain whitefish juvenile				🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	
Mountain whitefish adult				🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	
Mountain whitefish spawning										🟧	🟧	
Rainbow trout fry						?	?	?	?	?	?	
Rainbow trout juvenile				🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	
Rainbow trout adult				🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	
Rainbow trout spawning				?	?							

Figure 5.6. Species periodicity charts for the St. Mary, Belly, and Waterton Rivers. *Note: "?" identifies a data gap.*

5.2.6 Habitat Suitability Criteria

Physical habitat modelling component assessments require that relationships between hydraulic properties and biological responses of target species and life stages be quantified. The common approach to defining these relationships is to develop Habitat Suitability Criteria. HSC represent how suitable the gradient of a factor (depth, velocity, substrate, or cover) is to a target species and life stage. HSC typically represent the suitability of a factor on a scale between 0.0 and 1.0. A suitability value of 0.0 represents a condition that is wholly unsuitable, while a 1.0 indicates a condition that is 'ideally' suitable.

In general, it is commonly considered most appropriate to develop site-specific HSC data from the river in which the instream flow assessment is undertaken. However, many factors, such as presence of predators, presence of introduced species, modified hydrology, or modified habitat, can make development of HSC from the target stream system both infeasible and/or undesirable. Poor field conditions, such as low water visibility or dangerously high flows, can also make collection of HSC data infeasible in many river systems on a seasonal basis.

When site-specific HSC cannot be developed, an alternate procedure is to assess the applicability of HSC from another river. This requires observational data for the target species and life stages in the stream under study, in order to attempt a validation or transferability test of the HSC. Existing methods for testing transferability of HSC (Thomas and Bovee 1993) are not generally accepted and are known to produce inconsistent results (Dunbar and Ibbotson 2001). In the South Saskatchewan River Basin, attempts at validating transferability of HSC curves has resulted in less than satisfactory results (Bjornson and Fernet 1989, Fernet et al. 1990, Fernet et al. 1992, Golder 1994, Golder 1999). In the absence of site-specific or transferable HSC data, a workshop, attended by fisheries biologists with expertise in the target species, is often held to review literature-based curves and any site-specific habitat use data from the region of interest and to set the HSC using professional judgment. This is perhaps the most commonly applied technique for HSC development for instream flow assessments in Canada, the United States, and elsewhere.

Hardy (2000a, 2001) provides an extensive discussion of the different types of HSC, different methods for their development, and practical implications of their use in physical habitat modelling. Specific details on how the HSC curves were derived for this study and details of the expert workshop process are provided in a separate report (Addley et al. 2003). The report contains an in-depth discussion that lays an objective foundation, from an ecological perspective, for the assessment of the techniques used to develop the HSC curves that were used in this study. The report also provides a detailed account on the history of HSC curve development in Alberta, the previous use of expert workshops in Alberta, and the underpinnings of the use of 'envelope' HSC curves in the context of ecological niche theory and applied science. The final HSC curves used in this study are presented in Addley et al. (2003).

Today, it is common practice when using the PHABSIM habitat suitability models to validate the model output by comparing model suitability values predicted for each simulated habitat cell in a modelled reach with empirical field observations of fish presence or absence. The validation procedure runs the model at the same discharges as when the fish observations were made. The model should predict good habitat, where fish were observed, and poor habitat, where fish were not observed. Because the exact locations of the fish observations were not recorded in the original studies, this type of validation is not possible using the existing data. Although a validation process was not possible for this study, the habitat suitability criteria were developed using a large pool of site specific data collected across southern Alberta. The data were reviewed by an expert panel of fish biologists with many years of regional experience to reflect the best available knowledge of the habitat that each species and life stage uses (Addley et al. 2003).

The majority of fish habitat use observations conducted for IFN studies in the SSRB have been collected by underwater observations. However, there are several common conditions that will result in underwater observations providing unsatisfactory results. In the Red Deer River, turbidity prevented efficient and accurate underwater observations. As well, life stages that hide in cover, particularly fry that often bury themselves amongst cobbles, are also difficult to observe directly. In both these cases, electro-fishing is often necessary to collect habitat use data. Golder (1999) used boat electro-fishing to collect the majority of habitat use data on the Red Deer River.

5.2.7 WUA Results for Each Reach

Physical habitat availability was calculated for each reach where an existing PHABSIM study site was available. The species and life stages used for each reach are identified in Figures 5.3 through 5.6. For all life stages except spawning, substrate or cover was not included in the calculation of fish habitat availability. The reason for this was two-fold:

- The original hydraulic decks used for recalibration were not consistent in the coding of substrate or cover and did not allow for an equal evaluation of habitat for every reach. Time did not permit the re-coding of each hydraulic data set using the original field notes to apply a consistent code for each reach.
- For a recent study carried out on the Highwood River IFN (Clipperton et al. 2002), a sensitivity analysis was conducted that compared the results of an analysis with and without the substrate code. Although the magnitude of the WUA curves may change, it was discovered that when the curves are normalized, which is a standard procedure, the shape of the WUA curves were virtually identical.

The channel index code (either substrate or cover) for each habitat unit remains as a constant within the PHABSIM models. This means that the channel index value does not change as different flows are modelled and the useable habitat calculation is then driven by the suitability of the depth and velocity at each flow modelled. The only apparent exception to this rule is when the channel index code contains a suitability criterion of zero preference for a certain range of substrate or cover. This is the case for spawning life stages that select suitable habitat based largely on suitable substrate and that avoid unsuitable substrate types. For all spawning life stages, a binary substrate code was used that indicated a preference of 1.0 for gravel (and for some species, small cobble.) All other substrate types were coded with a preference of 0.0.

Other life stages may be more typically associated with a certain type of substrate or cover type, but in general it has been the observation in the SSRB that older life stages of the target fish did not avoid suitable depth and velocity conditions based solely on substrate or cover. This issue has been discussed at recent HSC workshops (Courtney and Walder 1999, Clipperton et al. 2002, Addley et al. 2003), and although a range of suitability values could be assigned, it was believed that a suitability of zero, indicating absolute avoidance, was never warranted for substrate or cover. This rationale then did not justify the additional effort required to re-code all of the data files for a parameter that would have a minimal effect on the final result. However, it is recognized that other studies have shown that proximity to substrate/cover can be acritical habitat feature for fish (e.g. Orth 1987, EPRI 2000), and that juvenile fish may show some preference for cover to avoid predation. It is believed that the cover requirements of the older life stages of the target fish in the SSRB are not critical. If, in the future, cover is indeed found to be an important factor, then the necessary data should be collected.

Another common pattern observed time and again is the indication of peak habitat for fry life stages at very low flow. On occasion, the peak habitat is at a flow that is lower than historical low flows. The reason can be attributed to suitability criteria for fry life stages. Typically, fry inhabit shallow, slow habitats that can be found on the stream margins under normal flow conditions. In the habitat model, however, the largest area of habitat that meets the shallow and slow criteria will often occur at a very low flow, when the entire centre of the river channel is identified as suitable habitat. However, for many other reasons, such as the potential for high water temperatures, and fry having to share this habitat with larger fish, making them susceptible to heavy predation, the habitat at these lower flows is not likely ideal.

Within PHABSIM, there is the potential to develop conditional habitat suitability criteria in an attempt to create a more realistic picture within the models. Such criteria might indicate suitability for a range of depths and velocities if a certain cover type is present. They might also indicate suitability for a different range of depths and velocities when cover is absent. Another type of conditional curve that can be used in PHABSIM includes the evaluation of habitats in relation to adjacent conditions, such as distance from shore, distance from cover, or distance from holding habitats to feeding habitats. However, the information to create these types of curves was not collected in the original studies. Developing these curves would require additional field data collection. As indicated earlier in the report, the constraints of the project did not allow for collection of new data, and conditional curves were not created for this project. It is recommended that in the future, conditional criteria data be collected to develop HSC curves that better reflect habitat descriptors, such as distance from shore or cover, that are biologically relevant to the species and life stages of concern.

Using the re-calibrated hydraulic data (Section 5.2.3) and the HSC curves developed at the expert workshop (Section 5.2.6), WUA curves were developed for every life stage present in each different reach in the SSRB. Habitat computations were derived using a computer program based on the original PHABSIM models developed by the US Fish and Wildlife Service (see Sections 5.1.2 and 5.2.3 for descriptions of PHABSIM). The resulting WUA curves for each reach are presented in Appendix D. A sample set of WUA curves from the Oldman River is provided in Figure 5.7.

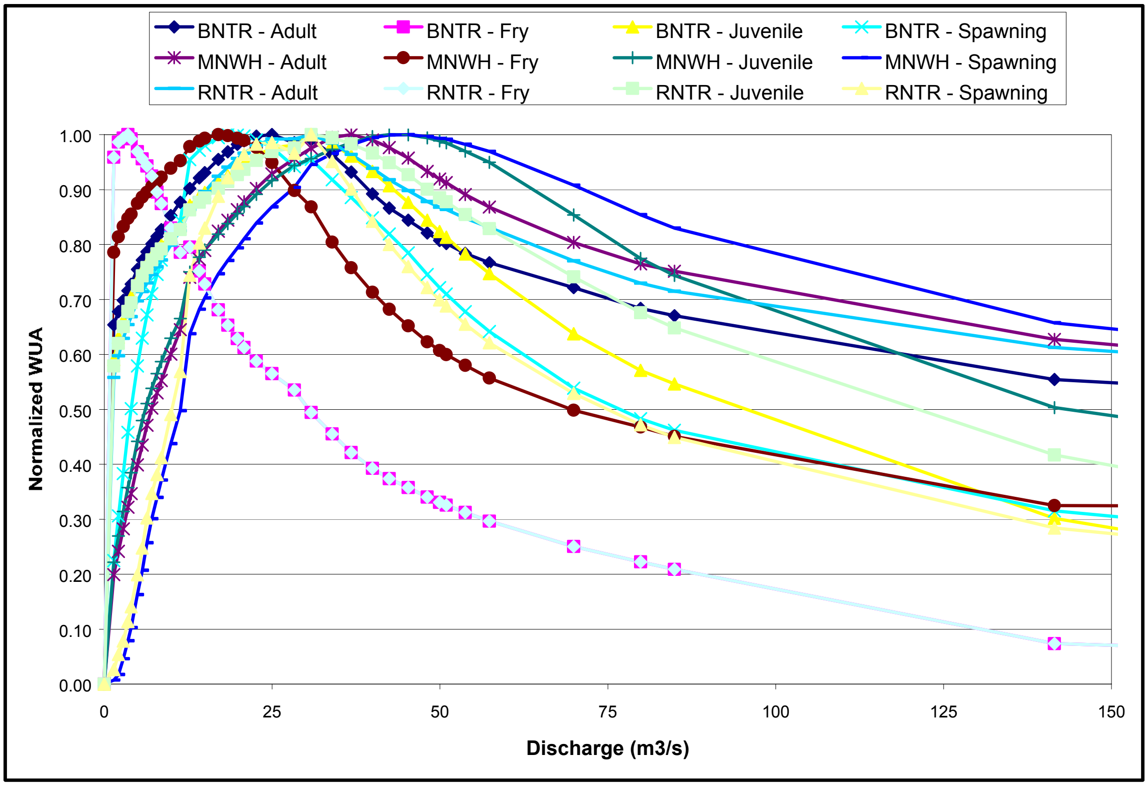


Figure 5.7. Oldman River Reach 6 (OM6) WUA curves for all target management species and life stages.

5.3 Fish Habitat IFN Determination Method

5.3.1 Background

In a recent study, a working group consisting of IFN experts was formed to develop an IFN determination for the Highwood River based on current scientific understanding and protocols, as directed by the Natural Resources Conservation Board (Clipperton et al. 2002). Despite the practical necessity of making IFN determinations throughout the world, there is no general agreement within the scientific community on a single method for making those determinations. It is important to note, however, that there is general agreement that a single flow determination will not protect nor is best for an ecosystem, nor is optimal for the full suite of organisms in an aquatic ecosystem.

As stated by Bovee (1982):

- A flow that is beneficial to one life stage may be detrimental to another life stage.
- A flow that is beneficial to one species may be detrimental to another.
- Various life stages and species may require different amounts of water at different times of the year.

- A flow that maximizes usable habitat in one part of the stream may not provide very much usable habitat in another part of the same stream.
- More water does not necessarily mean more habitat.

As part of the Highwood River IFN re-evaluation, Clipperton et al. (2002) reviewed several methods for developing an IFN determination, including the Fish Rule Curve. The Highwood River IFN Working Group adopted an ecosystem approach to recommending instream flow needs. This was deemed to be essential not only to protect long-term fisheries productivity, but also to ensure the sustainability of the ecosystem. It was decided by Clipperton et al. (2002) that a new evaluation protocol should be developed that better reflected the variable flow concepts of the Natural Flow Paradigm as described by Poff et al. (1997) and others (see discussion in Section 4.0).

A growing number of jurisdictions and agencies in the United States and throughout the world are adopting approaches that provide a variable flow recommendation that generally follows the concepts of the Natural Flow Paradigm. The specific methods and final format of the recommendations used in different jurisdictions varies, depending on site-specific water management issues. However, each has stressed the ecological necessity to establish a variable flow regime based on the natural range of hydrological variability. Some examples include:

- Southeast Australia (Arthington et al. 1991),
- River Babingley, England (Petss 1996),
- Trinity River, California (USFWS and Hoopa Valley Tribe 1999),
- Colorado River (Muth et al. 2000),
- Columbia River (Independent Scientific Group 2000),
- Nooksak River (Hardy 2000a),
- Klamath River Basin, California (Hardy and Addley 2001),
- Mokelumme River, California (McGurk and Paulson 2002), and
- South Africa (Brown and King 2002).

There is also widespread understanding in the scientific community that uncertainty is inherent in any IFN process. Decisions and assumptions at certain points in the process must be made based on professional judgment. Such assumptions and decisions are largely unavoidable, but an effort should be made to reduce the number of steps within a protocol that rely entirely on professional judgment. The approach developed by the Highwood River IFN Working Group was based, in part, on the desire to minimize arbitrary decisions and to provide an IFN description that could confidently be considered highly protective (Clipperton et al. 2002). The protocol that was developed for the Highwood River was adopted for the current SSRB IFN evaluations.

The basic concept of the Highwood River IFN Working Group protocol is to compare a series of constant-percent reductions from natural flow to the naturalized flow regime, and to evaluate each in terms of habitat losses relative to natural conditions. The protocol consists of five basics steps:

- Develop a series of constant-percent flow reductions from the naturalized flow, in 5% increments;
- Calculate the Ecosystem Base Flow (EBF);
- Identify high flow weeks to remove from the analysis;

- Conduct habitat time-series analyses for the natural flow and for each constant-percent flow reduction with the added constraint of the EBF; and
- Review the habitat evaluation metrics to identify the fish habitat IFN.

Instream flow needs are then defined in a weekly time-step and are presented in a flow exceedence curve format. The exceedence curve format provides an instream flow needs description that includes elements of flow variability similar to the natural intra- and inter-annual variations in flow. The weekly time-step accounts for the variability of the regional hydrology. In previous studies, the monthly time-step was found to be too coarse for the water mass balancing procedures that are typically done with the Water Resources Management Model (WRMM), as part of the water management planning process in this region.

5.3.2 Step 1: Percent Reduction in Flow from Natural

The first step in defining the full protection of the aquatic environment flow is to select a method for reducing flows from natural levels. There are a number of ways this could be done. One approach would be to vary the reduction of natural flow by season. However, this would add a level of complexity to the evaluation that is not necessary for a planning level study. For this study, the natural flow was reduced in even 5% increments, starting with a 5% reduction (i.e. 5%, 10%, 15%). A constant-percent flow departure from natural will maintain the pattern of natural flow variability both within and between years. In addition to retaining elements of temporal flow variability, this approach eliminates the relatively large changes in an IFN recommendation that can occur for relatively small changes in the natural flow when other approaches are used.

The natural flow data were obtained from Alberta Environment (2001b). The flow files used for each reach were confirmed with Alberta Environment to ensure compatibility with the flow files used in the WRMM.

5.3.3 Step 2: Defining The Ecosystem Base Flow

Another element the analysis approach addressed was the impact on habitat during naturally low flow periods. The Highwood River IFN Working Group believed that a constant-percent reduction from natural flows, if applied during periods when flows are naturally low (e.g., late summer, early fall), would likely result in significant negative impacts to habitat availability during those periods (Clipperton et al. 2002). The rationale provided by the Highwood River IFN Working Group for this is based on the observation that in many east slope streams in Alberta these low flow periods create potentially limiting habitat conditions, even under the natural flow regime. Based on this premise, a highly protective ecosystem IFN should not result in an increase in the frequency, duration, or magnitude of naturally limiting habitat conditions.

To address instream needs at low flows, a threshold flow value was defined below which the instream flow need was the natural flow. This threshold value was referred to as the Ecosystem Base Flow (EBF). The EBF was defined for each reach and was calculated on a weekly time-step so that the EBF value varies from week to week. Site-specific WUA curves and site-specific hydrology are required to calculate the weekly EBF values. Sale et al. (1981) proposed using habitat duration curves instead of flow duration curves to select an estimated instream flow need. A habitat duration analysis approach was incorporated into the Highwood River process to define the EBF (Clipperton et al. 2002).

The 80% habitat exceedence value represents a relatively limited habitat condition. Increasing the frequency of occurrence of limited habitat conditions is not desired in defining an IFN. The discharge corresponding to the 80% habitat exceedence value is defined as the EBF (Figure 5.8). The species life stage with the highest flow requirement, as determined by the site-specific WUA curves, was used to calculate the 80% habitat exceedence value. Habitat duration curves were then calculated for each week, using the natural flow data for each reach. Because the WUA curve typically has low habitat values associated with both high and low discharges, the actual 80% habitat exceedence value may be due to a high or low discharge in the period of record, depending on the week. The lowest discharge that corresponds with the 80% habitat exceedence value was selected as the EBF.

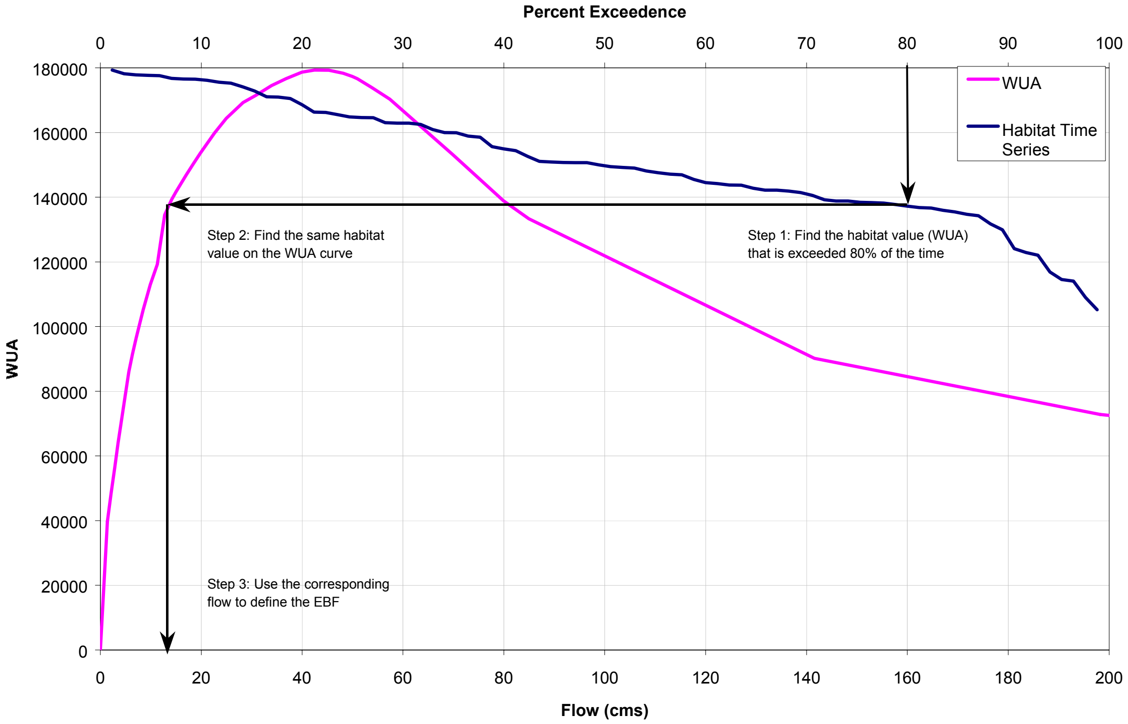


Figure 5.8. Example of the 80% habitat exceedence procedure for defining the EBF using the Week 33 habitat exceedence curve and the mountain whitefish juvenile WUA curve from the Oldman River Reach OM6. The EBF in this example is 13.6 m^3/s.

The Highwood River IFN Working Group also defined a method for protecting the seasonality of flows by modifying the EBF during the freshet period (Clipperton et al. 2002). To achieve protection during these weeks, the 95% flow exceedence value was calculated and the EBF was defined as either the weekly 95% flow exceedence discharge or the discharge corresponding to the 80% habitat exceedence value, whichever was greater.

This protocol was critical in the Highwood River process because additional information regarding riparian and channel maintenance flow requirements were not known. However, because riparian and channel maintenance flows were included in the SSRB WMP process, and are expected to meet fisheries needs during the freshet, the fish habitat analysis was removed from that period. The EBF for the weeks where fish habitat was included in the analysis was largely based on the discharge corresponding with the 80% habitat exceedence value.

5.3.4 Step 3: Determining Flows for Fish Habitat-Time Series Analysis

High flows often pose a problem in evaluating physical habitat for fish. There is an upper limit of flow where the validity of the fish habitat-based flow information (WUA curves) becomes questionable. WUA curves are based on two pieces of information, hydraulics and biology. The hydraulic data that are used have a limited range of extrapolation either above or below a measured or calibrated flow. More importantly, the information that is used to generate the HSC curves comes primarily from direct observations of fish. Fish habitat use at very high flows has rarely been sampled due to the physical limitations and safety considerations of collecting field data under high flow conditions.

In the higher flow ranges, normally from the beginning to the end of the spring freshet, other ecosystem tools should be used instead of WUA curves for fish. For example, it would be better to evaluate flows required for riparian vegetation needs, channel maintenance processes and other ecosystem processes dependent on high flows such as sediment transport, fish habitat forming processes, riparian seed dispersal, or invertebrate requirements. When considering flow ranges that are relevant for any of the ecosystem components there will always be some overlap.

Another limitation is that WUA curves are typically bell-shaped indicating the highest available habitat occurs at a specific flow and reduced habitat is present at both lower and higher flows. Higher flows can cause reduced habitat availability for fish due to high velocities. However, extremely high flows are typically short in duration and lower velocity habitat refugia are likely available to allow for survival in the short term. At extremely high flows, very large reductions from the natural flow can show an increase in fish habitat availability. Because riparian and channel maintenance flows are being evaluated as part of the SSRB process, it was decided to use only the fish habitat information for an appropriate flow range, as determined by the site-specific WUA curves and hydrology at each reach.

Following the method developed by the Highwood River IFN Working Group, an upper limit to the flow range for the habitat-time series analysis was defined (Clipperton et al. 2002). This was accomplished by removing weeks within the year that are beyond the evaluation range of a WUA curve. The criterion adopted by Clipperton et al. (2002) was to remove any week where the median flow was greater than the flow corresponding to the WUA peak that occurs at the highest flow for all of the life stages from the time series analysis. This step effectively removed the spring freshet from the fish habitat analysis. This does not mean that every individual flow datum point above the peak of the highest flow WUA curve was removed from the analysis. This approach removes only weeks where the majority of flows are beyond the limits of the WUA curves. Many individual flow records that are above the peaks of all of the WUA curves remain in the analysis.

5.3.5 Step 4: Conducting Habitat Time Series

Habitat time series for the constant-percent departure from natural flows were evaluated by examining the percent reduction in habitat availability. Time series evaluations are a highly recommended component of the instream flow incremental methodology (IFIM) as described by Bovee et al. (1998). The two basic requirements to conduct a habitat time series are WUA curves and stream discharge data.

The habitat suitability curves developed by a workshop process (Addley et al. 2003) and the recalibrated hydraulic models (see Section 5.2.3) were used to create new WUA curves for each reach in the SSRB where an existing PHABSIM study site was located (Section 5.2.7). The new

WUA curves were used to calculate the habitat time series for natural flow and for each constant-percent departure from the natural flow, for the period of record. Habitat time series were calculated, based on updated fisheries management objectives, for each management species and life stage identified for each reach.

A habitat time series is based on calculation of the available habitat for every discharge record used in the evaluation. For each discharge, a habitat value was calculated by linear interpolation between the two adjacent discharges represented in the WUA curve. The discharge records evaluated were based on mean weekly, naturalized flows from 1912 to 1995 (Alberta Environment 2001b). Only open-water season habitat was evaluated. This was defined as the period from Week 14 through Week 44 (approximately from the beginning of April to the end of October). Although there may be site-specific and seasonal differences in the duration and timing of the open-water season, a consistent period of evaluation was deemed suitable for the planning stage. Weeks at high flow conditions, as defined in Section 5.3.4, were also excluded from evaluation.

5.3.6 Step 5: Reviewing Evaluation Metrics

The overall strategy for determining instream flow needs for moderate and low flow periods was to identify an instream flow regime that would limit fish habitat reductions to amounts that would be generally be accepted as small, relative to the natural flow regime. The rationale is simply that if habitat reductions are limited to small amounts, it can reasonably be assumed a high level of protection has been provided by the IFN. Fish habitat is assumed to be an appropriate surrogate for providing ecosystem protection at low to moderate flows.

Several metrics were used to evaluate the effects of change in discharge relative to natural conditions. Each metric can be used to examine different effects of changes in flow, such as chronic (long-term) impacts, intermediate, or acute (short-term) impacts. The following metrics were calculated for each species and life stage at each reach:

1. **The change in total average habitat from natural.** The total average habitat was calculated for the naturalized flow regime and then compared against each incremental percent-reduction-from-natural-flow time series. The averages were computed from data for all weeks and all years, except for weeks removed as described in Section 5.3.4.
2. **Maximum weekly loss in average habitat.** The habitat averages for each week were calculated for all years (1912-1995) for the naturalized flow and then calculated for a 5%, 10%, 15% and so on departure from natural. The greatest percent loss from natural was reported.
3. **Maximum instantaneous habitat loss.** This was the greatest single percentage habitat loss recorded for all weeks in all years.
4. **Percent changes in average habitat.** These were calculated separately for the 50-90%, 10-50%, and 10-90% habitat exceedence ranges.
5. **Maximum weekly loss in average habitat.** This was calculated separately for the 50-90%, 10-50%, and 10-90% habitat exceedence ranges.
6. **Maximum yearly habitat loss.** This was calculated as the yearly average habitat loss, compared with natural, for the single worst year on record.

Although all habitat metrics were reviewed, the change in total average habitat, the maximum weekly loss in average habitat, and the maximum instantaneous habitat loss (metrics 1, 2, and 3 respectively), were viewed as the most useful metrics for making comparisons.

The difference in total average habitat (metric 1) was viewed as an indicator of chronic effects of flow reduction on both habitat availability and the aquatic ecosystem over the long term. This metric included data pooled across all weeks (except for weeks removed as described in Section 5.3.4) and for the entire period of record from 1912-1995. It was considered that a reduction in total average habitat of less than 10% could be considered small in the context of the magnitude of uncertainties inherent in the habitat calculations. A high level of protection would be provided with overall average habitat losses of less than 10%.

The maximum weekly loss in average habitat (metric 2) was considered to be an indicator of intermediate chronic effects of flow reduction on habitat availability and the aquatic ecosystem over an intermediate length of time. Many of the data points for some of the weeks included in the analysis of total average habitat loss will indicate a habitat gain with reduced flows relative to natural. To ensure that habitat gains in some weeks were not masking major habitat losses in other weeks, the maximum weekly loss in average habitat was used as an evaluation metric. This metric would detect problems with specific times of the year. A threshold value slightly higher than that used for the average habitat metric was used, given the shorter period of time represented by this metric. A threshold value of 15% was adopted for the maximum weekly loss in average habitat.

The final key evaluation metric chosen was the maximum instantaneous habitat loss (metric 3). This metric is based on the habitat available for the natural flow, during each individual week for the period of record and for each of the constant-percent flow departures from natural. Although the term instantaneous is used, the habitat values being evaluated are actually weekly averages, because a weekly time-step was used for all of the modelling. The maximum instantaneous habitat loss represents acute effects on habitat availability and the aquatic ecosystem. Because the other two evaluation metrics were based on averaged data, a check was needed to ensure that large habitat losses were not being masked in the longer-term evaluations. The rationale for including this metric was that an instantaneous habitat loss, if of sufficient magnitude, might result in significant changes to the ecosystem that could persist over a much longer time period than the duration of the acute habitat reduction. The threshold value for this metric was defined as an instantaneous habitat loss of 25%. This higher threshold is considered appropriate because the habitat reduction is expected to be short-term. Because the habitat values used are based on weekly modelling, the actual instantaneous loss for a single day, or for hours within a day, could be higher than 25%.

No single habitat evaluation metric can adequately assess the change in habitat from natural. Impacts of the same habitat loss are greater if it is long-term rather than short-term. By using all three metrics, we have a measure of impacts on habitat that are long-term chronic (difference in average habitat), seasonal or short-term chronic (maximum weekly loss in average habitat), and acute (maximum instantaneous habitat loss).

Each species and life stage identified for each reach was included in the final analysis and evaluation metrics were calculated for each life stage. The life stage negatively-impacted the most dictated whether habitat loss criteria were exceeded, because all other life stages would have had smaller habitat losses or habitat gains. The rationale for this approach is that by protecting the highest flow requirements and the life stage with greatest sensitivity to habitat loss, all life stages with lower flow requirements will also be protected within a variable flow regime.

5.3.7 Summary of the Final Approach

The final approach developed by Clipperton et al. (2002) has many advantages compared with the other methods available. The approach utilizes site-specific habitat data that are available, the concept and implementation is straightforward relative to the other methods, it considers chronic and acute impacts to the ecosystem, and it follows the Natural Flow Paradigm. The following summary outlines the steps in the application of this analysis approach.

1. Flow time series were created as a constant-percent reduction from natural, in even 5% increments, based on naturalized weekly average flows. Using a constant-percent departure from the natural flow regime as an IFN recommendation ensures the integrity of the natural flow regime is preserved.
2. In the reaches where site-specific fish habitat data did not exist, the hydrological flow statistic was used to determine the EBF. In the reaches with habitat data, selecting the greater of the 95% exceedence flow or the 80% habitat retention flow was used. In some instances, using only the 80% habitat retention value did not adequately account for the hydrographic transition from spring runoff to late season base flow. While there are no precedents for this approach, our goal was to make every attempt to ensure the intra-annual variability of flow, relative to the natural flow regime, was maintained. Further biological grounding regarding the setting of the EBF is critical and it is recommended this work be carried out in the future.
3. A flow range, based on an evaluation of site-specific WUA curves for all life stages, was determined for conducting the habitat time series analysis. All weeks with a median flow greater than the flow corresponding to the WUA peak that occurs at highest flow were removed from the habitat time series analysis. This effectively removed the spring freshet from the habitat time series analysis. The rationale for this step in the analysis is provided in Section 5.3.4.
4. A habitat time series was constructed for the naturalized-flow time series and for each percent-reduction from natural flow time series. Evaluation metrics were calculated for each biologically significant period (BSP) and for the entire open-water season (excluding weeks removed in step 3) for all life stages present in each reach. The available habitat for each of the percent-reduction from natural flow time series, with the added constraint of the EBF, was compared against the habitat available under the natural flow by using several evaluation metrics. The key evaluation metrics and thresholds are:
    - a 10% loss in total average habitat from natural;
    - a 15% maximum weekly loss of average habitat from natural; and
    - a 25% maximum instantaneous habitat loss from natural.
5. Starting with the 5% departure from the natural-flow time series, each metric was checked to see if it met or exceeded the defined thresholds. If the criteria were met, then the 10% departure from the natural flow regime was evaluated through a similar time series analysis. This was repeated for each flow-reduction time series, in 5% increments, until at least one of the three evaluation criteria was exceeded. The fish habitat IFN was then initially defined as the preceding flow reduction time series where all of the evaluation criteria are met.

All the evaluation metrics, for each life stage and each BSP, were reviewed for outliers. The results were also reviewed to determine if all of the metrics were following a consistent pattern of habitat loss. Based on this review, the final fish habitat IFN was either left unadjusted as determined by the evaluation metric thresholds, or it was defined as a different constant-percent flow reduction using professional judgment. Each reach was evaluated on a case-by-case basis in this manner.

5.3.8 Modification for the South Saskatchewan River Basin

At the onset of the fish habitat evaluations, the protocol as defined in the Highwood River IFN process (Clipperton et al. 2002) was to be applied without modification. However, due to the larger number and different types of reaches being evaluated relative to the Highwood River, several modifications to the method were required in the process of developing the fish habitat IFN.

As described above, the high flow weeks identified for removal from the fish habitat analysis were not included in the final fish habitat IFN because riparian and channel maintenance IFN information were available during those weeks of the year. In the Highwood River IFN process, the fish habitat recommendation was extrapolated to the higher flow weeks as a surrogate for these other ecological processes that were not directly measured (Clipperton et al. 2002). In some instances, all weeks (from week 14 – 44) had median flows higher than the flow at the peak of the furthest right WUA curve. In these situations, the evaluation proceeded with weeks 16 – 36 removed from the analysis. The reason for selecting these weeks is that they provide a one-week overlap with the riparian evaluation (week 15 in the spring and week 37 in the fall) for the integration process.

The WUA curve that peaks at the highest flow was used to calculate the 80% habitat exceedence flow, to define the EBF for the Highwood River. However, in some reaches of the SSRB, two or more WUA curves peaked at the same flow, and occasionally a spawning life stage had a WUA curve that peaked at the highest flow. If two life stages had the same or similar peaks, the life stage with the fastest rate of habitat loss as flows were reduced was chosen. In cases where a spawning life stage had the highest WUA curve peak, one of two steps was taken. Initially, a life stage that is present year-round was used to define the ecosystem base flow (EBF) and to identify the high flow weeks. When reviewing the evaluation metrics, for Reaches RD4 and RD5 on the Red Deer River, the spawning life stage was showing very large habitat losses. In this case the EBF was calculated using the spawning life stage for the spawning weeks, in combination with the initial EBF defined using the life stage present year round for the remaining weeks.

A spawning life stage was often the first life stage to exceed one or more of the key evaluation metrics at the lowest constant-percent reduction from the natural flow. The IFN method defined for the Highwood River process used a single flow reduction and applied it across all the different BSPs (Clipperton et al. 2002). This was an acceptable practice when the most habitat limiting life stage is present year-round. Because spawning life stages are only present during a specific period within the year, it would be difficult to justify an IFN for the entire year defined solely on the spawning life stage. To balance the IFN across the entire year, while maintaining the original method of using a single flow reduction for the entire open-water season, the spawning life stages were occasionally allowed to exceed the defined thresholds. Caution was used in this approach, because there is the potential danger of creating a bottleneck by limiting the amount of spawning habitat. A future approach could be to adjust the fish habitat recommendation on more of a seasonal basis. However, a method to conduct this type of evaluation has not been developed, and hence was not applied for the SSRB.

The Highwood River IFN Working Group determined that commonly occurring low flows during the latter portion of the open-water season were very likely limiting, even under natural conditions (Clipperton et al. 2002). As such, the EBF value from week 33 was extended for all remaining weeks in the open-water season and replaced the 80% habitat duration flow calculated for those weeks. The rationale and method for modifying the EBF calculation for the Highwood River were consensus-based decisions made by the Working Group (Clipperton et al. 2002). For the SSRB evaluation, the final EBF was left unadjusted as the weekly 80% habitat exceedence flow, since replicating the consensus process used for the Highwood River was not possible at this stage in the planning process. Leaving the EBF unmodified does not mean habitat is not naturally limiting at low flow periods for some reaches throughout the SSRB. Additional information is required to identify reaches where frequent low flow conditions are naturally limiting. Adjustments to the EBF could be made, if required, when an IFN is to be implemented.

The largest adjustment to the Highwood River protocols required for their use in the present project was in the interpretation of the habitat evaluation metrics. In an ideal situation, all the evaluation metrics would show a similar pattern of habitat loss and all would exceed the defined thresholds at approximately the same flow reduction. This was generally the pattern for the Highwood River. (Clipperton et al. 2002) acknowledged that an adjustment to the IFN could be made after reviewing the more detailed evaluation output, if any alarming results were found. However, no method or protocol was developed for evaluating the other metrics or for determining an appropriate IFN when the three key metrics showed an inconsistent pattern of habitat loss.

Some patterns of habitat loss that arose in the SSRB did not follow the ideal pattern. These were likely due to a combination of site-specific hydraulics, channel geometry, and the WUA curves of the reach being evaluated. In some cases, large maximum instantaneous losses were found, while many of the other metrics showed very small habitat losses or even habitat gains. This occurred, for example, when a reach contained an island and maximum instantaneous habitat losses were observed in the high flow range, due to bimodal WUA curves. Sharp changes in the slope of the WUA curve as a result of combining low- and high-flow habitat models can also produce results with high maximum instantaneous losses and limited average and weekly habitat losses. A final situation where this pattern was common occurred if life stages, such as rainbow trout and walleye spawning, were only present during higher flow weeks.

Although these maximum instantaneous habitat losses are occurring, it is not necessarily indicative of a general pattern of habitat loss. The maximum instantaneous habitat loss is a telling metric of acute habitat conditions. However, it must be considered in context of the other metrics that evaluate intermediate and chronic habitat conditions. These results should not be ignored. The level of risk at which these large maximum instantaneous habitat losses may cause ecological problems is unknown but it may be more appropriate to deal with isolated maximum habitat losses at an operational level, rather than at the current planning study level. To overcome this problem, expert judgment was used to develop an instream flow need that was reflective of acute and chronic habitat losses for all species, at all times of the year. Balancing and compromising between yearly habitat losses and losses within specific BSPs was required. Future development of the fish habitat evaluation method could potentially resolve some of these shortfalls. However, due to the constraints of the planning phase, adjustments to the existing method were not possible. The evaluations provided in this report are considered to be valid and suitable for the current planning exercise.

5.4 Fish Habitat IFN Results and Discussion

The following section summarizes the fish habitat IFN results for each reach evaluated in the SSRB. Site-specific fish habitat results were developed for the open-water season only. To remain consistent for the SSRB evaluation, the open-water season was defined as week 14 through week 44 (beginning of May to the beginning of November) for every reach.

The results for each reach are expressed as a percent reduction from the natural flow, with an associated EBF. A summary table is provided with the key habitat evaluation metrics, showing the species that triggered the IFN. The detailed results showing all the habitat evaluation metrics for each reach, for all species and life stages, are located in Appendix E. The results from this section are subsequently incorporated with the other ecosystem components to create the final integrated ecosystem IFN (Section 9.0).

Each species and life stage that was identified as a management priority within a reach and that had HSC curves available was evaluated. The only exception to this was for the evaluation of lake sturgeon. Habitat use data for lake sturgeon in Alberta are unavailable. Some general habitat descriptions and swimming speed information were available to generate draft HSC curves during the HSC workshop (see Section 5.2.6). However, workshop participants had little or no experience with lake sturgeon. As a compounding factor, the site selection for the original IFN studies did not consider lake sturgeon as a target management species. As such, the location of the study sites may not be representative of the specialized habitat of lake sturgeon. Although lake sturgeon remains an important management species for some reaches within the SSRB, they were not included in the IFN determination at this stage in the process. The habitat requirements for lake sturgeon need to be more fully addressed in reaches where they have been identified as target management species when defining the IFN.

Reach balancing is another issue that has not been addressed in the results presented in this section. The IFN determinations may not follow the natural pattern of increasing flows from upstream to downstream. This variation has been observed and accounted for in other IFN studies in Alberta (Fernet et al. 1990, Golder 1999,) and elsewhere (H. Beecher and T. Annear, 2003, personal communication). The fish habitat results for this study were left unmodified for inclusion in the integrated IFN.

Figure 5.9 shows the reaches where site-specific PHABSIM study sites were available to develop the fish habitat IFN results. Reaches defined as having good site-specific data are indicative of locations where the hydraulic and habitat modelling results provide good quality data, over a wide range of flows, that require a minimal level of adjustment prior to analysis. Reaches defined as having acceptable site-specific data are indicative of locations where the hydraulic and habitat modelling results are good, but either a limited flow range was modelled or there was a poor transition between high and low flows. This can result in WUA curves with multiple peaks or WUA curves that do not mesh neatly in the transition from low to high flows. WUA can be adjusted prior to use in the habitat evaluation to mitigate inconsistencies. In cases that indicate poor site-specific data, the hydraulic calibration was determined to be unsuitable for further analysis. In locations that indicate no site-specific data, a PHABSIM study site was not available.

In reaches with either poor or no site-specific data, the Tessmann method (Tessmann 1979) was used in lieu of a site-specific habitat evaluation. The Tessmann method is the current office-based standard applied in Alberta for determining IFN at locations with no site-specific data available. It is a hydrology method that is derived from the Tennant method (Montana method) commonly used throughout North America (Tennant 1976). A monthly flow recommendation is calculated based on an evaluation of the mean annual flow and mean monthly flow. The recommendation is then transformed into a weekly recommendation for application in Alberta.

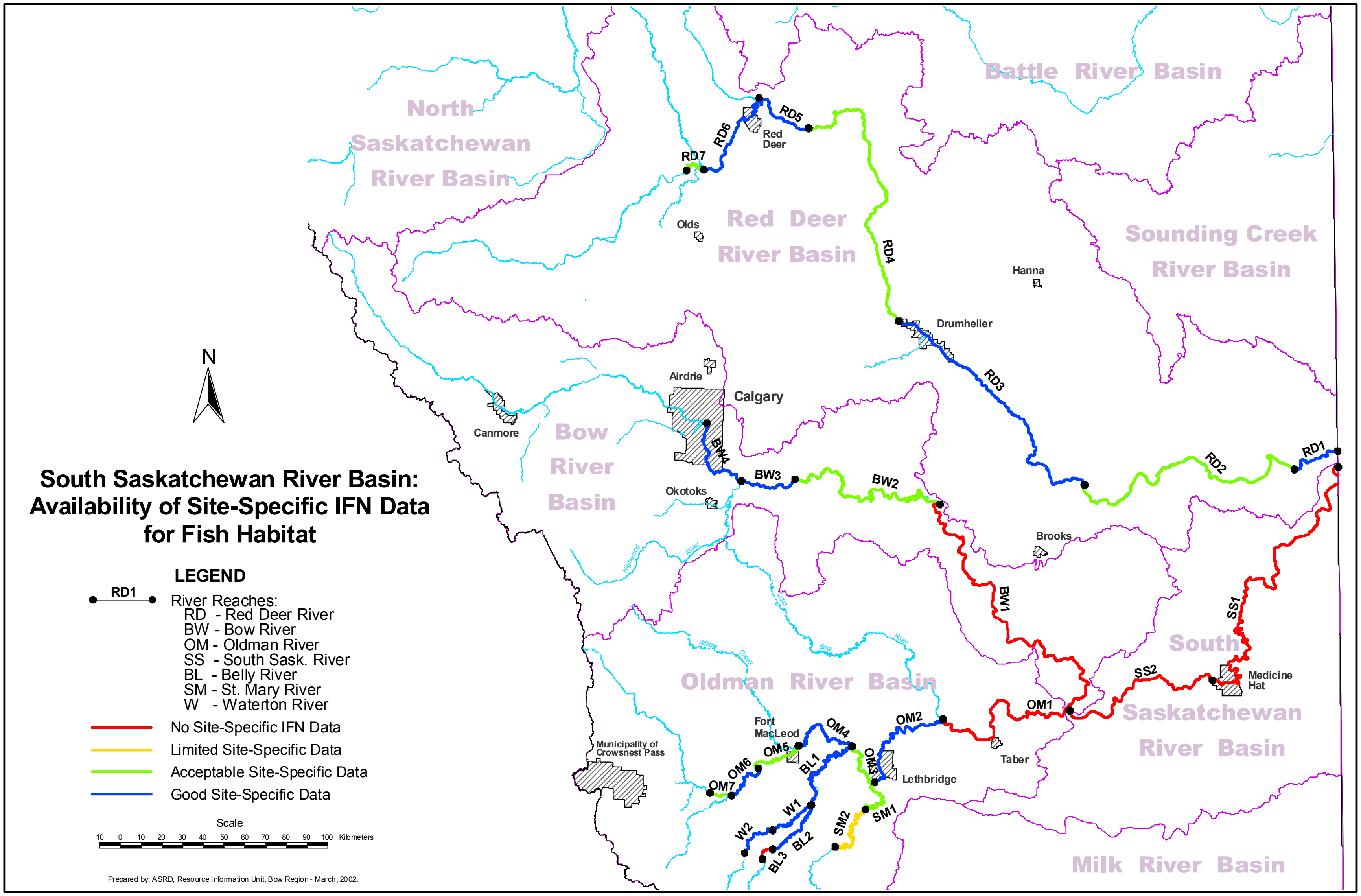


Figure 5.9. Availability of site-specific fish habitat IFN (PHABSIM) study sites used to develop the fish habitat IFN determination for the SSRB WMP.

5.4.1 Winter Ice-Covered IFN for Fish Habitat

For the purpose of this evaluation, the winter ice-covered period was defined to be from week 45 through week 13, (i.e. November – March) for every reach. The scope of this project did not allow for individual consideration of the average timing of the ice-covered period on a reach-by-reach basis. Therefore the same weeks were used for every reach. There is a growing body of knowledge that under-ice habitat is just as critical, and potentially even more critical, as habitat during the open-water times of the year (Power et al. 1993, Cunjak 1996, Cunjak 1996, Tesaker 2000, Prowse 2001, Alfredsen and Tesaker 2002). Tesaker (2000) noted that the formation and presence of ice strongly influences many variables. He stressed that "modification of geometry of flow may change the winter habitat to the better or worse."

Many scientists now understand that ice formation and break-up processes can significantly affect a variety of biological, hydrological and geomorphological processes (Beltaos 1995). The manner of formation and the type of ice present can affect (1) migration of fish under ice, (2) variation of velocity during ice formation and break-up, (3) long-term influence of ice on local fish populations and types of fish, (4) available physical winter habitat, and (5) bedload scour and sediment transport. Consequently, instream flow studies and recommendations based solely on the needs of aquatic organisms and habitat characteristics observed in the open-water period provide only a partial understanding of important ecological processes (Maki-Petays et al. 1999; Whalen et al. 1999). At this time, there are no known tools available to better define the instream flow recommendations for under-ice conditions. The province of Alberta and the Department of Fisheries and Oceans (Canada) are currently investigating the development of tools for the ice-covered time of year. Until better tools are available, the calculated Tessmann values will be recommended for the winter period for the SSRB WMP.

5.4.2 Red Deer River Fish Habitat IFN Results

Red Deer River Reach 1 (RD1)

The fish habitat IFN determination for RD1 is a 20% reduction from the natural flow, with the added weekly constraint of the EBF. The habitat-limiting life stages in this reach are walleye spawning and goldeye adults (Table 5.1). The key evaluation metrics that approach the defined thresholds in this reach are the maximum instantaneous habitat losses and the maximum weekly habitat losses. Although not defined as a primary metric, the maximum yearly habitat losses also show that, in some years, habitat losses are becoming large for some life stages. All the evaluation metrics show a trend of increasing habitat losses with continued reductions from the natural flow. The maximum weekly habitat loss for walleye spawning exceeds the defined threshold by a fraction of a percent in the IFN. However, all other metrics remained below the thresholds. Therefore, the results for a 20% flow reduction shown in Table 5.1 are considered to be protective of fish habitat in this reach.

The goldeye adult Weighted Useable Area curve peaks at a flow of 92.21 m^3/s. It is used to define the EBF (Figure 5.10) and to identify the wet weeks to be removed from the analysis. Weeks 23-28 have weekly median flows that are greater than the peak of the goldeye adult WUA curve and are removed from the analysis of the total mean habitat loss. The walleye spawning WUA curve peaks at a flow of 119.51 m^3/s, but was not used to define a portion of the EBF because the habitat losses for spawning were considered to be protected using the goldeye adult values for the entire year.

Table 5.1. Red Deer River Reach 1 (RD1) from the Saskatchewan Border upstream to near Bindloss. Habitat evaluation metrics for a 20% reduction from the natural flow with the added constraint of the EBF.

Species	Total Mean (Weeks 14-22: 29-44)	Maximum Weekly	Maximum Instantaneous	BSP2 Total Mean (Weeks 16-23)	Maximum Yearly
WALL-S	N/A	**-15.36%**	**-23.44%**	-6.21%	-20.16%
GOLD-A	-6.02%	-12.02%	**-22.54%**		-11.56%

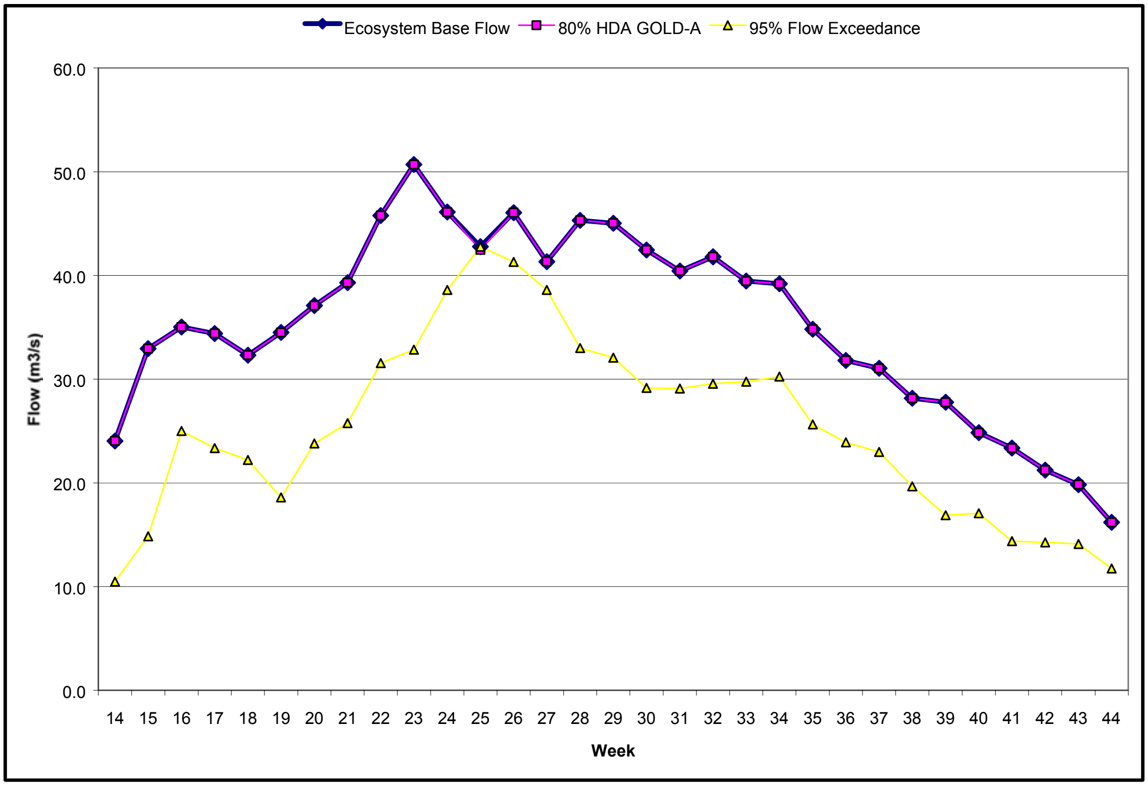


Figure 5.10. The weekly Ecosystem Base Flows for the Red Deer River Reach 1 (RD1), using the maximum value between the 80% habitat duration analysis for goldeye adult and the 95% flow exceedence.

Red Deer River Reach 2 (RD2)

In the current evaluation, reach boundaries were adjusted to overlap with the reaches used in the WRMM model. The reach boundaries defined in the initial fish habitat IFN study (Golder 1999) identified a single reach that contains the current reaches RD1 through RD3. The flow differences between Reaches RD1 and RD2 are minor. Since a separate study site to evaluate fish habitat was not available, the results from RD1 were applied directly to this reach.

Red Deer River Reach 3 (RD3)

The same study site used for the RD1 evaluation was also used for the RD3 evaluation, because Reach RD3 was contained wholly within a single reach as defined in the initial fish habitat IFN study (Golder 1999). All the WUA curves for RD3 are identical to those for RD1 because the study site is the same for both reaches. The only difference in the evaluation between RD3 and RD1 is the hydrology used for the time series evaluation.

The fish habitat IFN determination for RD3 is a 20% reduction from the natural flow, with the added weekly constraint of the EBF. The habitat limiting life stages in this reach are walleye spawning and goldeye adults (Table 5.2). The key evaluation metrics that approach the defined thresholds in this reach are the maximum instantaneous habitat losses and the maximum weekly habitat losses. The maximum weekly habitat loss for walleye spawning marginally exceeded the 15% habitat loss threshold. However, because the other key metrics for walleye spawning were still below the thresholds, and the weekly metric only exceeded the threshold by a fraction of a percent, the 20% flow reduction from natural was considered to be highly protective. All the evaluation metrics for every life stage show a trend of increasing habitat losses with continued reductions from the natural flow.

Table 5.2. Red Deer River Reach 3 (RD3) from Dinosaur Provincial Park upstream to Drumheller. Habitat evaluation metrics for a 20% reduction from the natural flow with the added constraint of the EBF.

Species	Total Mean (Weeks 14-22: 28-44)	Maximum Weekly	Maximum Instantaneous	BSP2 Total Mean (Weeks 16-23)	Maximum Yearly
WALL-S	N/A	**-15.17%**	**-23.42%**	-7.41%	-20.96%
GOLD-A	-6.22%	-11.24%	**-22.52%**		-10.99%

The goldeye adult WUA curve peaks at a flow of 92.21 m^3/s and is used to define the EBF (Figure 5.11) and to identify the wet weeks to be removed from the analysis. Weeks 23-27 have weekly median flows that are greater than the peak of the goldeye adult WUA curve and are removed from the analysis of the total mean habitat loss. The walleye spawning WUA curve peaks at a flow of 119.51 m^3/s, but was not used to define a portion of the EBF since the habitat losses for spawning were protected using the goldeye adult values for the entire year.

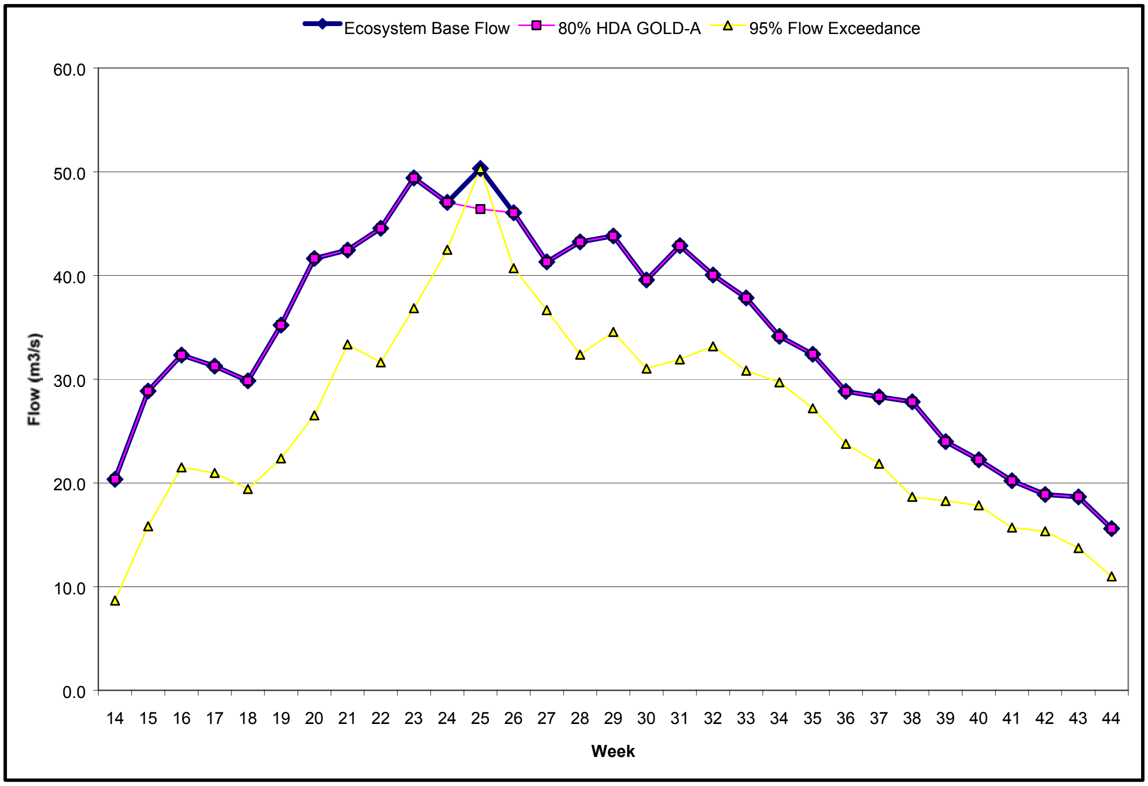


Figure 5.11. The weekly Ecosystem Base Flows for the Red Deer River Reach 3 (RD3) using the maximum value between the 80% habitat duration analysis for goldeye adult and the 95% flow exceedence.

Red Deer River Reach 4 (RD4)

Reaches RD4 and RD5 were identified as a single reach in the original fish habitat IFN study (Golder 1999). As such, a fish habitat evaluation was only conducted for RD5, and the results from RD5 were directly applied to RD4.

Red Deer River Reach 5 (RD5)

The fish habitat IFN determination for RD5 is a 25% reduction from the natural flow, with the added weekly constraint of the EBF. The habitat limiting life stages in this reach are walleye spawning, walleye adults, and goldeye adults. The key evaluation metric that approached the defined threshold in this reach is the maximum instantaneous habitat loss.

The results from this reach did not show a clear pattern of habitat loss across all the different metrics. As seen in Table 5.3 with walleye adult, although there was a large maximum instantaneous loss, the other metrics indicated habitat gains at the defined IFN. This can be caused by having WUA curves that peak at a relatively low flow compared with the typical hydrology of the site. In contrast, the goldeye adult results show a consistent pattern of habitat loss, but the values are well below the defined thresholds.

Table 5.3. Red Deer River Reach 5 (RD5) from the SAWSP diversion site upstream to the Blindman River confluence. Habitat evaluation metrics for a 25% reduction from the natural flow with the added constraint of the EBF.

Species	**Total Mean (Weeks 14:35-44)**	**Maximum Weekly**	**Maximum Instantaneous**	**BSP2 Total Mean (Weeks 16-28)**	**Maximum Yearly**
WALL-A	+4.72%	+0.11%	-18.37%		+2.34%
WALL-S	N/A	-5.74%	**-32.82%**	+4.88%	-13.16%
GOLD-A	-2.55%	-5.65%	-10.59%		-4.96%

The maximum instantaneous loss for walleye spawning exceeded the defined threshold criteria. However, the other metrics indicate a less definitive pattern of habitat loss. Continued reductions from the natural flow resulted in very large maximum instantaneous habitat losses for walleye spawning, and a steady increase in the maximum yearly loss. Several other life stages evaluated showed habitat losses below the thresholds, but did increase with continued reductions from natural flow. Other life stages showed habitat gains for most metrics other than the maximum instantaneous habitat loss metric. The resulting fish habitat IFN determination was judged to be the best balance of habitat reductions between all of the life stages.

The goldeye adult WUA curve peaks at a flow of 49.55 m^3/s and the walleye spawning WUA curve peaks at a flow of 77.83 m^3/s. Both curves are used to define the EBF (Figure 5.12), with the walleye spawning curve used for weeks 16-28 and the goldeye adult used for all remaining weeks. The goldeye adult curve was used to identify the wet weeks to be removed from the analysis. Weeks 15-34 have weekly median flows that are greater than the peak of the goldeye adult WUA curve. However, weeks 16-34 were removed from the analysis of the total mean habitat loss to provide a one-week overlap with the riparian descriptions and to ensure a smooth transition between these components in the spring.

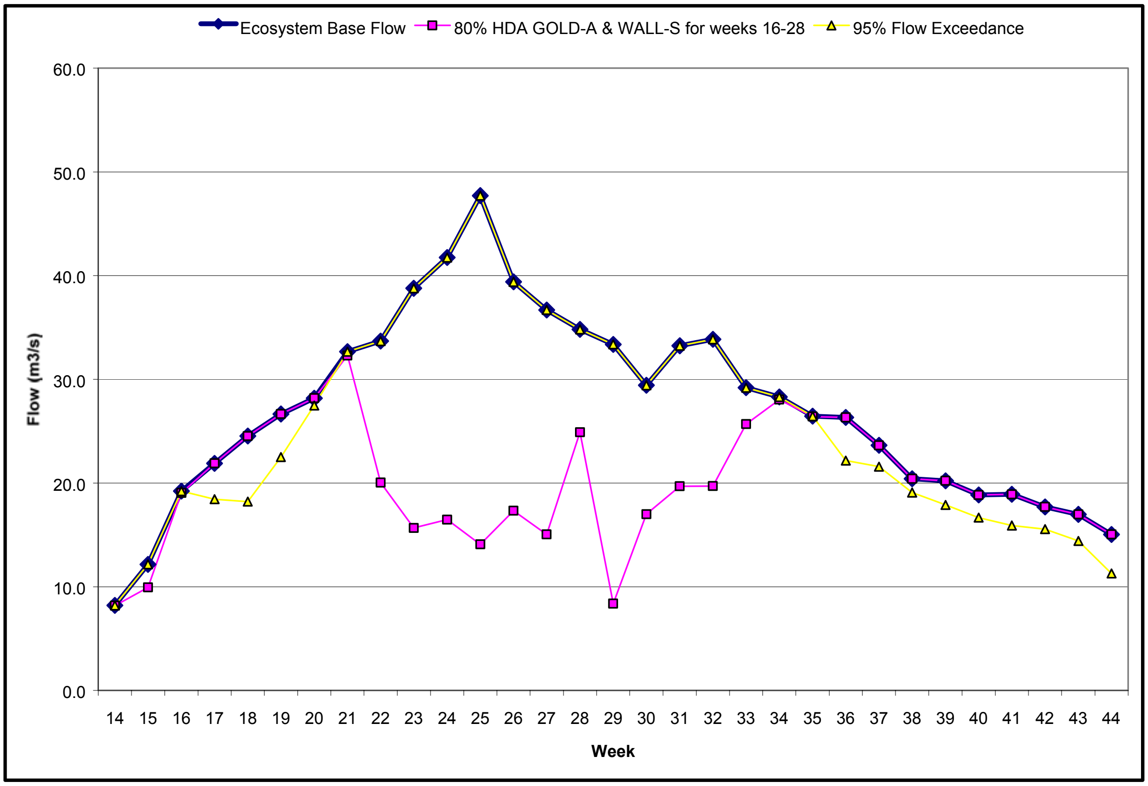


Figure 5.12. The weekly Ecosystem Base Flows for the Red Deer River Reach 5 (RD5) using the maximum value between the 80% habitat duration analysis for goldeye adult and walleye spawning and the 95% flow exceedence.

Red Deer River Reach 6 (RD6)

The fish habitat IFN determination for RD6 is a 20% reduction from the natural flow, with the added weekly constraint of the EBF. The habitat limiting life stage in this reach is mountain whitefish spawning (Table 5.4). The key evaluation metrics that approach the defined thresholds in this reach are the maximum instantaneous habitat losses and the maximum weekly habitat losses. The total mean habitat loss for BSP3, the time of year when mountain whitefish spawning occurs, also shows a large habitat loss. Most of the evaluation metrics, for most of the life stages, show a trend of increasing habitat losses with continued reductions from the natural flow.

Although the evaluation metrics for mountain whitefish spawning are exceeded at a 20% reduction in flow from natural, a 15% reduction from natural met all of the defined criteria. However, because mountain whitefish spawning only occurs in BSP3, the IFN determined for the entire year was deemed to be a compromise between the results for the spawning life stage and the remaining life stages that are present year round. Continued reductions in flow result in very rapid declines in habitat for mountain whitefish spawning and a steadily increasing trend of habitat loss across all of the metrics for most of the other life stages.

The mountain whitefish adult WUA curve peaks at a flow of 113.2 m^3/s and is used to define the EBF (Figure 5.13) and to identify the wet weeks to be removed from the analysis. There are no weeks that have a weekly median flow greater than the peak of the mountain whitefish adult WUA curve. As a surrogate for the analysis, the typically wettest weeks, from mid-May to mid-July (weeks 20-29), are removed from the analysis of the total mean habitat loss.

Table 5.4. Red Deer River Reach 6 (RD6) from the Blindman River confluence upstream to the Medicine River confluence. Habitat evaluation metrics for a 20% reduction from the natural flow with the added constraint of the EBF.

Species	**Total Mean (Weeks 14-19: 30-44)**	**Maximum Weekly**	**Maximum Instantaneous**	**Total Mean BSP3**	**Maximum Yearly**
MNWH-A	-5.03%	-9.92%	-14.66%	-8.13%	-7.12%
MNWH-S	N/A	**-18.47%**	**-30.57%**	**-13.59%**	-24.53%

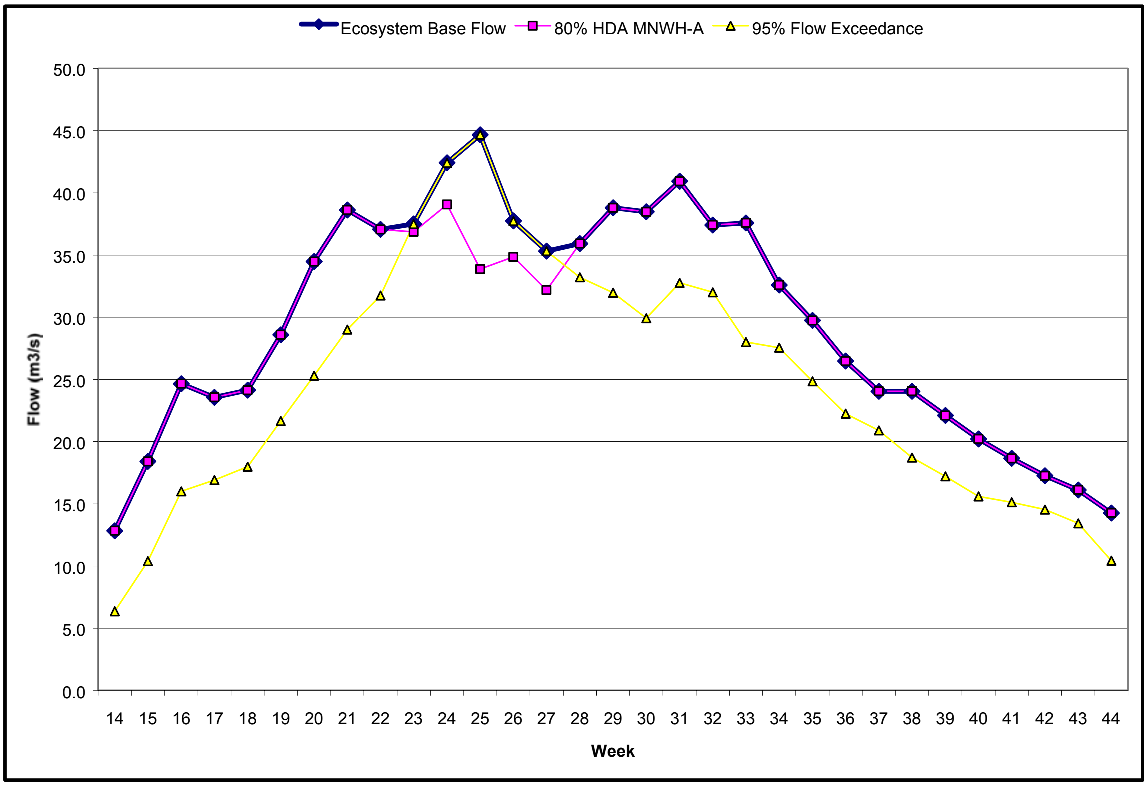


Figure 5.13. The weekly Ecosystem Base Flows for the Red Deer River Reach 6 (RD6) using the maximum value between the 80% habitat duration analysis for mountain whitefish and the 95% flow exceedence.

Red Deer River Reach 7 (RD7)

The fish habitat IFN determination for RD7 is a 25% reduction from the natural flow, with the added weekly constraint of the EBF. The habitat limiting life stage in this reach is walleye adult (Table 5.5). The key evaluation metrics that approach the defined thresholds in this reach are the maximum instantaneous habitat losses and maximum weekly habitat losses. The maximum instantaneous habitat loss for walleye was allowed to exceed the threshold criteria, while the maximum weekly habitat loss is very close to the defined threshold. However, the total mean habitat loss metric for walleye adult is fairly low, and the 25% flow reduction IFN selected is believed to provide a balance between acute and chronic habitat losses. All the other life stages show a trend of increasing habitat losses with continued reductions from the natural flow.

Table 5.5. Red Deer River Reach 7 (RD7) from the Medicine River confluence upstream to the Dickson Dam. Habitat evaluation metrics for a 25% reduction from the natural flow with the added constraint of the EBF.

Species	**Total Mean (Weeks 14-19: 30-44)**	**Maximum Weekly**	**Maximum Instantaneous**
WALL-A	-1.01%	**-12.82%**	**-27.45%**
BNTR-A	-2.47%	-8.49%	-20.09%
MNWH-J	-5.49%	-7.91%	-14.29%

The mountain whitefish juvenile WUA curve peaks at a flow of 226.4 m³/s and is used to define the EBF (Figure 5.14) and to identify the wet weeks to be removed from the analysis. There are no weeks that have a weekly median flow greater than the peak of the mountain whitefish juvenile WUA curve. As a surrogate for the analysis, the typically wettest weeks, from mid-May to mid-July (weeks 20-29), are removed from the analysis of the total mean habitat loss.

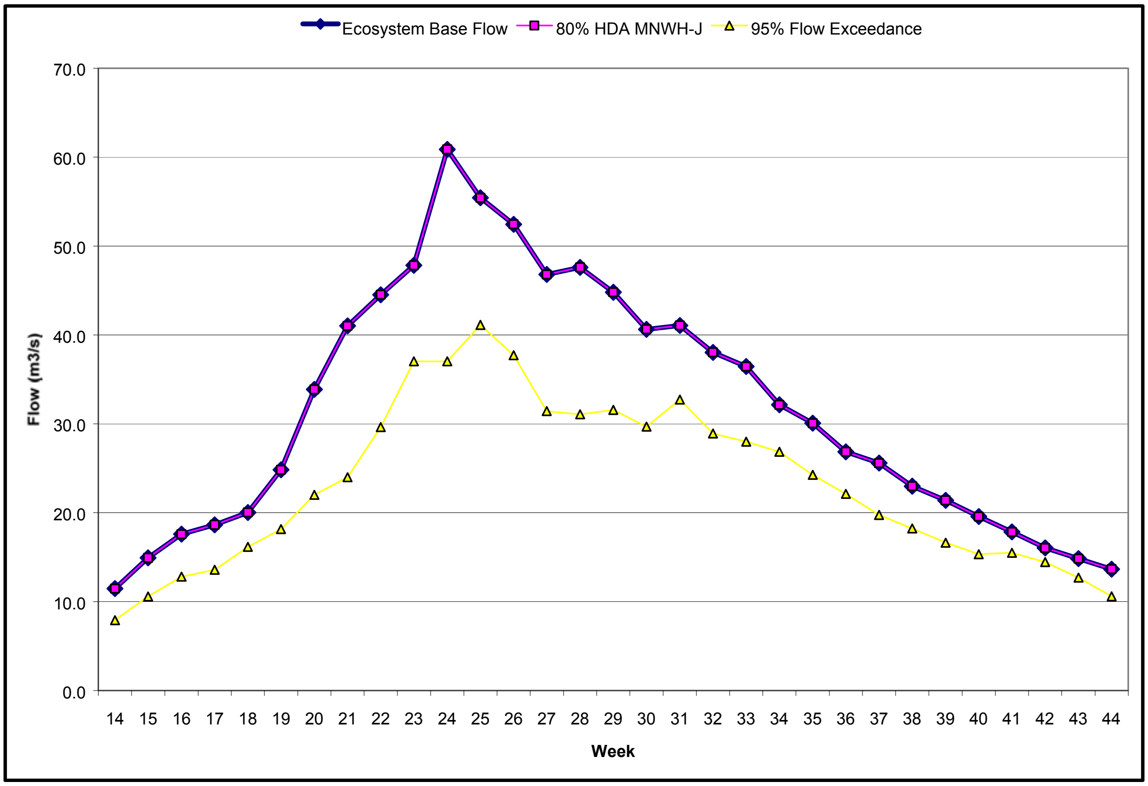


Figure 5.14. The weekly Ecosystem Base Flows for the Red Deer River Reach 7 (RD7) using the maximum value between the 80% habitat duration analysis for mountain whitefish juvenile and the 95% flow exceedence.

5.4.3 Bow River Fish Habitat IFN Results

Bow River Reach 1 (BW1)

Reach-specific PHABSIM data are not available for the Bow River from the Grand Forks (the confluence with the Oldman River) upstream to the Bassano Dam. The species composition for this reach of the Bow River also differs from the immediate upstream reach, which does not allow for a transfer of results to this reach. The EBF for fish habitat was developed using the Tessmann calculation for the entire year (Figure 5.15). These values must be combined with the other components to develop the ecosystem IFN.

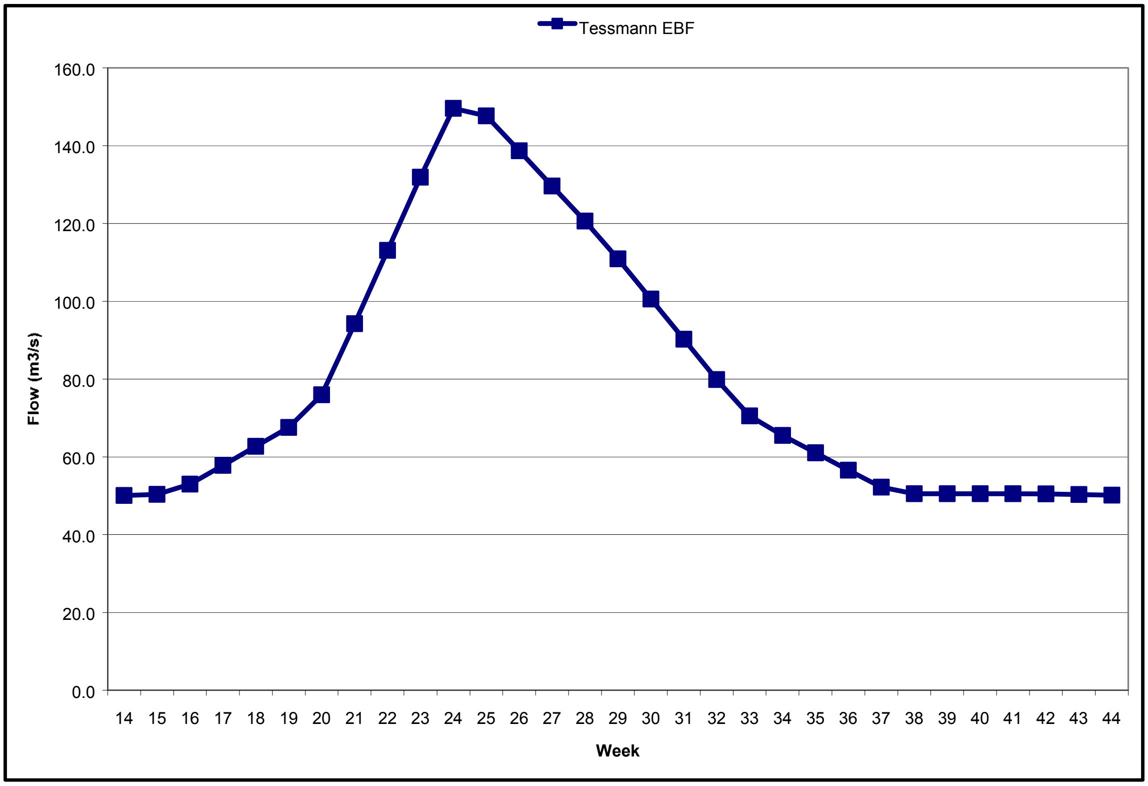


Figure 5.15. The weekly Ecosystem Base Flows for the Bow River Reach 1 (BW1) using the Tessmann calculation.

Bow River Reach 2 (BW2)

The fish habitat IFN determination for BW2 is a 25% reduction from the natural flow, with the added weekly constraint of the EBF. The habitat limiting life stages in this reach are brown trout and rainbow trout adults and brown trout fry (Table 5.6). The key evaluation metrics that approach the defined thresholds in this reach are the maximum instantaneous habitat losses and maximum weekly habitat losses. The total mean habitat loss for BSP2, which covers most of the year, is also provided to illustrate chronic habitat losses.

The WUA curves for most life stages in this reach indicated two distinct habitat peaks, one at a low flow and a second at a moderate to high flow. This pattern appears to be a result of side channels that become inundated at higher flows and begin to form useable habitat. Due to the bimodal nature of the WUA curves, the pattern of habitat loss with some of the different metrics was not consistent and several metrics indicate habitat gains with increased flow reductions. As an example, the brown trout fry results for maximum instantaneous habitat loss exceed the defined criteria, while the more chronic measure of habitat loss shown for BSP2 indicates a habitat gain. The weekly habitat loss for brown trout adults exceeds the defined threshold by a very small margin, while all other metrics meet the threshold criteria. The defined IFN of a 25% flow reduction is judged to be protective and provide a suitable balance between acute and chronic habitat losses.

Table 5.6. Bow River Reach 2 (BW2) from the Bassano dam upstream to the Carseland weir. Habitat evaluation metrics for a 25% reduction from the natural flow with the added constraint of the EBF.

Species	**BSP2 Total Mean (Weeks 23-39)**	**Maximum Weekly**	**Maximum Instantaneous**
BNTR-F	+7.98	**-13.75%**	**-26.30%**
BNTR-A	-6.45	**-15.58%**	**-23.92%**
RNTR-A	-6.46	**-14.68%**	**-23.48%**

The mountain whitefish juvenile WUA curve peaks at a flow of 42.5 m^3/s and is used to define the EBF (Figure 5.16) and to identify the wet weeks to be removed from the analysis. Every week has a weekly median flow greater than the peak of the mountain whitefish juvenile WUA curve. Thus, a calculation of total mean habitat for the entire year was not available. The change in the mean habitat was still calculated for each BSP and provides some indication of longer-term habitat changes from natural. The habitat changes for BSP2, which spans a majority of the open-water season, is presented in Table 5.6. For the purpose of integrating the fish habitat results with the other components, weeks 14-15 and 37-44 were used. This allows for a one-week overlap with the riparian descriptions and ensures a smooth transition between these components in the spring and the fall.

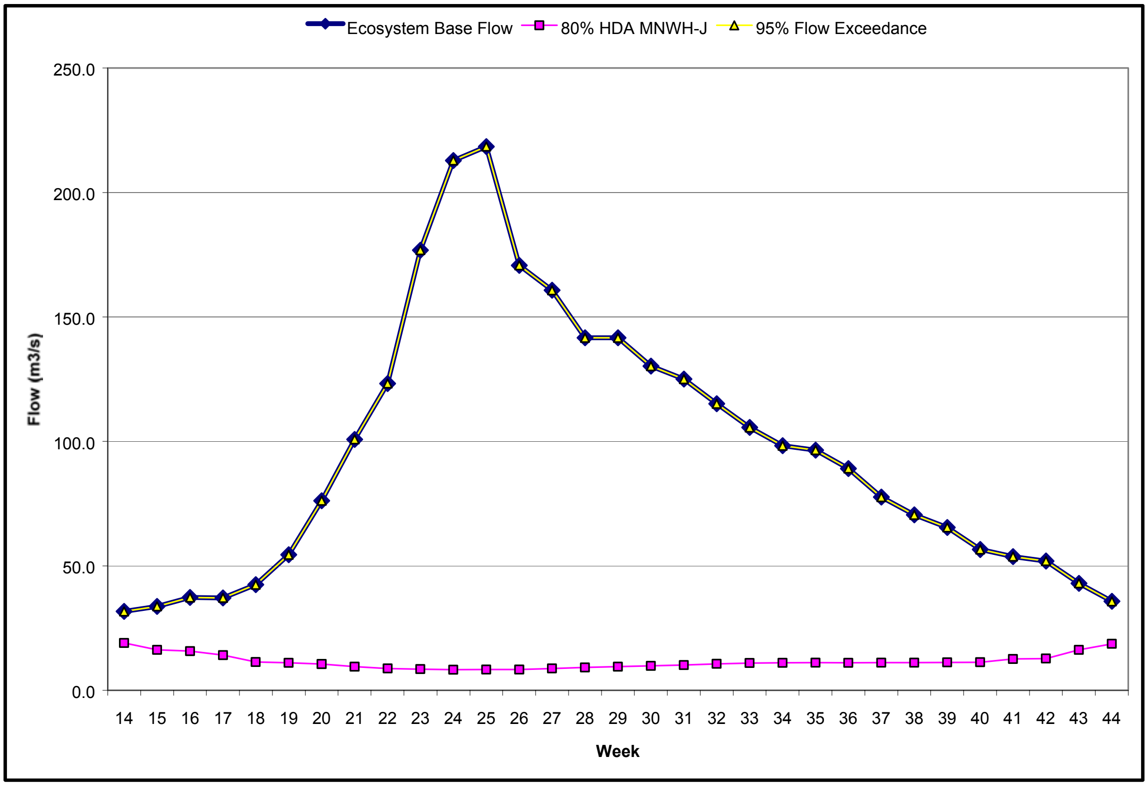


Figure 5.16. The weekly Ecosystem Base Flows for the Bow River Reach 2 (BW2) using the maximum value between the 80% habitat duration analysis for mountain whitefish juvenile and the 95% flow exceedence.

Bow River Reach 3 (BW3)

The fish habitat IFN determination for BW3 is constrained only by the EBF. All reductions in flow, until the flow is entirely limited by the EBF, meet all the defined threshold criteria except for the maximum instantaneous habitat loss for rainbow trout spawning (Table 5.7). Although the maximum habitat loss criterion was exceeded for rainbow trout spawning, all other metrics were below the identified thresholds. Some metrics indicated habitat gains relative to natural. Minimal habitat losses were shown for mountain whitefish adults and juveniles, for the longer-term metrics.

Table 5.7. Bow River Reach 3 (BW3) from the Carseland weir upstream to the Highwood River confluence. Habitat evaluation metrics for flows constrained only by the EBF.

Species	**Total Mean (Weeks 14-19: 37-44)**	**Maximum Weekly**	**Maximum Instantaneous**	**Maximum Yearly**
MNWH-A	-1.30%	-9.95%	**-21.11%**	0.17%
MNWH-J	-4.02%	-9.81%	**-20.69%**	-0.81%
MNWH-S	N/A	-9.37%	**-20.63%**	-12.99%
RNTR-S	N/A	**-14.45%**	**-27.76%**	-3.02%

The EBF for this reach provided suitable protection of the hydraulic habitat for all species and life stages. The WUA curves indicate suitable habitat at flows that are relatively low for most times of the year for this reach. A potential explanation for this result is that the Bow River in this reach has a relatively wide, single channel. As flows are reduced, the habitat suitability in terms of both depth and velocity remain fairly constant. As a result, the WUA curves in this reach peak at a relatively low flow. The peak of the WUA curves is also very broad and is not very sensitive to changes in flow. In order to meet the goal of intra- and inter-annual flow variability, it is even more critical that these results be incorporated with the riparian IFN determination.

The mountain whitefish juvenile WUA curve peaks at a flow of 113.2 m^3/s and is used to define the EBF (Figure 5.17) and to identify the wet weeks to be removed from the analysis. Weeks 20-36 have weekly median flows that are greater than the peak of the mountain whitefish juvenile WUA curve and are removed from the analysis of the total mean habitat loss.

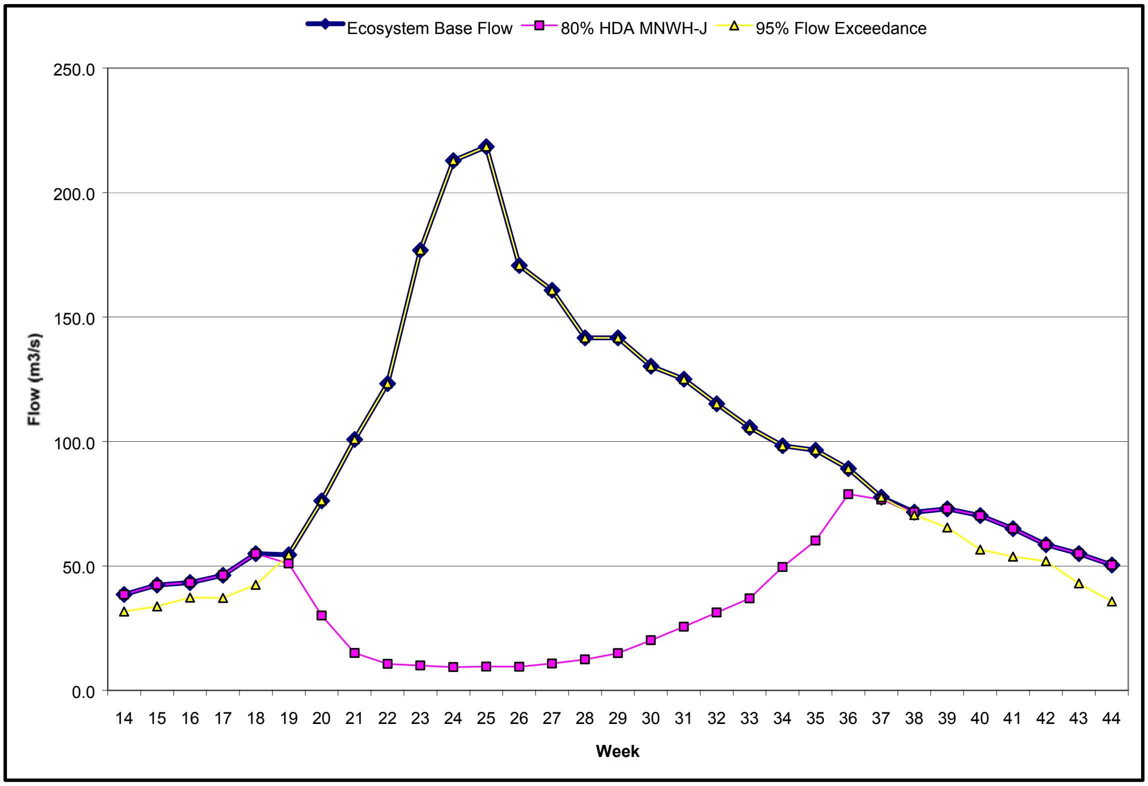


Figure 5.17. The weekly Ecosystem Base Flows for the Bow River Reach 3 (BW3) using the maximum value between the 80% habitat duration analysis for mountain whitefish juvenile and the 95% flow exceedence.

Bow River Reach 4 (BW4)

The fish habitat IFN determination for BW4 is a 55% reduction from the natural flow, with the added weekly constraint of the Ecosystem Base Flow. The habitat limiting life stage in this reach is mountain whitefish adult (Table 5.8). The key evaluation metrics that approach the defined thresholds in this reach are the maximum instantaneous habitat losses and maximum weekly habitat losses. The habitat reductions begin to flatten off with continued reductions from the natural flow, which again indicates that the EBF is in large part providing much of the habitat protection for this reach. The WUA curves in Reach BW4 peak at a relatively low flow compared with the natural hydrology. The WUA curve peaks are also very broad and are therefore not very sensitive to changes in flow. In order to meet the goal of intra- and inter-annual flow variability, it is even more critical that these results be incorporated with the riparian IFN determination.

Table 5.8. Bow River Reach 4 (BW4) from the Highwood River confluence upstream to the WID weir. Habitat evaluation metrics for a 55% reduction from the natural flow with the added constraint of the EBF.

Species	**Total Mean (Weeks 14-17:43-44)**	**Maximum Weekly**	**Maximum Instantaneous**
MNWH-A	-7.73%	**-14.63%**	**-22.47%**
RNTR-A	-4.41%	-12.10%	-20.25%

The mountain whitefish adult WUA curve peaks at a flow of 59.4 m^3/s and is used to define the EBF (Figure 5.18) and to identify the wet weeks to be removed from the analysis. Weeks 18-42 have weekly median flows that are greater than the peak of the mountain whitefish juvenile WUA curve and are removed from the analysis of the total mean habitat loss. For the purpose of integrating the fish habitat results with the other components, weeks 14-17 and 37-44 were used. This allows for a one-week overlap with the riparian descriptions and ensures a smooth transition between these components in the fall.

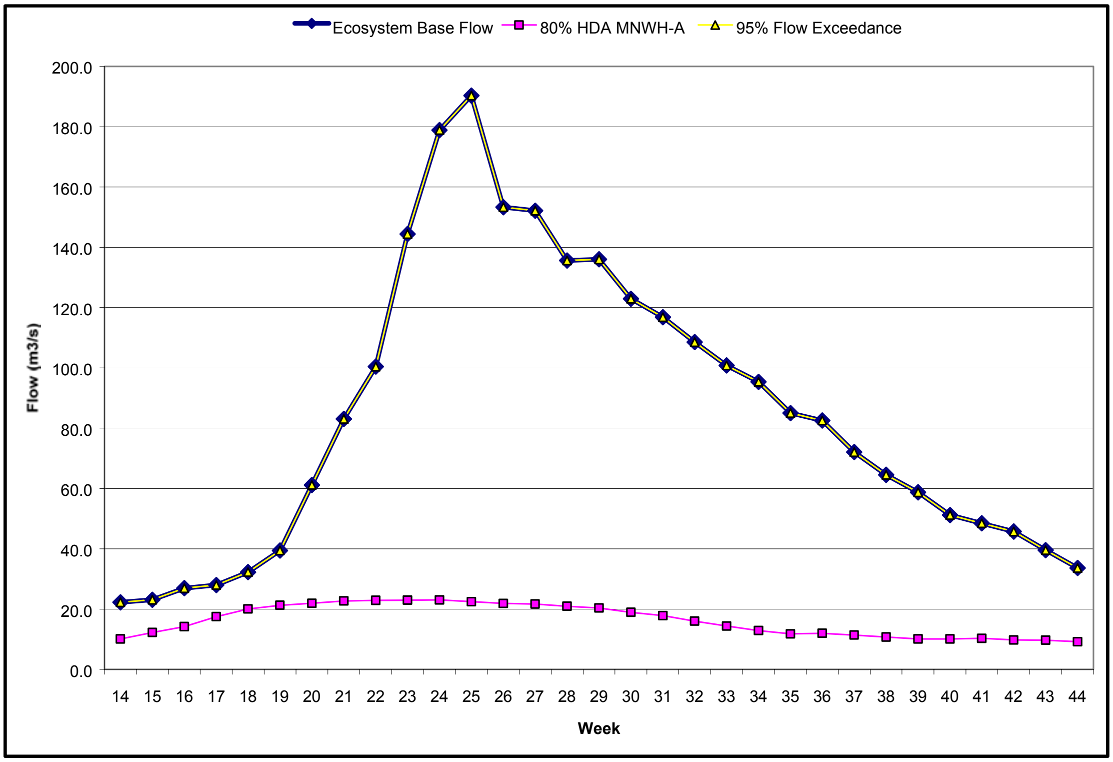


Figure 5.18. The weekly Ecosystem Base Flows for the Bow River Reach 4 (BW4) using the maximum value between the 80% habitat duration analysis for mountain whitefish adult and the 95% flow exceedence.

5.4.4 Oldman River Fish Habitat IFN Results

Oldman River Reach 1 (OM1)

Site-specific PHABSIM data are not available for the Oldman River from the Grand Forks upstream to the confluence of the Little Bow River. The EBF for fish habitat was developed using the Tessmann calculation for the entire year (Figure 5.19). These values must be combined with the other components to develop the ecosystem IFN.

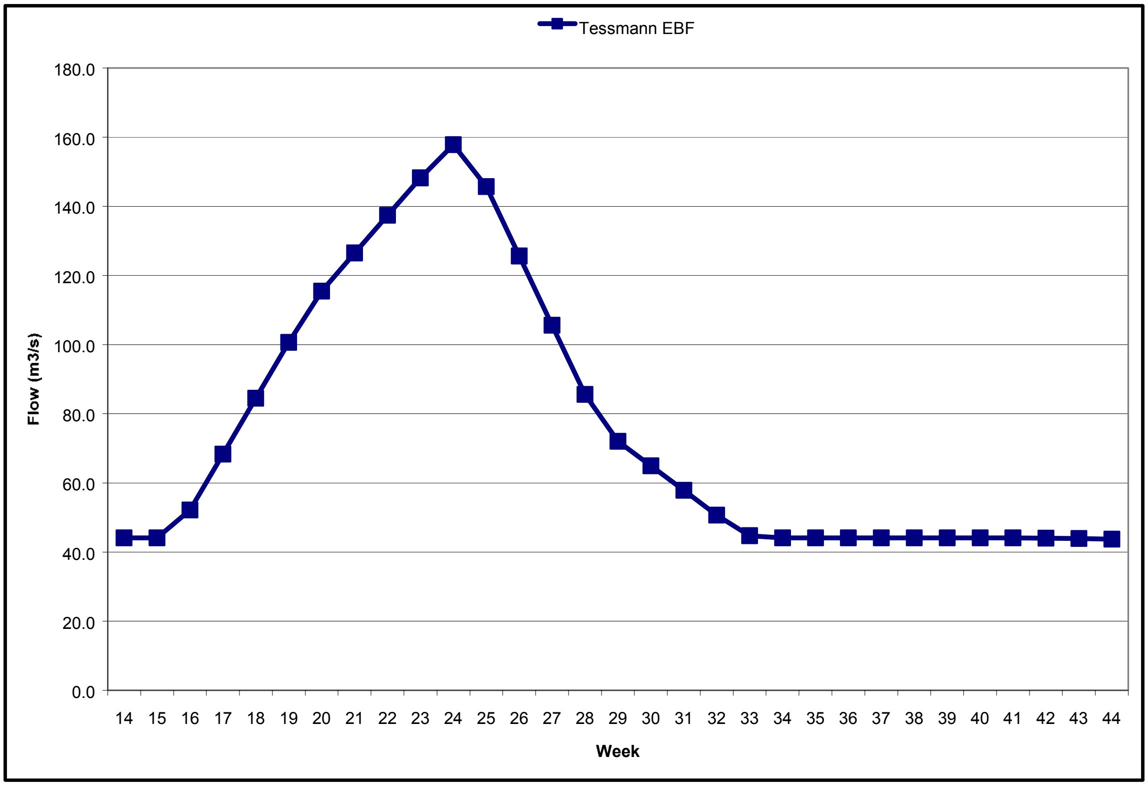


Figure 5.19. The weekly Ecosystem Base Flows for the Oldman River Reach 1 (OM1) using the Tessmann calculation.

Oldman River Reach 2 (OM2)

The fish habitat IFN determination for OM2 is a 40% reduction from the natural flow, with the added weekly constraint of the EBF. The habitat limiting life stages in this reach are mountain whitefish spawning and adult, and walleye spawning (Table 5.9). The key evaluation metrics that approach the defined thresholds in this reach are the maximum instantaneous habitat losses and maximum weekly habitat losses. The maximum instantaneous habitat losses for the spawning life stages were allowed to exceed the defined threshold. All metrics show a steady pattern of increased habitat loss with continued flow reductions and approach the defined thresholds.

This reach of the Oldman River was difficult to evaluate because many of the longer-term habitat metrics indicated habitat gains. For BSP1, the shorter-term evaluation metrics indicate high habitat losses for walleye spawning, whereas overall habitat gains are shown for BSP1 when walleye spawning occurs. A sensitivity analysis was conducted to assist in the interpretation of the maximum instantaneous habitat losses. For walleye spawning, a maximum instantaneous habitat loss greater than 20% occurred 17.5% of the time. Habitat losses greater than 25% remained relatively high, occurring 14.8% of the time. In comparison, greater than 20% maximum instantaneous habitat losses for mountain whitefish spawning occurred 26.7% of the time, whereas habitat losses greater than 25% occurred only 5.5% of the time. This, along with the other metrics, indicates the habitat losses for mountain whitefish spawning show a more consistent pattern with increased flow reductions. On the other hand, there appear to be a few critical low-flow situations for walleye spawning habitat that result in large maximum instantaneous habitat losses that are not indicative of the majority of the flows evaluated. Large maximum instantaneous habitat losses typically occur at low flows and are usually moderated by the EBF. The results for this reach suggest the EBF could be adjusted for the first few weeks of walleye spawning, to reduce the maximum instantaneous habitat losses. This adjustment has not been made for the current planning level evaluation, but should be examined prior to any IFN implementation. The mountain whitefish adult WUA curve peaks at a flow of 68.0 m^3/s and is used to define the EBF (Figure 5.20) and to identify the wet weeks to be removed from the analysis. Weeks 16-32 have weekly median flows greater than the peak of the mountain whitefish adult WUA curve and are removed from the analysis of the total mean habitat loss.

Table 5.9. Oldman River Reach 2 (OM2) from the Little Bow River confluence upstream to the St. Mary River. Habitat evaluation metrics for a 40% reduction from the natural flow with the added constraint of the EBF.

Species	**Total Mean (Weeks 14-15: 33-44)**	**Maximum Weekly**	**Maximum Instantaneous**	**Total Mean BSP1**	**Total Mean BSP3**
MNWH-A	-4.98%	-6.70%	-19.08%	+19.34%	-6.03%
MNWH-S	N/A	-11.45%	**-26.89%**	N/A	-11.03%
WALL-S	N/A	-10.23%	**-40.49%**	+23.98%	N/A

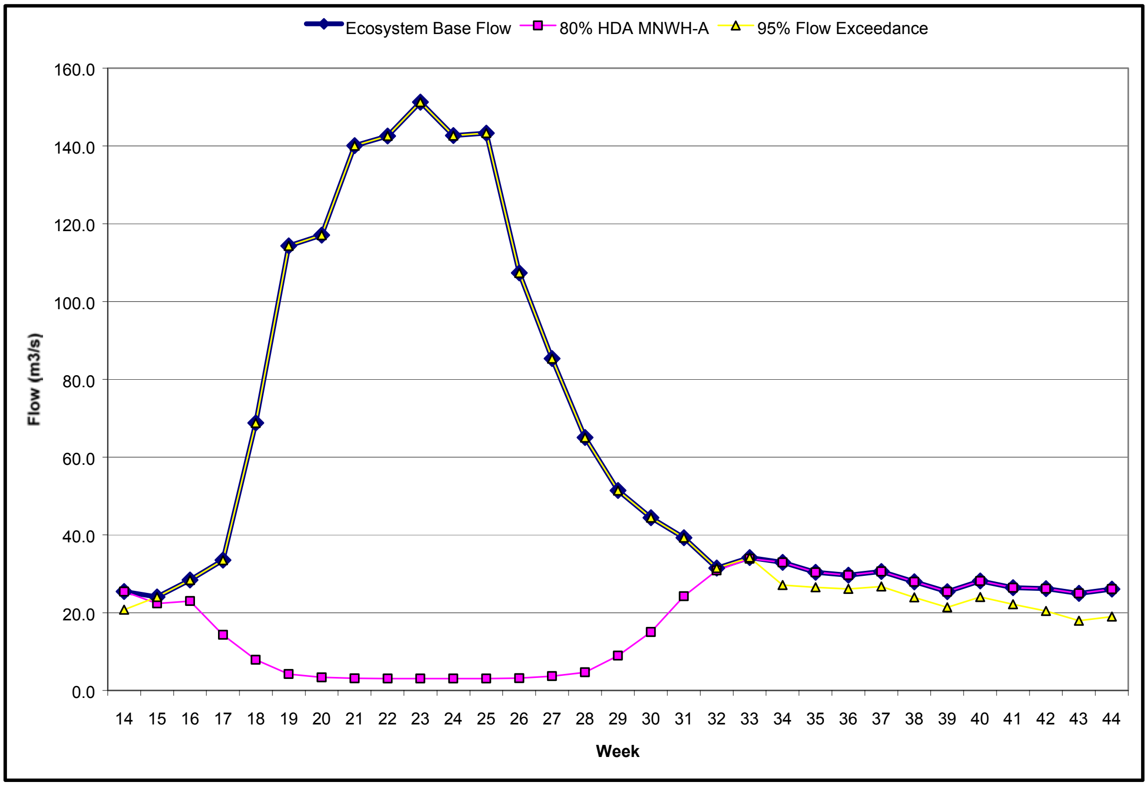


Figure 5.20. The weekly Ecosystem Base Flows for the Oldman River Reach 2 (OM2) using the maximum value between the 80% habitat duration analysis for mountain whitefish adult and the 95% flow exceedence.

Oldman River Reach 3 (OM3)

The fish habitat IFN determination for OM3 is a 30% reduction from the natural flow, with the added weekly constraint of the EBF. The habitat limiting life stages are mountain whitefish adult and spawning, and brown trout adult (Table 5.10). The key evaluation metrics that approach the defined thresholds in this reach are the maximum instantaneous habitat losses and maximum weekly habitat losses.

Table 5.10. Oldman River Reach 3 (OM3) from the St. Mary River confluence upstream to the Belly River confluence. Habitat evaluation metrics for a 30% reduction from the natural flow with the added constraint of the EBF.

Species	**Total Mean (Weeks 14-19: 27-44)**	**Maximum Weekly**	**Maximum Instantaneous**	**BSP3 Mean (Weeks 40-44)**	**Maximum Yearly**
MNWH-A	-8.38%	-10.81%	**-21.70%**	-10.03	-10.49%
MNWH-S	N/A	-11.55%	**-23.51%**	**-10.83**	-21.84%
BNTR-A	-6.48%	-9.16%	**-21.47%**	-6.48	-9.20%

The hydraulic modelling results from this reach could only be extended to 169.8 m^3/s, corresponding to the peak of several WUA curves. To complete the time series analysis, an arbitrary habitat value was assigned at a flow of 1870 m^3/s, the highest flow being evaluated. This resulted in a straight-line habitat relationship between 169.8 m^3/s and 1870 m^3/s, representing a gradual habitat decline for that range. The habitat value for all flows greater than 169.8 m^3/s was based on this criterium. The WUA results for flows less than 169.8 m^3/s displayed an irregular pattern for some life stages. However, the results were determined to be suitable for the current planning exercise and the Ecosystem Base Flows are considered to be accurate. Results from this reach should be evaluated carefully, based on the results from both upstream and downstream reaches, to validate the decisions made.

The mountain whitefish adult WUA curve peaks at a flow of 169.8 m^3/s and is used to define the EBF (Figure 5.21) and to identify the wet weeks to be removed from the analysis. Weeks 20-26 have weekly median flows greater than the peak of the mountain whitefish juvenile WUA curve and are removed from the analysis of the total mean habitat loss.

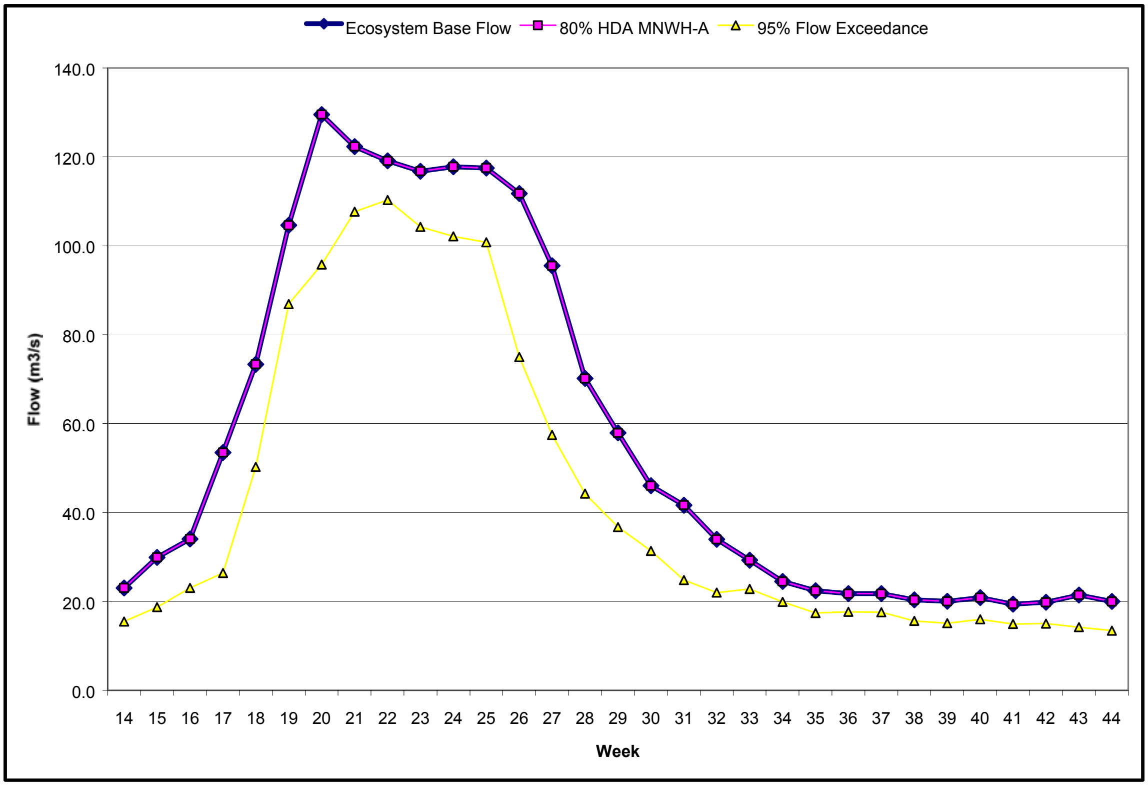


Figure 5.21. The weekly Ecosystem Base Flows for the Oldman River Reach 3 (OM3) using the maximum value between the 80% habitat duration analysis for mountain whitefish adult and the 95% flow exceedence.

Oldman River Reach 4 (OM4)

In a few reaches, as in this case Oldman River Reach 4, the 80% habitat retention curve does not follow an expected pattern. The specifics of why this occurred were not investigated in this study, but it seems reasonable to suggest it is due to a combination of the stream hydraulics and hydrology. The results of the 80% habitat evaluation do not necessarily scale in proportion with the hydrology from upstream to downstream. It is recommended that these anomalies be investigated.

The fish habitat IFN determination for OM4 is a 15% reduction from the natural flow, with the added weekly constraint of the EBF. The habitat limiting life stages in this reach are mountain whitefish and walleye spawning (Table 5.11). The key evaluation metrics that approach the defined thresholds in this reach are the maximum instantaneous habitat losses and maximum weekly habitat losses. The maximum instantaneous habitat loss for walleye spawning exceeds the defined threshold. However, the maximum weekly habitat loss and the total mean habitat loss for BSP1 indicate that the acute habitat losses are not indicative of chronic habitat losses. Flow reductions beyond 15% of natural result in a very rapid decline in habitat for both mountain whitefish and walleye spawning. Although the habitat limiting species are both spawning life stages, life stages present year-round, such as mountain whitefish adults, also show a steady trend of habitat loss with continued flow reductions.

The mountain whitefish adult WUA curve peaks at a flow of 49.5 m^3/s and is used to define the EBF (Figure 5.22) and to identify the wet weeks to be removed from the analysis. Weeks 17-28 have weekly median flows greater than the peak of the mountain whitefish adult WUA curve and are removed from the analysis of the total mean habitat loss.

Table 5.11. Oldman River Reach 4 (OM4) from the Belly River confluence upstream to the Willow Creek confluence. Habitat evaluation metrics for a 15% reduction from the natural flow with the added constraint of the EBF.

Species	**Total Mean (Weeks 14-16:29-44)**	**Maximum Weekly**	**Maximum Instantaneous**	**Total Mean BSP1**
MNWH-A	-4.53%	-6.60%	-11.74%	
MNWH-S	N/A	-10.59%	**-21.74%**	N/A
WALL-S	N/A	-9.90%	**-29.63%**	+5.07%

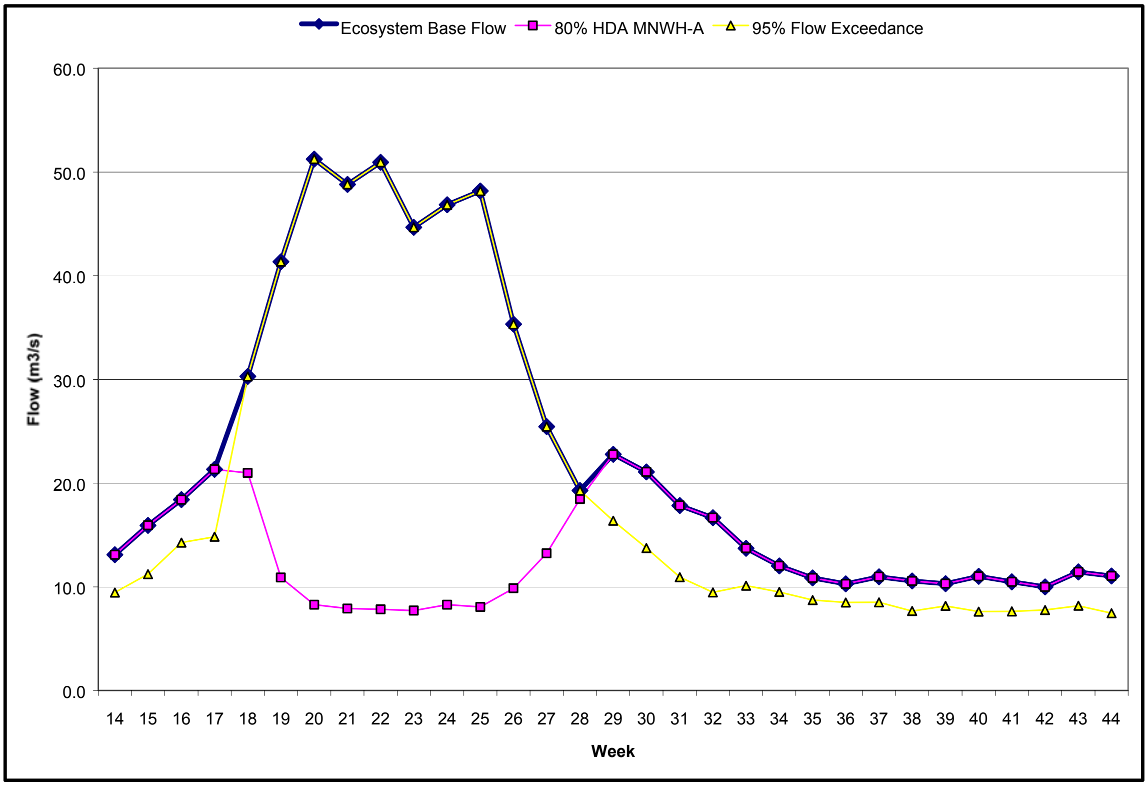


Figure 5.22. The weekly Ecosystem Base Flows for the Oldman River Reach 4 (OM4) using the maximum value between the 80% habitat duration analysis for mountain whitefish adult and the 95% flow exceedence.

Oldman River Reach 5 (OM5)

The fish habitat IFN determination for OM5 is a 30% reduction from the natural flow, with the added weekly constraint of the EBF. The habitat limiting life stages in this reach are mountain whitefish adult and spawning, and rainbow trout spawning (Table 5.12). The key evaluation metrics that approach the defined thresholds in this reach are the maximum instantaneous habitat losses and maximum weekly habitat losses. The rainbow trout spawning life stage has a very high maximum instantaneous habitat loss value. However, the other key habitat metrics were not consistent with this pattern and the maximum instantaneous threshold was allowed to exceed the threshold to this extent. All other species and life stages showed consistent habitat losses with continued flow reductions. The results for a 30% flow reduction are judged to provide a balance between all life stages throughout the year.

Table 5.12. Oldman River Reach 5 (OM5) from the Willow Creek confluence upstream to the LNID weir. Habitat evaluation metrics for a 30% reduction from the natural flow with the added constraint of the EBF.

Species	**Total Mean (Weeks 14-16: 29-44)**	**Maximum Weekly**	**Maximum Instantaneous**	**Total Mean BSP1**	**Maximum Yearly**
MNWH-A	-7.24%	-11.02%	-19.98%		-6.30%
MNWH-S	N/A	**-12.65%**	**-23.39%**	N/A	-22.14%
RNTR-S	N/A	-2.57%	**-46.17%**	+16.20%	-4.70%

The mountain whitefish juvenile WUA curve peaks at a flow of 42.5 m^3/s and is used to define the EBF (Figure 5.23) and to identify the wet weeks to be removed from the analysis. Weeks 17-28 have weekly median flows greater than the peak of the mountain whitefish juvenile WUA curve and are removed from the analysis of the total mean habitat loss.

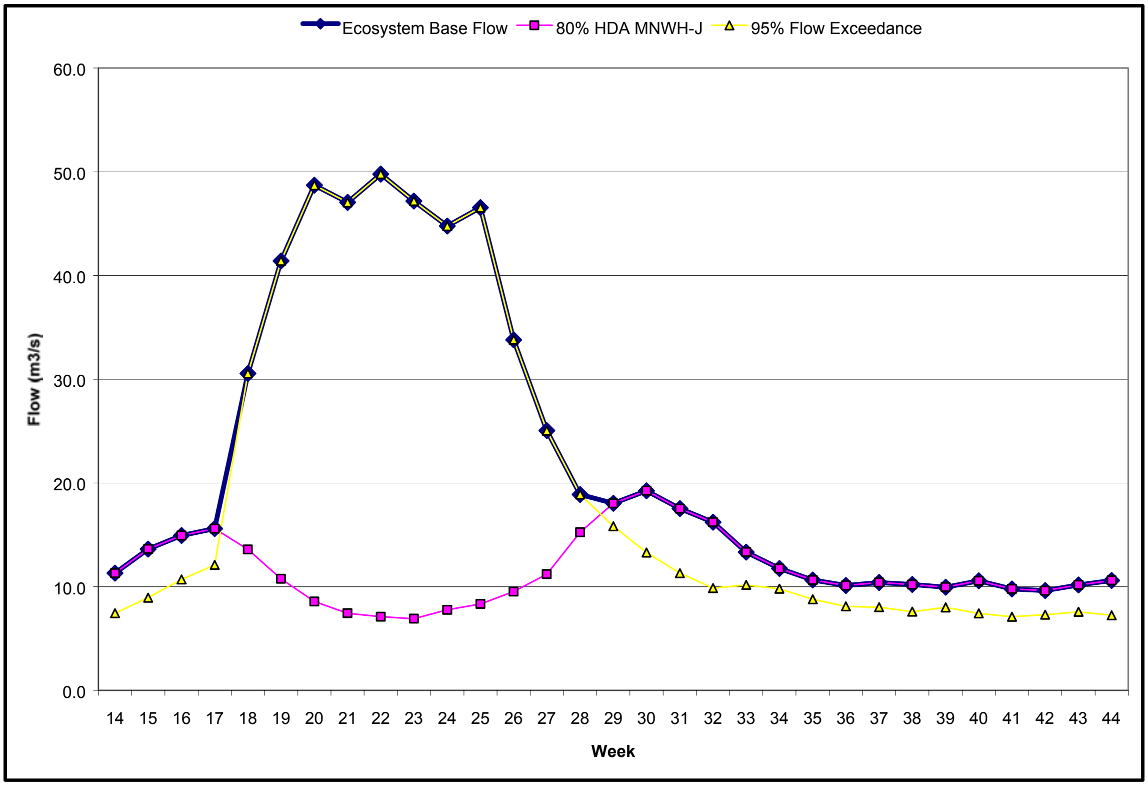


Figure 5.23. The weekly Ecosystem Base Flows for the Oldman River Reach 5 (OM5) using the maximum value between the 80% habitat duration analysis for mountain whitefish juvenile and the 95% flow exceedence.

Oldman River Reach 6 (OM6)

The fish habitat IFN determination for OM6 is a 20% reduction from the natural flow, with the added weekly constraint of the EBF. The habitat limiting life stages in this reach are mountain whitefish adult and spawning, and rainbow trout spawning (Table 5.13). The key evaluation metrics that approach the defined thresholds in this reach are the maximum instantaneous habitat losses and maximum weekly habitat losses. The maximum instantaneous habitat losses exceed the defined threshold for both spawning life stages. The rainbow trout results do not indicate that the acute habitat losses are indicative of chronic habitat losses. The mountain whitefish spawning habitat losses show a more consistent pattern of habitat loss. The habitat evaluation metrics show a consistent pattern of habitat loss with continued flow reductions in all of the life stages present year-round in the reach. The results for a 20% flow reduction are judged to provide a balance between all life stages throughout the year.

A flow reduction of 20% is judged to be the best balance of habitat reductions between all the life stages. The results for this reach suggest the EBF could be adjusted in the spring and fall to reduce the maximum instantaneous habitat losses for the spawning life stages. This adjustment has not been made for the current planning level evaluation, but should be examined prior to any IFN implementation.

Table 5.13. Oldman River Reach 6 (OM6) from the LNID weir upstream to the Pincher Creek confluence. Habitat evaluation metrics for a 20% reduction from the natural flow with the added constraint of the EBF.

Species	Total Mean (Weeks 14-16: 29-44)	Maximum Weekly	Maximum Instantaneous	Total Mean BSP1	Total Mean BSP3
MNWH-A	-4.24%	-7.23%	-17.68%		
MNWH-S	N/A	-10.63%	**-29.12%**	N/A	**-10.14%**
RNTR-S	N/A	-5.60%	**-31.60%**	+7.80%	N/A

The mountain whitefish juvenile WUA curve peaks at a flow of 42.5 m^3/s and is used to define the EBF (Figure 5.24) and to identify the wet weeks to be removed from the analysis. Weeks 17-28 have weekly median flows that are greater than the peak of the mountain whitefish juvenile WUA curve and are removed from the analysis of the total mean habitat loss.

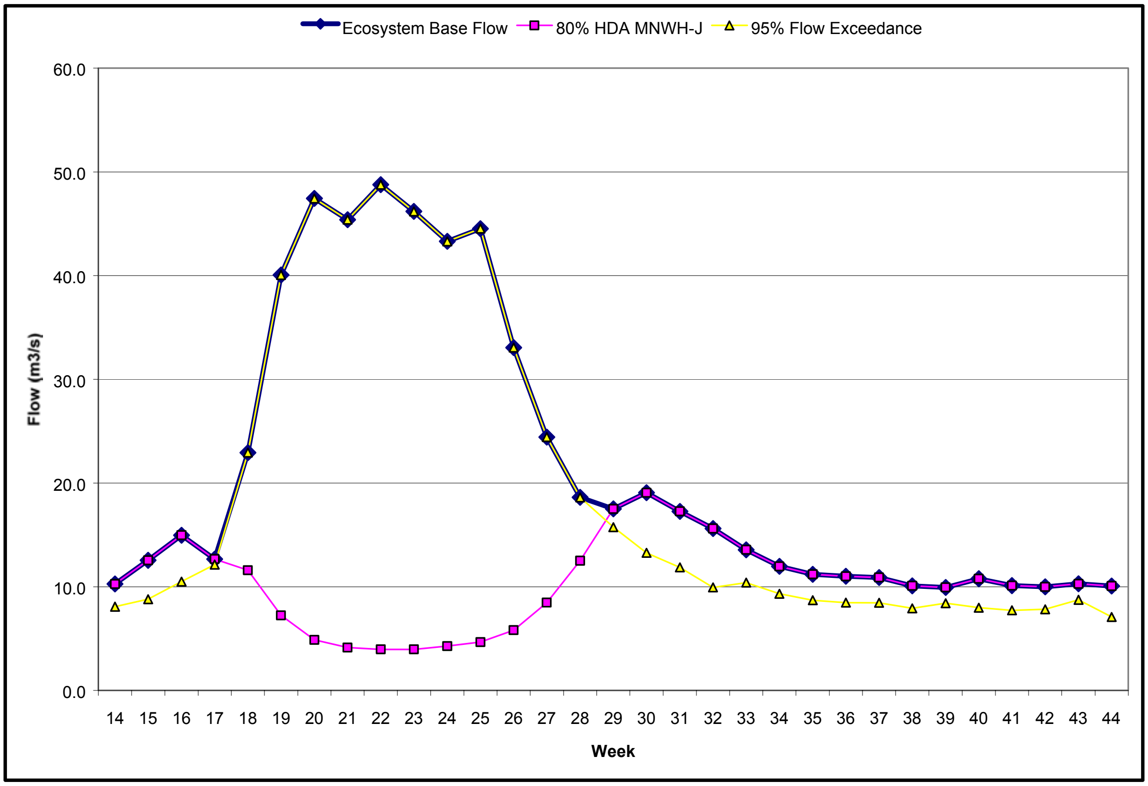


Figure 5.24. The weekly Ecosystem Base Flows for the Oldman River Reach 6 (OM6) using the maximum value between the 80% habitat duration analysis for mountain whitefish juvenile and the 95% flow exceedence.

Oldman River Reach 7 (OM7)

The fish habitat IFN determination for OM7 is a 20% reduction from the natural flow, with the added weekly constraint of the EBF. The habitat limiting life stages in this reach are mountain whitefish and rainbow trout spawning (Table 5.14). The key evaluation metric that approaches the defined threshold in this reach is the maximum instantaneous habitat loss. The maximum instantaneous habitat loss for rainbow trout spawning exceeds the defined threshold. However, the results for a 20% flow reduction are judged to provide a balance between all life stages throughout the year. A threshold for maximum yearly habitat loss was not defined, although some of the results were judged to be large enough to prevent further reductions in flow. Although spawning life stages triggered the IFN, both the spring and fall seasons contributed to the IFN determination. Mountain whitefish juveniles are present year-round and also showed a consistent pattern of habitat loss that approached the threshold values at the defined fish habitat IFN.

Table 5.14. Oldman River Reach 7 (OM7) from the Pincher Creek confluence upstream to the Oldman Dam. Habitat evaluation metrics for a 20% reduction from the natural flow with the added constraint of the EBF.

Species	**Total Mean (Weeks 14-17: 31-44)**	**Maximum Weekly**	**Maximum Instantaneous**	**Maximum Yearly**
MNWH-S	N/A	-7.92%	**-23.46%**	-22.68%
RNTR-S	N/A	-1.98%	**-27.27%**	-7.82%
MNWH-J	-2.93%	-4.57%	-16.52%	-3.70%

The mountain whitefish juvenile WUA curve peaks at a flow of 26.9 m^3/s and is used to define the EBF (Figure 5.25) and to identify the wet weeks to be removed from the analysis. Weeks 16-30 have weekly median flows greater than the peak of the mountain whitefish juvenile WUA curve and are removed from the analysis of the total mean habitat loss.

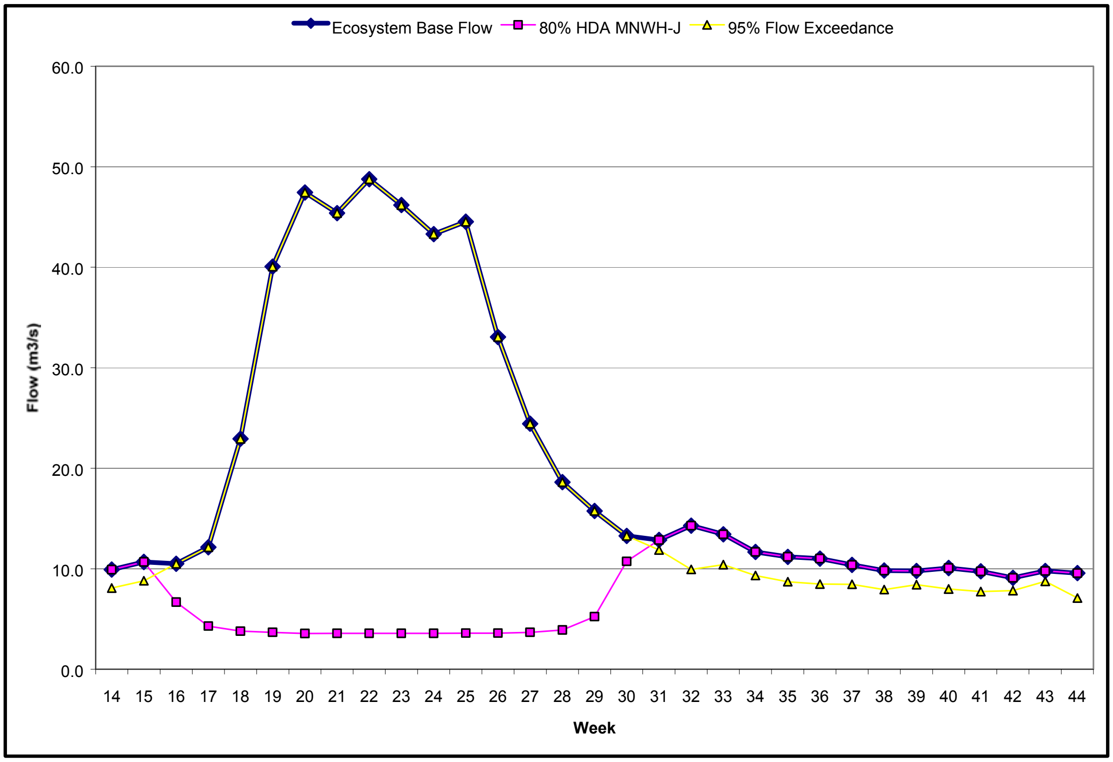


Figure 5.25. The weekly Ecosystem Base Flows for the Oldman River Reach 7 (OM7) using the maximum value between the 80% habitat duration analysis for mountain whitefish juvenile and the 95% flow exceedence.

5.4.5 Southern Tributaries Fish Habitat IFN Results

Belly River Reach 1 (BL1)

The fish habitat IFN determination for BL1 is a 30% reduction from the natural flow, with the added weekly constraint of the EBF. The habitat limiting life stage in this reach is mountain whitefish adult (Table 5.15), that had a consistent pattern of habitat loss across all of the key metrics. The key evaluation metrics that approach the defined thresholds are the maximum instantaneous habitat loss and the maximum weekly habitat loss. However, the total mean habitat loss was also very near the threshold criteria.

The mountain whitefish adult WUA curve peaks at a flow of 48.1 m^3/s and is used to define the EBF (Figure 5.26) and to identify the wet weeks to be removed from the analysis. Weeks 19-28 have weekly median flows greater than the peak of the mountain whitefish adult WUA curve and are removed from the analysis of the total mean habitat loss.

Table 5.15. Belly River Reach 1 (BL1) from the Oldman River upstream to the Waterton River confluence. Habitat evaluation metrics for a 30% reduction from the natural flow with the added constraint of the EBF.

Species	**Total Mean (Weeks 14-18:29-44)**	**Maximum Weekly**	**Maximum Instantaneous**
MNWH-A	-7.03%	**-12.78%**	**-24.06%**
MNWH-J	-4.26%	-8.33%	-18.86%
BNTR-A	-3.27%	-7.46%	-14.53%

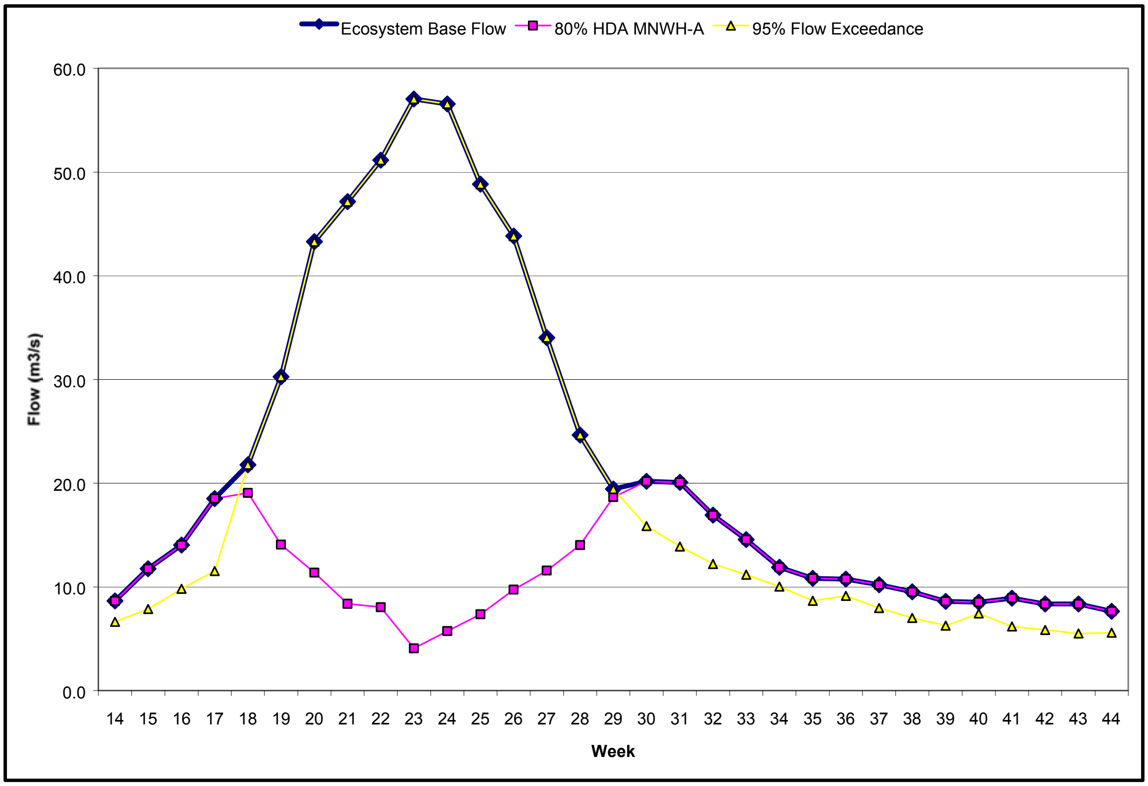


Figure 5.26. The weekly Ecosystem Base Flows for the Belly River Reach 1 (BL1) using the maximum value between the 80% habitat duration analysis for mountain whitefish adult and the 95% flow exceedence.

Belly River Reach 2 (BL2)

The fish habitat IFN determination for BL2 is a 20% reduction from the natural flow, with the added weekly constraint of the EBF. The habitat limiting life stages in this reach are mountain whitefish adult and juvenile (Table 5.16). All the key evaluation metrics showed a consistent pattern of habitat loss and approached the threshold values for the defined IFN. Although the maximum instantaneous habitat loss value exceeds the defined threshold for mountain whitefish adult and walleye adult by a very small margin, the other key metrics remained below the thresholds. This determination is therefore expected to be highly protective for all life stages.

The mountain whitefish juvenile WUA curve peaks at a flow of 14.2 m^3/s and is used to define the EBF (Figure 5.27) and to identify the wet weeks to be removed from the analysis. Weeks 19-29 have weekly median flows greater than the peak of the mountain whitefish juvenile WUA curve and are removed from the analysis of the total mean habitat loss.

Table 5.16. Belly River Reach 2 (BL2) from the Waterton River confluence upstream to the point 125 river kilometres upstream of the Oldman River. Habitat evaluation metrics for a 20% reduction from the natural flow with the added constraint of the EBF.

Species	**Total Mean (Weeks 14-18:30-44)**	**Maximum Weekly**	**Maximum Instantaneous**
MNWH-A	-6.00%	-9.88%	**-25.86%**
MNWH-J	-6.36%	-9.06%	-20.35%
BNTR-A	-1.27%	-4.97%	-21.24%
WALL-A	+5.31%	+2.11%	**-25.92%**

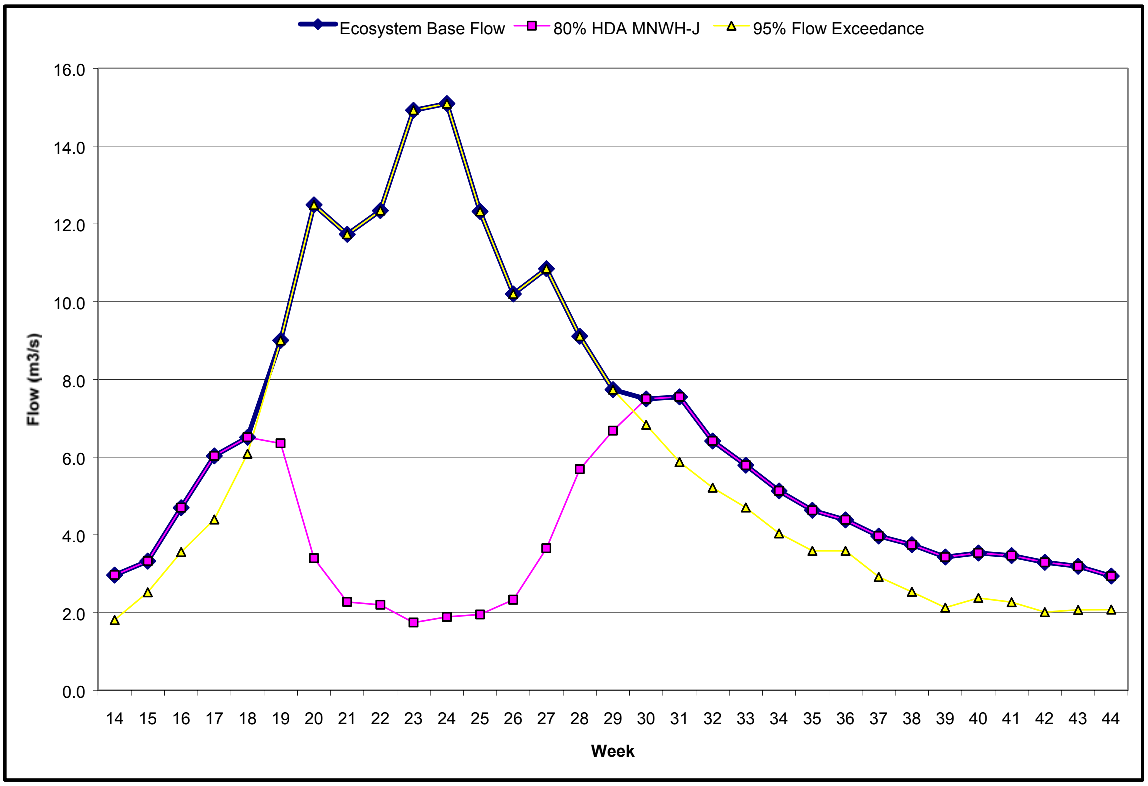


Figure 5.27. The weekly Ecosystem Base Flows for the Belly River Reach 2 (BL2) using the maximum value between the 80% habitat duration analysis for mountain whitefish juvenile and the 95% flow exceedence.

Belly River Reach 3 (BL3)

Reach-specific PHABSIM data are not available for the BL3 reach of the Belly River. Therefore, the final fish habitat IFN determination was developed using the Tessmann (1979) calculation for the entire year (Figure 5.28). These values must be combined with the other components to develop the ecosystem IFN.

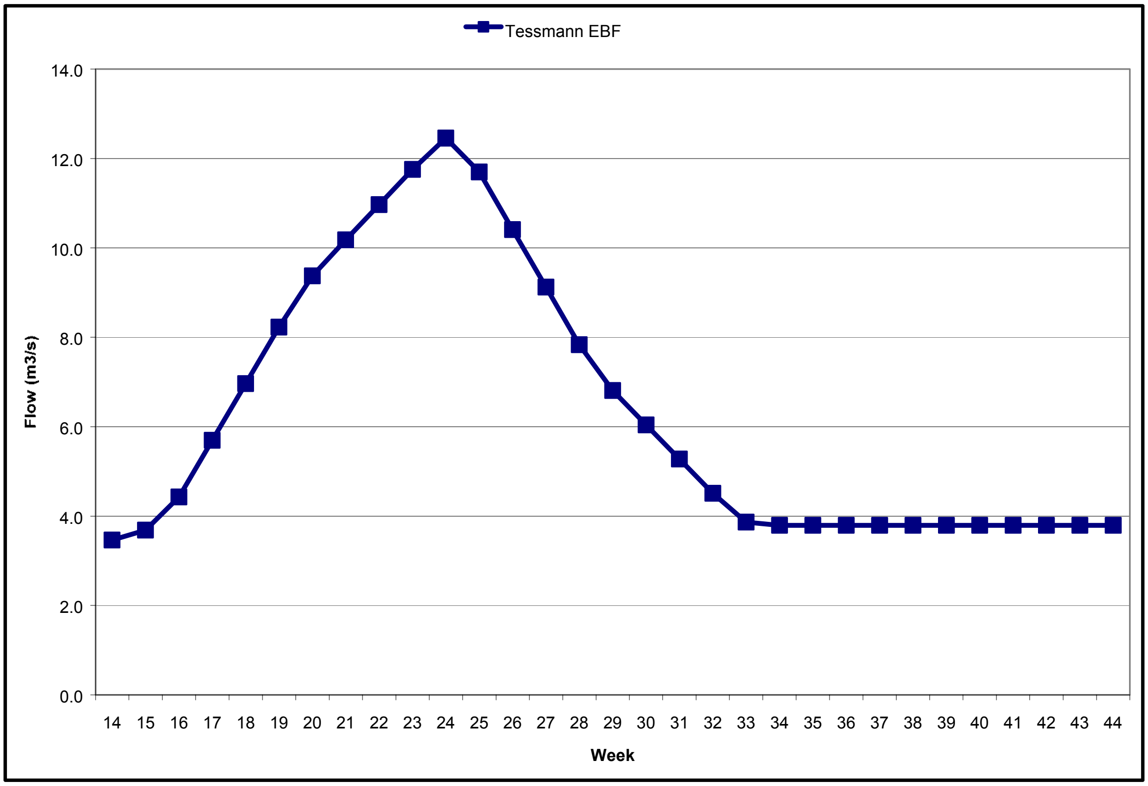


Figure 5.28. The weekly Ecosystem Base Flows for the Belly River Reach 3 (BL3) using the Tessmann calculation.

St. Mary River Reach 1 (SM1)

The fish habitat IFN determination for SM1 is a 40% reduction from the natural flow, with the added weekly constraint of the EBF. The habitat limiting life stages in this reach are mountain whitefish and walleye spawning (Table 5.17). The key evaluation metrics that approach the defined thresholds in this reach are the maximum instantaneous habitat losses and maximum weekly habitat losses. Although the walleye spawning maximum instantaneous habitat loss is very large, the weekly habitat loss is at the threshold, and the total mean habitat loss in BSP1 shows a large habitat gain. These results suggest that adjustments to the EBF during a few weeks in the spring could reduce the maximum instantaneous habitat losses. These adjustments have not been made at this time. All other life stages present year-round show a consistent pattern of habitat loss with continued reductions in flow.

The mountain whitefish juvenile WUA curve peaks at a flow of 34.0 m^3/s and is used to define the EBF (Figure 5.29) and to identify the wet weeks to be removed from the analysis. Weeks 18-30 have weekly median flows greater than the peak of the mountain whitefish juvenile WUA curve and are removed from the analysis of the total mean habitat loss.

Table 5.17. St. Mary River Reach 1 (SM1) from the Oldman River to 37 river kilometres upstream. Habitat evaluation metrics for a 40% reduction from the natural flow with the added constraint of the EBF.

Species	Total Mean (Weeks 14-17: 31-44)	Maximum Weekly	Maximum Instantaneous	Total Mean BSP1
MNWH-A	-4.56%	-8.32%	-17.33%	
WALL-S	N/A	-15.54%	-41.42%	+21.73
MNWH-S	N/A	-13.05%	-24.48%	

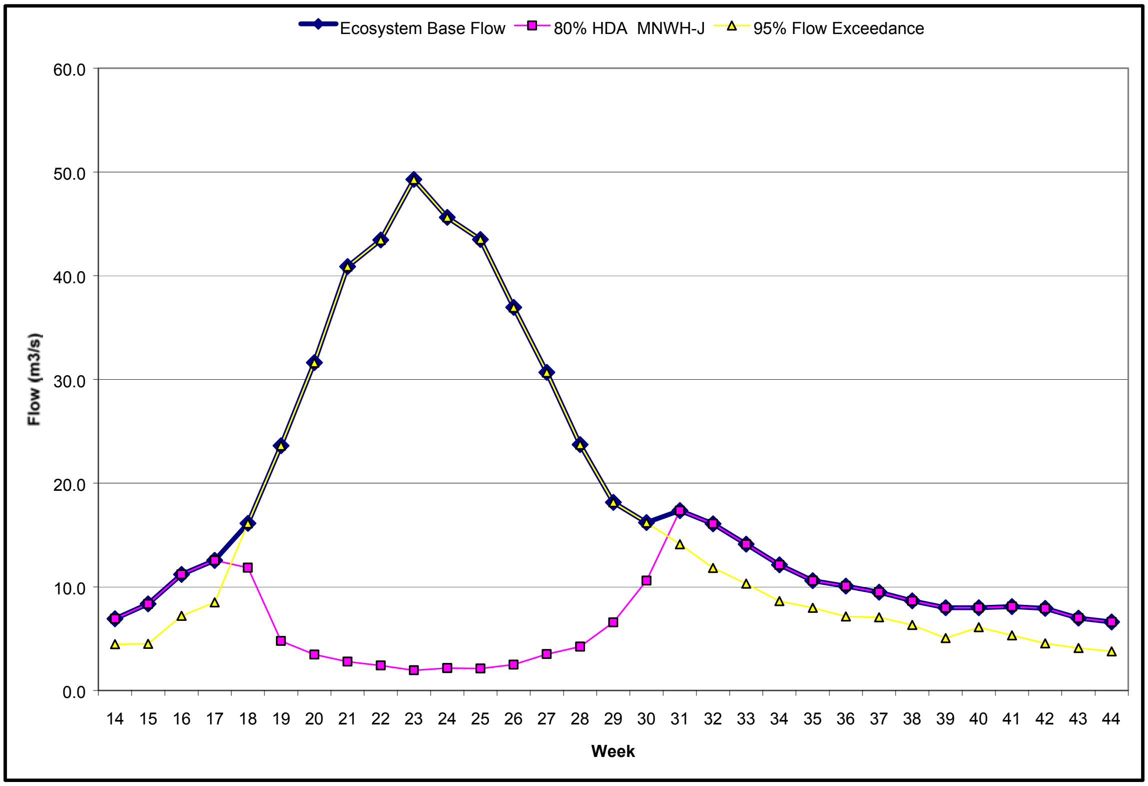


Figure 5.29. The weekly Ecosystem Base Flows for the St. Mary River Reach 1 (SM1) using the maximum value between the 80% habitat duration analysis for mountain whitefish juvenile and the 95% flow exceedence.

St. Mary River Reach 2 (SM2)

In the original IFN study, SM2 was defined as three separate reaches (Bjornson and Fernet 1989). The reach definitions were largely based on geomorphology, since there are no major tributaries present within this reach. Although three reaches were defined, only one study site was developed. The availability of a single study site, and a single flow dataset within SM2, made it necessary to treat SM2 as a single reach for the purpose of the fish habitat analysis for this phase of the SSRB WMP.

The hydraulic calibration for this reach produced poor results. The models could only be calibrated for a very limited range of low flows. It was decided that the modelling for this reach was not producing suitable results for the purpose of evaluating fish habitat. Therefore, the final fish habitat IFN determination was developed using the Tessmann (1979) calculation for the entire year (Figure 5.30). These values must be combined with the other components to develop the ecosystem IFN.

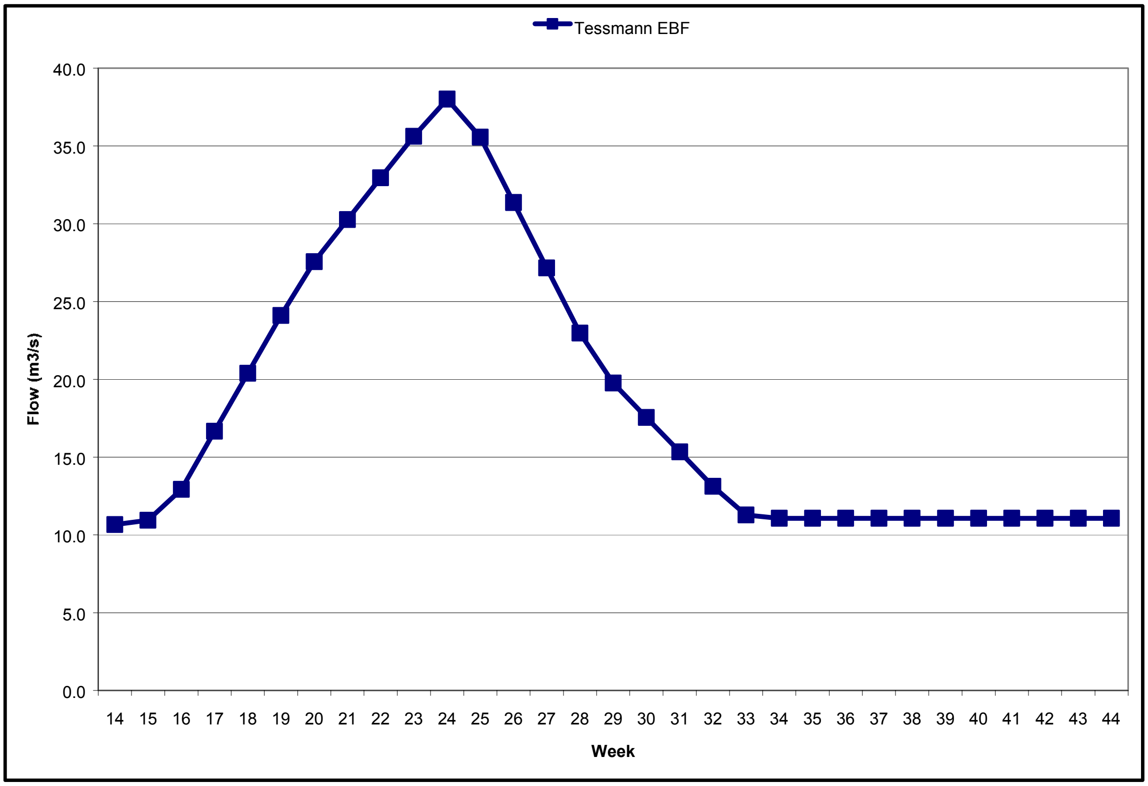


Figure 5.30. The weekly Ecosystem Base Flows for the St. Mary River Reach 2 (SM2) using the Tessmann calculation.

Waterton River Reach 1 (W1)

The fish habitat IFN determination for W1 is a 25% reduction from the natural flow with the added weekly constraint of the EBF. The habitat limiting life stages are mountain whitefish spawning and adult (Table 5.18). The key evaluation metrics that approach the defined thresholds in this reach are the maximum instantaneous habitat losses and maximum weekly habitat losses. With continued reductions in flow, the habitat metrics presented a consistent pattern of habitat loss for all metrics and for most of the life stages present in this reach.

The mountain whitefish adult WUA curve peaks at a flow of 29.0 m^3/s and is used to define the EBF (Figure 5.31) and to identify the wet weeks to be removed from the analysis. Weeks 18-28 have weekly median flows greater than the peak of the mountain whitefish juvenile WUA curve and are removed from the analysis of the total mean habitat loss.

Table 5.18. Waterton River Reach 1 (W1) from the Belly River to 45 river kilometres upstream. Habitat evaluation metrics for a 25% reduction from the natural flow with the added constraint of the EBF.

Species	Total Mean (Weeks 14-17: 29-44)	Maximum Weekly	Maximum Instantaneous
MNWH-A	-8.09%	**-12.51%**	**-21.67%**
RNTR-A	-6.78%	-10.57%	-18.58%
MNWH-S	N/A	**-14.34%**	**-25.97%**

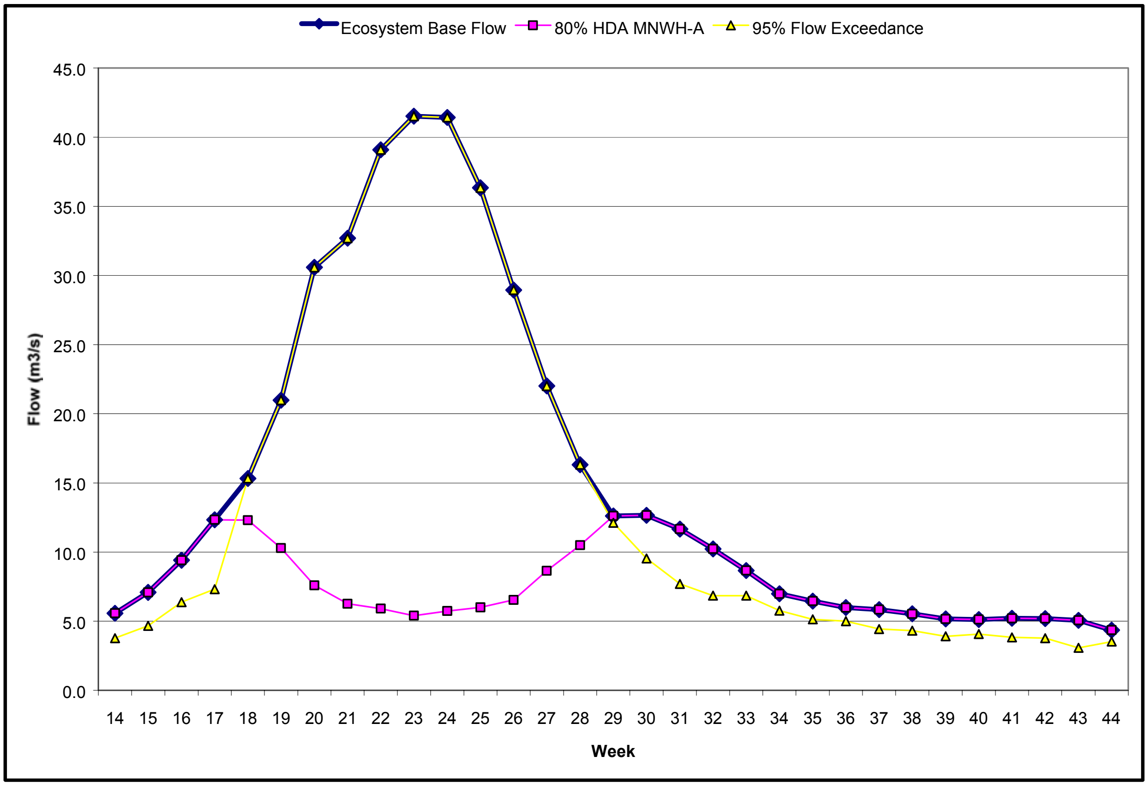


Figure 5.31. The weekly Ecosystem Base Flows for the Waterton River Reach 1 (W1) using the maximum value between the 80% habitat duration analysis for mountain whitefish adult and the 95% flow exceedence.

Waterton River Reach 2 (W2)

The fish habitat IFN determination for W2 is a 20% reduction from the natural flow, with the added weekly constraint of the EBF. The habitat limiting life stages in this reach are mountain whitefish spawning and adult, and rainbow trout spawning (Table 5.19). The key evaluation metrics that approach the defined thresholds in this reach are the maximum instantaneous habitat losses and maximum weekly habitat losses. Although the maximum instantaneous habitat losses have exceeded the defined threshold for the spawning life stages, the other evaluation metrics were below the threshold criteria. The results for a 20% flow reduction are judged to provide a balance between all life stages throughout the year. Continued flow reductions resulted in the other metrics approaching or exceeding the thresholds, with the maximum instantaneous habitat losses becoming exceedingly large.

The mountain whitefish adult WUA curve peaks at a flow of 19.8 m^3/s and is used to define the EBF (Figure) and to identify the wet weeks to be removed from the analysis. Weeks 18-29 have weekly median flows greater than the peak of the mountain whitefish juvenile WUA curve and are removed from the analysis of the total mean habitat loss.

Table 5.19. Waterton River Reach 2 (W2) from 45 river kilometres upstream of the Belly River upstream to the Waterton Reservoir. Habitat evaluation metrics for a 20% reduction from the natural flow with the added constraint of the EBF.

Species	**Total Mean (Weeks 14-17: 30-44)**	**Maximum Weekly**	**Maximum Instantaneous**	**Maximum Yearly**
MNWH-A	-4.98%	-8.85%	**-23.13%**	-4.33%
MNWH-S	N/A	-10.66%	**-28.55%**	**-26.77%**
RNTR-S	N/A	-6.44%	**-32.47%**	-5.42%

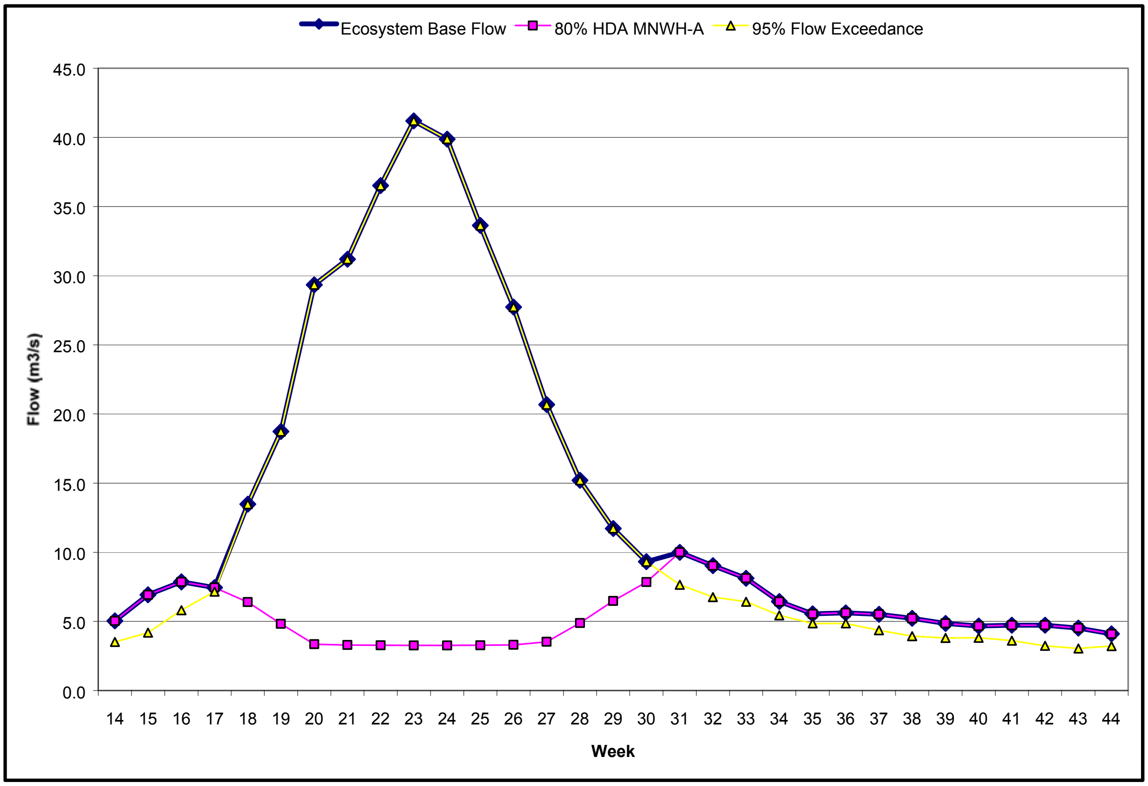


Figure 5.32. The weekly Ecosystem Base Flows for the Waterton River Reach 2 (W2) using the maximum value between the 80% habitat duration analysis for mountain whitefish adult and the 95% flow exceedence.

5.4.6 South Saskatchewan River

South Saskatchewan River Reach 1 (SS1)

Reach-specific fish habitat data are not currently available for the South Saskatchewan River from the Saskatchewan border upstream to Highway 41. Habitat information is also not available for lake sturgeon, a key management species for this reach of the river. Therefore, the current evaluation for fish habitat used the Tessmann (1979) calculation to define the EBF (Figure 5.33). These values must be combined with the other components to develop the ecosystem IFN.

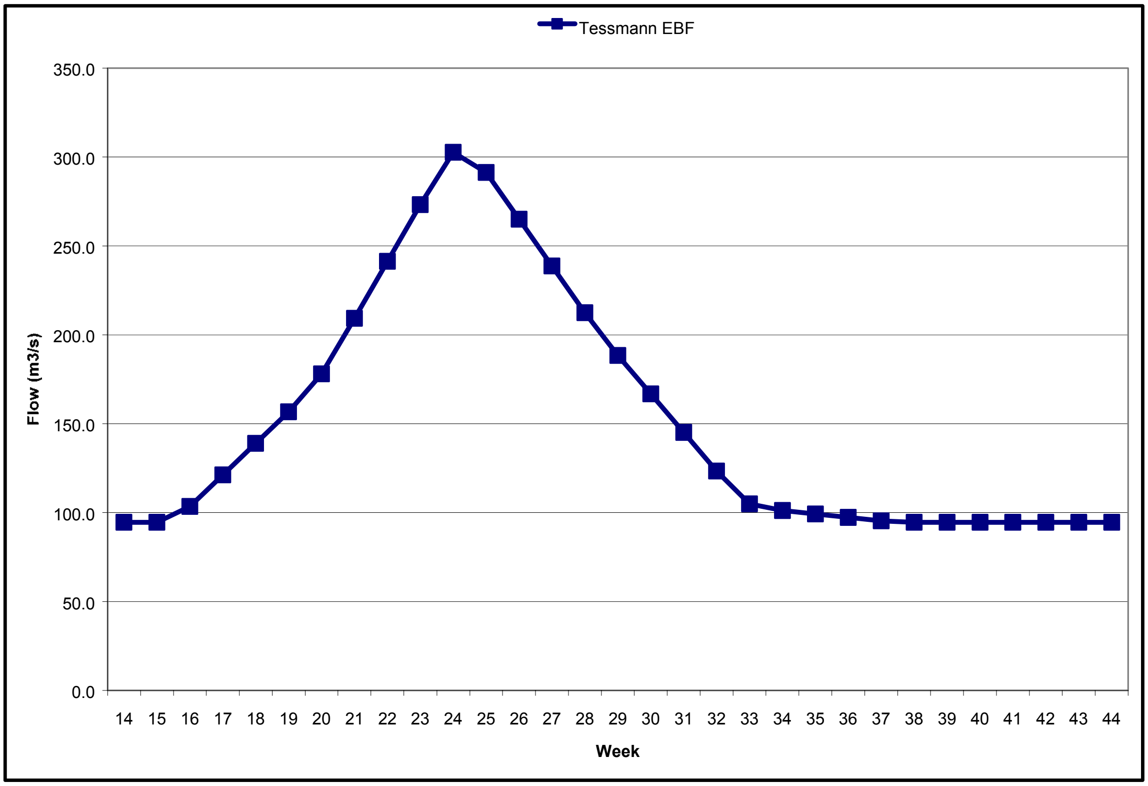


Figure 5.33. The weekly Ecosystem Base Flows for the South Saskatchewan River Reach 1 (SS1) using the Tessmann calculation.

South Saskatchewan River Reach 2 (SS2)

Reach-specific fish habitat data are not currently available for the South Saskatchewan River from Highway 41 upstream to the Grand Forks. Habitat information is also not available for lake sturgeon, a key management species for this reach of the river. Therefore, the current evaluation for fish habitat used the Tessmann (1979) calculation to define the EBF (Figure 5.34). These values must be combined with the other components to develop the ecosystem IFN.

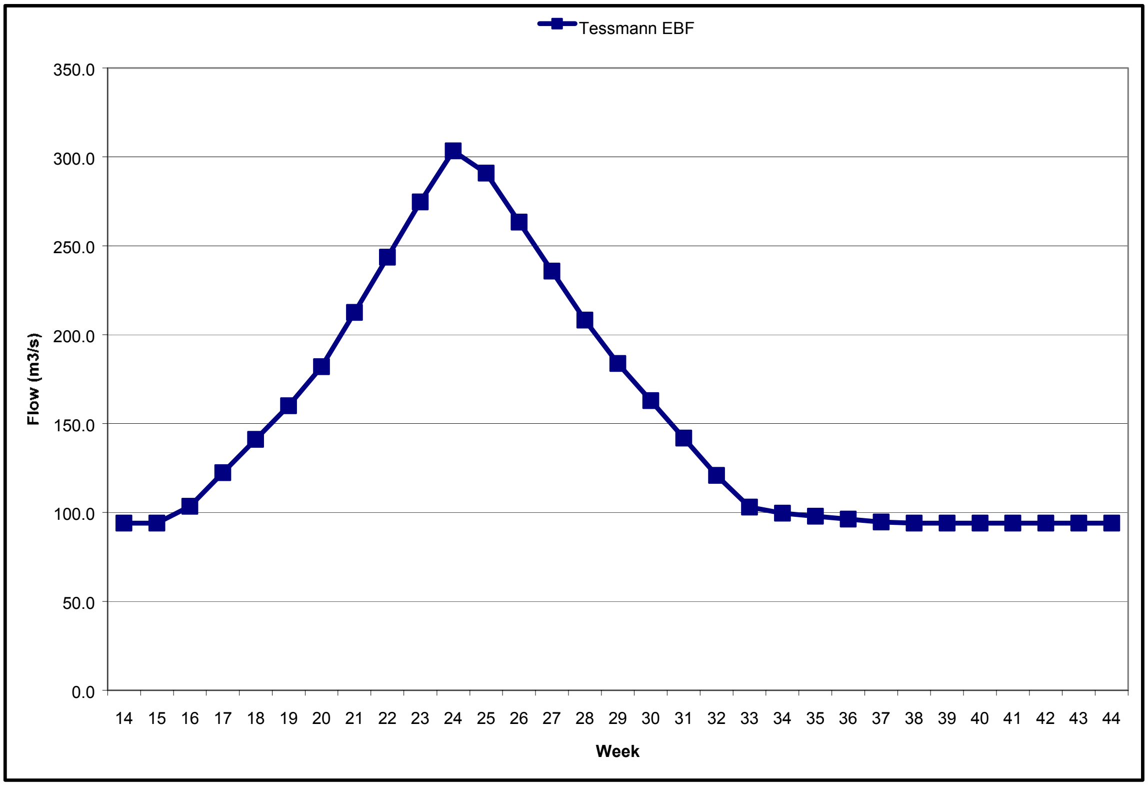


Figure 5.34. The weekly Ecosystem Base Flows for the South Saskatchewan River Reach 2 (SS2) using the Tessmann calculation.

5.4.7 Summary of Fish Habitat Results

The fish habitat results for each reach are presented in Table 5.20. The fish habitat IFN determination has two distinct components that act together to protect fish habitat for a range of flow conditions. The first component is the EBF, to protect naturally limiting habitat under low flow conditions. When natural flows are above the EBF, the fish habitat IFN determination indicates that reductions in the flow should not fall below the EBF. When natural flows are below the EBF, the fish habitat determination indicates no reductions in flow should occur.

The second component of the fish habitat IFN determination is a constant-percent flow reduction from the natural flow regime. The purpose of this component of the fish habitat recommendation is to protect a range of habitat conditions that vary within the year and between years. Providing a variable flow recommendation ensures there will be some years with good habitat conditions for every life stage present, as opposed to managing for a single life stage and providing a single flow IFN that can be detrimental to other life stages. With a variable flow IFN as provided by the constant-percent flow reduction, some years will have a flow regime that may be very well suited to adult life stages, while other years provide better spawning or rearing habitat.

Most of the results presented in Table 5.20 indicate a constant-percent flow reduction from natural in the 15% to 30% range. There are four reaches, however, with results that differ from the majority. Two reaches on the Bow River, BW3 and BW4, indicate very large flow reductions. The habitat results from Reach BW3 did not respond with continued percent reductions from the natural flow. The natural flow could be reduced entirely to the EBF across all flow ranges and still meet the habitat metric criteria. As a result, the flow recommendation for fish habitat at reach BW3 was just the EBF flows and no percent reduction rule was applied. At reach BW4, the habitat units were also unresponsive to reductions in flow resulting in a final flow reduction of 55% from natural with the added constraint of the EBF. In both cases, the WUA curves peak at a relatively low flow compared with the hydrology of the reach. Curve peaks are broad and are not sensitive to flow reductions. This is also the case for Reach OM2 and Reach SM1, where 40% flow reductions are indicated. Although the integration process with the other ecosystem components as detailed in section 9 will alleviate some of these large reductions in flow for many weeks of the year, the results should be interpreted and applied with caution. A reach balancing process, normally carried out during the running of the water balance model, is required to ensure results increase incrementally from upstream to downstream and make good biological sense.

Table 5.20. Summary of fish habitat IFN determinations to be incorporated into the ecosystem IFN.

River Reach	% Reduction from Natural Flow	Method for Defining the Ecosystem Base Flow	Weeks Included for Integrated IFN
RD1	20%	80% HDA – GOLD Adult	14-22 : 29-44
RD2	20%	Used RD1 Values	14-22 : 29-44
RD3	20%	80% HDA – GOLD Adult	14-22 : 28-44
RD4	25%	Used RD5 values	14-15 : 34-44
RD5	25%	80% HDA – GOLD Adult & WALL Spawning	14-15 : 34-44
RD6	20%	80% HDA – MNWH Adult	14-19 : 30-44
RD7	25%	80% HDA – MNWH Juvenile	14-19 : 30-44
BW1	N/A	Tessmann	All
BW2	25%	80% HDA – MNWH Juvenile	14-15 : 37-44
BW3	N/A	80% HDA – MNWH Juvenile	14-19 : 37-44
BW4	55%	80% HDA – MNWH Adult	14-17 : 37-44
OM1	N/A	Tessmann	All
OM2	40%	80% HDA – MNWH Adult	14-15 : 33-44
OM3	30%	80% HDA – MNWH Adult	14-19 : 27-44
OM4	15%	80% HDA – MNWH Adult	14-16 : 29-44
OM5	30%	80% HDA – MNWH Juvenile	14-16 : 29-44
OM6	20%	80% HDA – MNWH Juvenile	14-16 : 29-44
OM7	20%	80% HDA – MNWH Juvenile	14-15 : 31-44
BL1	30%	80% HDA – MNWH Adult	14-18 : 29-44
BL2	20%	80% HDA – MNWH Juvenile	14-19 : 30-44
BL3	N/A	Tessmann	All
SM1	40%	80% HDA – MNWH Juvenile	14-17 : 31-44
SM2	N/A	Tessmann	All
W1	25%	80% HDA – MNWH Adult	14-17 : 29-44
W2	20%	80% HDA – MNWH Adult	14-17 : 30-44
SS1	N/A	Tessmann	All
SS2	N/A	Tessmann	All

Notes – GOLD = Goldeye, MNWH = Mountain Whitefish, WALL = Walleye, HDA = Habitat Duration Analysis.