FINAL
Lamprey River
Protected Instream Flow Report

13 July 2009

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FINAL
Lamprey River
Protected Instream Flow
Report

Prepared by

Normandeau Associates, Inc.
Rushing Rivers Institute
University of New Hampshire

Watershed Management Bureau
NH Department of Environmental Services
PO Box 95 - 29 Hazen Drive
Concord, NH 03302-0095
Telephone 603-271-3548
Fax 603-271-7894
http://des.nh.gov/organization/divisions/water/wmb/rivers/instream/index

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Thomas S. Burack
Commissioner

Michael Walls
Assistant Commissioner

Harry T. Stewart. P. E., Director
Water Division

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Glossary

ACOE	U.S. Army Corps of Engineers
ADO	Affected dam owner
Aestivate	To enter a state of torpor during hot or dry conditions
Akal	Medium to fine gravel (0.2 - 2 cm or 0.08 - 0.8 inches)
AMC	Appalachian Mountain Club
AWU	Affected water user
BSI	Basin stress index
cfs	Cubic feet per second
cfsm	Cubic feet per second per square mile
Choriotop	A substrate classification system based on the Austrian Standard ONORM 6232
CUT	Continuous under threshold
EPT	Ephemeroptera, Plecoptera and Trichoptera
FTM	Floodplain transect method
Gigalithal	Bedrock
GIS	Geographic information system
GPS	Global positioning system
GRAF	Generic Resident Adult Fish
HMU	Hydromorphological unit
IHA	Indicators of hydrologic alteration
IPUOCR	Instream public uses, outstanding characteristics and resources
LBFC	Lamprey baseline fish community
Macrolithal	Coarse blocks, head-sized cobbles, mix of cobbles, gravel and sand (20 - 40 cm or 7.9 - 15.8 in)
Megalithal	Large cobbles, blocks and bedrock (>40 cm or >15.8 in)
MesoHABSIM	A computer simulation of meso-scale habitat
Mesolithal	Fist- to hand-sized cobbles with a mixture of medium to fine gravel (6.3 - 20 cm or 2.5 - 7.9 in)
Microlithal	Coarse gravel with a mixture of medium to fine gravel (2- 6.3 cm or 0.8 - 2.5 in)
NAI	Normandeau Associates, Inc.
NFP	Natural flow paradigm
NHDES	New Hampshire Department of Environmental Services
NHF&GD	New Hampshire Fish & Game Department
NHI	Natural heritage inventory
NHNHB	New Hampshire Natural Heritage Bureau
NRCS	Natural Resources Conservation Service
Pelal	Silt, loam, clay and sludge (<0.063 mm or 0.002 in)
PHABSIM	Physical habitat simulation model
Phytal	Submerged plants, floating stands or mats
PISF	Protected instream flow
POTW	Publicly owned treatment works
Psammal	Sand (0.063 - 2 mm or 0.002 - 0.08 in)
R&G	Rearing and growth bioperiod

RSA	Revised statutes annotated
RTE	Rare, threatened and endangered species
Sapropel	Organic sludge
SimStream	Software used to process data collected in a MesoHABSIM study
TFC	Target fish community
TMDL	Total maximum daily load
TRC	Technical review committee
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
WMP	Water management plan
WMPA	Water management planning area
WMPAAC	Water management planning area advisory committee
WWTP	Wastewater treatment plant
XFC	Expected Fish Community
Xylal	Tree trunks, branches, roots
YOY	Young of Year (Juvenile Fish)

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EXECUTIVE SUMMARY

Introduction

Pursuant to the Rivers Management and Protection Program (Section 483:9-c Establishment of Instream Flows), protected instream flows are to be established for each designated river. Chapter 278 (Laws of 2002) created a pilot program to study and establish protected instream flows and adopt water management plans for the Lamprey River and the Souhegan River. This report describes the scientific methods used to study and develop protected instream flows for the Lamprey Designated River. The findings of this report will be used to formally establish protected instream flows for the Lamprey Designated River and will provide the basis for the development of a Water Management Plan to be completed during the second phase of this project.

This report is the summation of several tasks that have been completed as the first phase of the Lamprey Designated River Protected Instream Flow Study and Water Management Plan pilot project. The tasks performed as part of this study include:

- Task 1 – preliminary identification and listing of river-specific protected entities described categorically in statute RSA 483:1 (Statement of Policy) and 483:9-c as instream public uses, outstanding characteristics, and resources
- Task 3 – an on-stream survey for locating the protected entities on the Lamprey Designated River and the initial report of the survey findings
- Task 4 – a report describing the final list of protected entities and their flow dependent status with the proposed methods for the evaluation of the protected instream flows
- Task 5 – field assessments, data analysis and preparation of the proposed protected instream flow study report
- Task 6 – a public hearing to present the study's findings for comment

Reports documenting these activities can be found at the DES website: http://des.nh.gov/organization/divisions/water/wmb/rivers/instream/lamprey/study.htm.

The development of the protected instream flows for the Lamprey Designated River is based on a multidisciplinary study of a complex system. Due to the technical nature of the methods used and the complexity of the system studied, the full report is detailed, lengthy and at times challenging to understand for the non-scientist. This executive summary provides an overview of the regulatory basis for the study, the study methods used, the results of the study and recommendations for the establishment and maintenance of protected instream flows on the Lamprey Designated River.

Protected Instream Flows and Protected Entities – Definition and Identification

The protected instream flow values are descriptions of the flow regime conditions that will support the flow dependent instream public uses. Under Env-Ws 1901.01 (Rules for the Protection of Instream Flow on Designated Rivers), the purpose of establishing and enforcing protected instream flows, is to “maintain water for instream public uses and to protect the resources for which the river or river segment is designated”. RSA 483:9-c, IV requires that the protected instream flow levels established by the Commissioner “shall be maintained at all times, except when inflow is less than the protected instream flow level as a result of natural causes or when the commissioner determines that a public water supply emergency exists which affects public health and safety.” Furthermore, RSA 483:9-c, V requires that, “the maintenance of protected instream flows shall constitute a condition of any permit issued by the [Department of Environmental Services] for any project or activity within a designated river of segment and corridor.” Lastly, Env-Ws 1907.02 (Protected Instream Flows and Water Quality Criteria) states that “protected instream flows established by the commissioner shall serve as water quality criteria for the purpose of administration of water quality standards by the department under the federal Clean Water Act.”

The instream public uses cited in Chapter 483 (New Hampshire Rivers Management and Protection Program) include the state’s interests in surface waters, including but not limited to: navigation; recreation; fishing; storage; conservation; maintenance and enhancement of aquatic and fish life; fish and wildlife habitat; wildlife; the protection of water quality and public health; pollution abatement; aesthetic beauty; and hydroelectric energy production. As noted in the introduction, the instream public uses, outstanding characteristics and resources (IPUOCRs or protected entities) were initially identified in Task 1 and field surveyed in Task 3. The protected entities were then assessed for their flow dependency in Task 4. Only those protected entities identified as being flow dependent were included for the assessment of their protected instream flows in Task 5. For the biological protected entities, flow dependence means that a species has one or more life stages requiring flowing water within the banks of the river channel of the designated segment; or is a community that provides habitat for such species. The human uses of recreation and public water supply were also considered to be flow dependent. As discussed in the Task 4 report, the flow dependent protected entities included: recreation (boating, fishing and swimming), the maintenance and enhancement of aquatic fish and life, fish and wildlife habitat, rare, threatened and endangered fish, wildlife, vegetation or natural/ecological communities and public water supply.

Natural Flow Paradigm

The development of the Protected Instream Flow values for the flow-dependent, protected entities was performed within the framework of the Natural Flow Paradigm (Poff and others, 1997). The Natural Flow Paradigm recognizes that the natural variability of stream flows is what determines the geomorphic and biologic characteristics of a river. The native riverine ecosystem contains multiple species, some of which thrive in wet years and others that thrive in dry years. Variability in the stream flow conditions allow these different species to coexist. The native riverine ecosystem is adapted to a flow regime that is not affected by diversions, discharges or withdrawals. If the riverine ecosystem is altered significantly, then the ecosystem will become impaired. However the adaptation of these species to variability in the flow regime does allow flexibility for water use by other entities.

The Natural Flow Paradigm also recognizes that minimum flows, once commonly used as instream flow limits, are not adequate for sustaining the riverine ecosystem or for the protection of its instream resources. The description of protected flows requires the use of the other stream flow components: flow frequency, duration, timing, and rate of change, as well as magnitude.

The application of the Natural Flow Paradigm concept in this study implies that the principal management objective is to allow streams to flow as close to their natural flow regime as possible. Low flows and floods are expected to occur as natural conditions and take place within the range of natural flows. Typical human influences tend to reduce flow variability by removing floods and droughts. This may make the availability of stream flow more reliable for human use, but is detrimental to biological integrity. Understanding the potential for the human alteration of the natural flow regime of the Lamprey River and the impact on its protected entities is a major objective of this study.

It is important to recognize that the natural river flow (even in the absence of any human intervention or water use) will not always meet all of the riverine ecosystem flow needs, nor should it. Native communities are adapted to meet periods of stress that occur within the natural ranges of frequency and duration. The Natural Flow Paradigm recognizes that rare natural extremes such as flood and droughts have important functions in supporting riverine ecosystems. For example, periods of flooding help sustain the floodplain plant communities found along the river by replenishing nutrients, eliminating competing plants and dispersing seeds. While periods of low flow, such as during droughts, allow for the development of river channel plant communities.

Protecting flow variability is necessary to insure that the ecosystem provides the variety of habitat conditions necessary to support the entire ecosystem. Water management measures will be required where human uses increase the durations or frequencies of flow conditions below specified protected flows and their associated durations.

Protected Instream Flow Assessment

The study area included the limits of the Lamprey Designated River, which begins at the Lee-Epping town boundary and ends at the Durham-Newmarket town boundary, covering a distance of 12 river miles. Due to the complexity of its riverine ecosystem, a multidisciplinary team of specialists (biologists, engineers, geologists, geographers, hydrologists and hydrogeologists) worked collaboratively to perform a comprehensive assessment of the flow-dependent protected entities. The assessment techniques used in this study differed depending on the entity type. In general, the assessment methods can be divided between those used for the assessment of human uses (recreation) and those used for the assessment of the riverine ecosystem (fish and riparian wildlife and vegetation).

Flow needs for the human recreation uses of boating and swimming were developed using questionnaires and surveys. No specific assessment of fishing recreation was performed as part of the study, since it was believed that the protected instream flows specifically developed for fish would be protective of this recreational resource. Public water supply was initially considered a flow-dependent use because water withdrawals had flow conditions under a 401 Water Quality Certification. Water supply use was assessed based on a review of public records, questionnaires and surveys. Water supply use was later determined not to be flow dependent because flow does not affect demand. Protected instream flows for fish were developed using Mesohabitat Simulation Model (MesoHABSIM), a habitat simulation model, and those for riparian wildlife and vegetation were developed using the Floodplain Transect Method.

Assessment of Human Use Flow Needs

Flow-dependent human use of the river is recreational boating. The instream flow needs for the recreational uses were assessed by a review of existing information, user surveys and questionnaires. Existing information reviewed included the nomination documents submitted for the designation of the Lamprey River, the Lamprey River Management Plans prepared by the Lamprey River Advisory Committee, guidebooks on paddling the Lamprey River published by the Appalachian Mountain Club (AMC) and online sources of information on paddling the Lamprey River. Local individuals were contacted for information on paddling and swimming use and locations.

Information on paddling and swimming use on the Lamprey Designated River was obtained by field surveys and questionnaires. Surveys and questionnaires are commonly used to assess recreation use for instream flow studies where the objective is to understand what factors influence the decision to engage in these activities, where these uses occur and at what flows the opportunities to engage in these activities become limited. To assess boating use and the flows required to support this recreational activity user surveys were distributed to paddlers at multiple boat launches located along the Lamprey Designated River.

Field surveys on swimming were performed at the four designated beaches (Ferndale Acres Campground, Glenmere Village, Wadleigh Falls Campground and Wellington Camping Park) and two popular swimming areas (Wadleigh Falls and Wiswall Dam) located along the Lamprey Designated River. Flow was not a determining factor in swimming except to avoid dangerous conditions.

Recreational paddling flow needs are specific to the activity and the desired flow varies in a relatively narrow range throughout the year. These flows are not always available, resulting in the seasonal use of the river for boating. This is traditionally an opportunistic use, such that boaters use the flows when they occur, but do not expect these flows to be continuously available.

Assessment of Environmental Flow Needs

Water use by aquatic (fish) and riparian (wildlife and vegetation) species is different from human use, because their use of water is time dependent. Their life cycles require differing flows through the year. To assess the flows necessary to support these protected entities two methods were used: MesoHABSIM and the Floodplain Transect Method.

Assessment for Fish

Protected instream flow requirements for fish were developed using the MesoHABSIM model. The MesoHABSIM model establishes the river-specific relationship between stream flow and habitat availability. The model evaluates the time distribution of habitat availability to identify significant changes in habitat frequency and duration. Protection is identified that will limit stream flows below these significant changes in habitat frequency and duration.

MesoHABSIM is an adaptation of the Physical Habitat Simulation (PHABSIM) habitat simulation model. Both models assume that habitat availability correlates positively with population. Both are methods of evaluating habitat change relative to stream flows. MesoHABSIM uses measurements taken at a biologically-significant scale that is more representative of watershed-wide conditions, while the PHABSIM method extrapolates micro-scale habitat measurements made at selected cross-sections to the watershed scale. Because of this extrapolation from micro-scale to watershed scale, site selection is critically important in the PHABSIM method. MesoHABSIM addresses this issue by evaluating representative reaches. The representative reaches are selected by quantitative assessment of their hydromorphologic makeup (pools, riffles, runs, etc.) relative to the river's makeup as a whole. Each representative reach is a microcosm of a larger segment. The representative reaches assessed as part of this study comprised 55 percent of the Lamprey Designated River, which is significantly greater than if assessed by equivalent PHABSIM studies. Furthermore, MesoHABSIM uses a greater number of biologically-significant criteria as inputs for evaluating habitat than PHABSIM, which generally uses depth and velocity. These two factors play the greatest role in habitat suitability only when habitat is severely limited. MesoHABSIM measures habitat criteria at multiple locations within each type of stream hydromorphologic unit within the representative reaches. The MesoHABSIM method then uses logistic regression of these factors to select the most significant for defining habitat suitability.

The underlying assumption of MesoHABSIM is that over many centuries fish have adapted to their environment and that there is a strong functional relationship between the species composition and the physical form and structure of surrounding environment. This method builds upon a theory of biophysical habitat templates and corresponding biological communities (Poff and Ward 1990; Townsend and Hildrew 1994), which states that in a natural environment every niche is used by some species and the fauna is adapted to the normal range of conditions. Since the physical structure shapes the fauna composition, this relationship is reversed to identify the needs of the fauna by investigating characteristics of the physical habitat template. For this study, the habitat limitations were identified to find when the conditions occur so rarely, that it becomes unpredictable.

Human modification of a fluvial hydrosystem can result in a mismatch between the river's biological and physical templates (flow and river structure.) Hence, the determination of flow patterns that would be protective to the fish fauna is very limited when using heavily modified flow patterns or river structures for this purpose. Therefore, the prerequisite of this approach is that the physical templates used in the model will be as close as possible to natural under current climate and land use conditions. To accomplish this, baseline conditions must be defined for the physical templates.

To establish the baseline conditions for the determination of the protected instream flows, both the flows and the physical habitat template of the Lamprey Designated River were modified for the MesoHABSIM model. The flows used in the modeling were calculated as they would occur in the river without human modification. Meaning, the recorded stream flows for the Lamprey River were adjusted to reflect the quantified values for net water use (withdrawal minus return flow) and the storage and release of water from lakes or reservoirs. Major physical modifications of the river channel were also taken into account as they may also create unpredictable habitat levels. For example, impoundments do not have features that would support fluvial fish and therefore, were removed from the physical habitat model. With the baseline condition established, the habitat levels and corresponding flows were identified and used to establish the protected instream flow thresholds.

Similarly, to carry out the MesoHABSIM model, a Target Fish Community was established to identify the baseline species composition expected in the Lamprey Designated River. These species were identified from fish data collected from near-pristine rivers located in the Northeast with characteristics similar to the Lamprey Designated River. The Target Fish Community for this study consisted of 18 species and was dominated by: common shiner, fallfish, American eel, common white sucker, longnose dace and redbreast sunfish.

The fish species in the Target Fish Community were then evaluated to define their significant life cycle phases throughout the year. The Lamprey Designated River study identified six major life cycle phases. These significant life-cycle phases are called bioperiods, which define the timing component of protected flows for fish. The six bioperiods identified for this study included: overwintering, spring flood, clupeid spawning, GRAF (Generic Resident Adult Fish) spawning, rearing and growth, and salmon spawning. Each bioperiod is a biologically significant phase for one or more of the species identified in the Target Fish Community. Protected instream flows were then determined for each bioperiod.

To determine the protected flow magnitude, as well as the duration and frequency for a bioperiod, the natural availability of habitat was determined. Habitat preference criteria were developed for fish species and life stages. The habitat needs of the fish species were evaluated individually and collectively to define their criteria for habitat suitability. Using these criteria, the river was assessed for its habitat suitability by making repeated measurements of habitat parameters within representative reaches at multiple flows. The suitability criteria were then compared to conditions in the river and the relationship between flow and habitat was defined.

Although flow is related to habitat availability, it is not a linear relationship. The flow-habitat relationship is used to transform stream flows over time into habitat over time. From years of naturalized stream flows (stream flow gage data corrected for water withdrawals, releases or storage) and the relationship between habitat availability and flow, a daily record of available habitat for each bioperiod was established.

Habitat availability within the Lamprey Designated River for each bioperiod was assessed using time series analysis. Time series analysis identifies the duration and frequency of habitat availability at incremental levels. The years of habitat availability show the range, the frequency, and duration that the habitat occurred. The analysis identifies habitat limitations and magnitudes that demarcate drastic changes in frequency (e.g., sudden changes in habitat availability). For each of these habitat levels, frequency analysis was also used to identify durations that are unusual and to identify a series of thresholds that differentiate highly predictable or typical conditions from persistent and catastrophically long habitat shortages.

Three of these instances: the common, critical and rare, mark significant changes in the frequency of habitat availability, and were selected to represent the protected flows. These habitat availability levels are converted from habitat back to flow using the relationship between habitat availability and flow. These flow/habitat magnitudes and their associated durations representing significant changes in frequency are the protected instream flows for fish.

Assessment for Riparian Wildlife and Vegetation

Protected instream flow requirements for wetlands, floodplains, and channel habitats and their associated flora and fauna were determined using the Floodplain Transect Method, where representative transects are surveyed across the river channel and floodplain. In this method, an entity's elevational position on the stream bank or floodplain is identified, and the stream flow associated with raising water levels to this elevation position is identified through observation at multiple flows of flow/stage modeling. Life cycle needs are determined by species to describe the frequency and timing of these flows.

Cross sections and maps were constructed showing plant community boundaries and wildlife habitats associated with their topographic position. Surface water elevations during low, moderate, and high flow events along the transects were recorded along with the concurrent stream flows from gage station. Protected instream flows were defined as those stream gage flows associated with the water level supporting critical life cycle events for plant communities or wildlife habitats – for example:

- Filling oxbow/backwater marshes, swamps and floodplain pools during spring for plant development and breeding wildlife.
- Maintaining sufficient water cover over hibernating turtles and amphibians through the winter.
- Scouring of floodplain forest floors once every three years to discourage invasive species and prepare seedbeds.

Protected flows were defined under the Floodplain Transect Method using the magnitude, timing, and frequency of flows needed to support riparian wildlife and vegetation. In addition, there are plant communities and species that are sensitive to high flows occurring during bioperiods typically associated with low flows. For example, turtle and bird nests located in the high floodplain could be destroyed by flooding that occurs during the nesting season when flows are typically low. These sensitive entities are discussed in this report to inform flow managers contemplating management actions that might result in unnatural flood events (such as a dam release); it is not intended to imply that naturally occurring floods be controlled for the protection of these particular sensitive resources.

Lamprey Designated River Protected Instream Flows

The Lamprey Protected Instream Flows are described within the context of the Natural Flow Paradigm which includes the assumption that the ecosystem needs are best supported by maintaining the natural variability of stream flows. Human uses are usually met under these same conditions. The assessments conducted by this study have defined protected flows, using components of magnitude, timing, frequency and duration which establish the critical thresholds for maintaining the ecological and human uses by maintaining the natural variability of stream flows.

Protected Instream Flow for Boating

Boating environments on the Lamprey Designated River includes both flat water (impounded by bedrock outcrops or dams) and rapids (whitewater). Running the entire Lamprey

Designated River involves both types of experiences and requires a sufficient flow so that paddlers can pass through the rapids sections unimpeded. Based on the information gathered as part of this study, a flow of 275 cfs is required to support recreational boating of the full length of the Lamprey Designated River (ES-1). Boaters only using the flat water sections stated that the only flow limitation to their use of these sections of the river were high (flood) flows, which create dangerous conditions.

In the context of the Natural Flow Paradigm, the opportunity for boating the entire length of the Lamprey Designated River is dependent upon the natural availability of the supporting flow. This flow is dependent upon runoff and groundwater recharge, which is affected by climate, but may also be affected by dam operations and/or water withdrawals along portions of the Lamprey Designated River. The impact of any water uses on the magnitude, frequency and timing of flows that affect boating recreation will be considered during the Water Management Plan process.

Protected Instream Flows for Fish and Aquatic Life

Protected instream flow values for fish and aquatic life were defined for each of the six bioperiods (overwintering, spring flood, Clupeid spawning, GRAF spawning, rearing and growth and salmon spawning) by both magnitude and duration (Table ES-1). Each bioperiods recommendations consist of three levels of flow magnitude in cubic feet per second (cfs) and cubic feet per second per square mile (cfsm) and allowable and catastrophic durations for each magnitude.

The three flow magnitudes for each bioperiods' protected instream flows are: common, critical, and rare, where:

> The **common flow** is the flow corresponding to the highest habitat magnitude above which the frequency of occurrence begins to decline significantly.
>
> The **critical flow** is the flow corresponding to the second to the lowest habitat magnitude. Critical flow magnitudes describe less habitat availability than that provided by the common flow, but this habitat magnitude is not unusual.
>
> The **rare flow** is the flow corresponding to the lowest of habitat magnitudes for which the frequency of occurrence increases significantly. Rare flow habitat availability is severely reduced and very uncommon.

Each protected flow magnitude is characterized by two durations: allowable and catastrophic. Counting the days when flow is less than one of the flow magnitudes is the first step in determining whether protected flow conditions are met. The durations define limits on the consecutive days when flow is below a protected magnitude. Repeated occurrences when stream flow is below a flow magnitude for longer than these durations will result in a water quality violation requiring management.

Stream flow at levels below a protected magnitude for durations shorter than the allowable duration is acceptable and is a common condition. Flow below a protected magnitude for more than the allowable duration, but less than the catastrophic duration, is a persistent condition. A persistent condition that occurs for three consecutive years within the same bioperiod is a catastrophic condition representing impaired water quality requiring management. Flow below a protected magnitude for durations longer than the catastrophic duration that occurs twice in one bioperiod within ten years is a catastrophic condition representing impaired water quality requiring management.

Protected Instream Flows for Riparian Wildlife and Vegetation

Protective flows vary greatly among the numerous plants, natural communities, and wildlife species associated with the Lamprey Designated River riparian corridor. To facilitate discussion, flow-dependent riparian entities can be sorted into five groups with similar flow needs:

1. Periodic Flood PISF (annually or less in frequency)
2. Minimum Seasonal PISF (every winter, spring, and/or summer)
3. Maximum summer PISF
4. Generic Resident Adult Fish (fish) PISF (for eagles, osprey)
5. PIS water levels (not flows)

Group 1 includes high and low floodplain forests and oxbow/backwater swamps that depend on periodic flooding (annually or less often) to fill basins, deposit nutrients, and eliminate flood intolerant plants. Depending on landscape position, these communities may flood once a year to once every hundred years, occurring typically in late winter/early spring, for days to weeks (Table ES-1). Flows that are greater than 500 cfs every one to three years, and flows that are at least 1,500 cfs once every five years (with greater flows occurring less frequently) are typical under natural conditions, based on tree flood tolerance data, plant community descriptions, and soil characteristics. There is no intent to suggest creating floods for these entities, nor should such flood events be deliberately prevented through management practices.

Group 2 includes the instream plants and communities that have annual minimum winter, spring and early summer flows to set up optimum conditions for early vegetative growth and development. Herbaceous low riverbanks, riverweed river rapids, and marshes, along with their associated Rare Threatened and Endangered (RTE) plants are in this group, as well as hibernating wood turtles, which have minimum flow requirements in winter. Minimum monthly flows that are protective of all of these entities are 130 cfs from December through February, 100 cfs from May through June, and 10 cfs during July (Table ES-1). During the winter, daily flows should be at least 50 cfs, and flows of 500 cfs should occur for at least one week. These flows occur naturally in most years, and should not be prevented by management activities.

Group 3 are the plants and animals that are sensitive to the rare summer flood events. Turtle eggs and nestlings in the high floodplain, larval amphibians in floodplain pools, and blooming aquatic and emergent plants may be harmed by summer floods. Daily flows that are less than 500 cfs in June, July and October, and are less than 60 cfs in August and September are protective of all of these entities (Table ES-1). However, as previously stated, high flow criteria for these sensitive entities are discussed in this report to inform regulators contemplating management actions that might result in unnatural flood events (such as a dam release); it is not intended to imply that naturally occurring floods, regardless of timing, be controlled for the protection of these particular sensitive resources.

Group 4 are the fish-eating raptors, including bald eagles and osprey that may feed in the Lamprey Designated River at any time of year. The flows protective of these species are those of the Generic Resident Adult Fish (GRAF) as discussed in the fish section of the report.

Group 5 includes the plants and animals of the Lamprey's larger impoundments. They include pied-billed grebes, sedge wren (neither of which were observed) and the aquatic plants, water marigold and star duckweed. Protected flows for these species were not determined, as their required water levels were not well correlated with changes in flow in these impoundments. Instead, protective water levels were identified. These are summer water levels within 18 inches of the mean, with no reductions exceeding six inches for more than seven days from 15 March through 31 July.

Protected Instream Flows for the Lamprey Designated River

Table ES-1 represents the protected flows required to maintain instream public uses. This determination comes from comparing the timing and magnitude of the flow needs for fish, riparian vegetation, riparian wildlife, and human uses. The emphasis of this comparison was to determine the highest sustainable flow need of the entities in order to define the controlling flow. The selection of the highest flow needs as the protected instream flow magnitudes is tempered by the description of allowable and catastrophic durations, which are keyed to the flow magnitudes' natural ranges of occurrence. By satisfying the highest flow, all other flow needs are then met. The flow needs of riparian wildlife and vegetation, not met by fish flows, are incorporated in the protected instream flow recommendations.

Boating

The recommended protected instream flow for recreation is 275 cfs (1.5 cfsm), which in an average year is met over 30 percent of time (Table ES-1). If this human-related instream flow were to be the controlling protected instream flow, the protected instream flow for the Lamprey Designated River would be equal to the flows occurring only during spring snowmelt runoff, during the fall when water stored in Pawtuckaway Lake is released and/or during large storm events and as a result would not be continuously sustainable.

Fish and Aquatic Life

The protected instream flows for fish and aquatic life in the Lamprey Designated River are summarized in Table ES-1. The protected flows and their associated durations for each bioperiod are defined by the following:

- For the overwintering bioperiod (December 9 to February 28) flows should not be under **1.3 cfsm (238 cfs)** for longer than 20 days, under **0.6 cfsm (110 cfs)** for longer than 10 days, or under **0.4 cfsm (73 cfs)** for longer than seven days. Catastrophic durations for these flow levels (common, critical and rare) are 57, 37, and 30 days, respectively.
- During the spring flood bioperiod (March 1 to May 4) flows should not be under **3.4 cfsm (622 cfs)** for longer than 14 days, under **1.3 cfsm (238 cfs)** for longer than 10

days, or under **0.8 cfsm (146 cfs)** for longer than three days. Catastrophic durations for these flow levels are 42, 19, and nine days, respectively.

- During the American shad spawning bioperiod two events take place, the spawning of Clupeids and GRAF species. Therefore, the flow criteria for both of these events need to be fulfilled. For Clupeid spawning (May 5 to June 19) the flows should not be lower than **0.78 cfsm (143 cfs)** for longer than 13 days, nor less than **0.34 cfsm (62 cfs)** or higher than **0.85 cfsm (156 cfs)** for five days, or less than **0.31 cfsm (57 cfs)** or higher than **1.32 cfsm (242 cfs)** for four days. Catastrophic durations for these flow levels are 28, 13, and 10 days, respectively.
- During early summer the spawning habitat for GRAF species mostly declines if flow increases. Therefore, the flow recommendations for this bioperiod are different than for the others. Target flow levels and durations are recommended and duration counting begins with the shad spawning bioperiod start (May 5), but the criteria apply only during this bioperiod. For the GRAF spawning bioperiod (June 20 to July 4) flows should stay under **0.55 cfsm (101 cfs)** for at least 11 days, but no longer than 15 days in the catastrophic case. Flow should not be above **0.85 cfsm (156 cfs)**, but no less than **0.10 cfsm (18 cfs)** for longer than five days, but no longer than 10 days in the catastrophic case. The flows should not be higher than **1.32 cfsm (242 cfs),** but not lower than **0.09 cfsm (16 cfs)** for longer than two days, but no longer than three days in the catastrophic case. For high flows, in order to support spawning, long durations of high flow events should not be caused by management activities under the Water Management Plan. For low flows, rare flows should not be lower than those recommended for the preceding rearing and growth bioperiod, because the adult fish still need to survive.
- During the rearing and growth bioperiod (July 5 to October 6) flows should not be under **0.57 cfsm (104 cfs)** for longer than 46 days, under **0.10 cfsm (18 cfs)** for 15 days, or under **0.09 cfsm (16 cfs)** for five days. Catastrophic durations for these flow levels are 82, 32, and 15 days, respectively.
- During the Atlantic salmon spawning bioperiod (October 7 to December 8) the flows should not be under **0.49 cfsm (90 cfs)** for longer than 17 days, under **0.22 cfsm (40 cfs)** for 11 days, or under **0.11 cfsm (20 cfs)** for six days. Catastrophic durations for these flow levels are 55, 33, and 11 days, respectively.

These protected flow and duration prescriptions are intended to be used as thresholds to determine when management actions are necessary to maintain and support fish and aquatic life in the Lamprey Designated River. The specific management actions to be taken will be evaluated during the development of the Water Management Plan for the Lamprey Designated River.

Riparian Wildlife and Vegetation

The requirements of most riparian wildlife and vegetation are lower than those of fish. The needs of riparian life that are obviously not secured by fish specific flows are listed below and in Table ES-1:

Winter Survival and Development

>130 cfs seasonal mean – wood turtle (December 1 through February 28)

>500 cfs for one week or more – Herbaceous Low Riverbank, mannagrass, hempweed (December 1 through April 30)

Spring Spawning/Growth

>100 cfs seasonal mean – riverweed, knotty pondweed (May 1 through June 30)

<1,500 cfs daily mean except for natural events - floodplain vernal pools (March 15 through July 31)

Summer Survival and Development

<500 cfs daily mean except for natural events – wood turtle (June 1 through October 15)

$\leq$60 cfs daily mean in August/September except for natural events – Herbaceous low riverbank

<100 cfs seasonal mean – August /September except for natural events – riverweed, knotty pondweed

The requirement for $\leq$60 cfs of daily mean in August and September for maintenance of herbaceous low riverbank conflicts to some extent with the needs of the common shiner. During this time the flows for common shiner should fluctuate between 22 and 110 cfs. However, because the flows between 60 and 110 cfs will not occur very often, it is recommended that the criteria specified in Table ES-1 should be used for development of the Water Management Plan.

Maintenance of Protected Instream Flows for the Lamprey Designated River

The protected instream flows will be maintained by implementing a Water Management Plan. Under the Lamprey Designated River Water Management Plan, management actions will be implemented to offset catastrophic conditions. Implementation of management actions will be based on tracking river flows at the USGS Packers Falls gage and comparing them to the protected instream flows.

For recreational boating, the number of days of occurrence of flows equal to 275 cfs will be tracked annually by DES to ensure that the frequency of these events continues to match historical occurrence rates. The instream flow need for this use will continue to be met as it has been historically (that is, opportunistically) and the management strategy will consider this protected instream flow in the context of preserving the frequency of its occurrence, but will not attempt to meet recreation needs on a continuous basis.

The protected instream flows defined for fish will be assessed by DES on a day to day basis to determine whether flows below thresholds exceed catastrophic durations. Flows that continue below thresholds beyond allowable durations will be tracked. Repeated events occurring within successive bioperiods or occurring during the same bioperiod for three successive years represent persistent conditions. Persistent events will be tracked on an inter-annual basis and will be deemed catastrophic if they occur in three consecutive years within the same bioperiod with management actions triggered at the beginning of the onset of the third event under these flow conditions. If the frequency of catastrophic events is found to increase, then long term management actions may be required to offset or reduce the frequency of these events.

The instream flows supporting riparian wildlife and vegetation will be assessed by DES each year, so that management of these protected flows will react to the previous year's conditions and apply flow protections the following year. If the watershed did not meet these instream flows, then management actions for the following year may have to be implemented. This approach recognizes the ability of many plants and semi-aquatic wildlife to survive occasional water level changes through relocation, dormancy, or other physiological adaptations not available to fish.

Management alternatives for the maintenance of the protected instream flows for the Lamprey Designated River will be evaluated during the development of the Water Management Plan, which is the next phase of this project. This Plan will include Conservation, Water Use and Dam Management Plans for affected water users or affected dam owners located within the Lamprey Designated River Water Management Planning Area.

Table ES-1 - Instream protected flows for the segments of the Lamprey River Designated as protected pursuant to RSA 483:15, XIII.

Lamprey Protected Instream Flows for Fish			Common flow				Critical flow				Rare Flow			
Time of Year	**Controlling IPUOCR Flows**	**Bioperiod**	**Common flow (cfs)**	**Common flow (cfsm)**	**Allowable duration (days)**	**Catastrophic duration (days)**	**Critical flow (cfs)**	**Critical flow (cfsm)**	**Allow-able duration (days)**	**Cata-strophic duration (days)**	**Rare flow (cfs)**	**Rare flow (cfsm)**	**Allow-able duration (days)**	**Cata-strophic duration (days)**
Dec 9 – Feb 28	Flow	Overwintering	238	1.3	20	57	110	0.60	10	37	73	0.40	7	30
Mar 1 – May 4	Flow	Spring Flood	622	3.4	14	42	238	1.3	10	19	146	0.80	3	9
May 5 – Jun 19	Shad spawning	Clupeid Spawning	143	0.78	13	28	62 / **156**	0.34 / **0.85**	5	13	57 / **242**	0.31 / **1.3**	4	10
Jun 20 – Jul 4	GRAF spawning	GRAF Spawning	101 / **101**	0.55 / **0.55**	-- / **11***	15*	18 / **156**	0.10 / **0.85**	5*	10*	16 / **242**	0.087 / **1.3**	2*	3*
Jul 5 – Oct 6	Common Shiner	Rearing & Growth	104	0.57	46	82	18	0.10	15	32	16	0.087	5	15
Oct 7 – Dec 8	Atlantic Salmon	Salmon Spawning	90	0.49	17	55	40	0.22	11	33	20	0.11	6	11

Bold values are upper limits for instream flow for protection of GRAF spawning. Management activities should not create flow that exceed these magnitudes and durations.
Watershed area for calculating cfsm is 183 square miles at the index location used. Index location is the gage USGS 01073500 LAMPREY RIVER NEAR NEWMARKET, NH
-- No Common Flow Allowable duration is described for this bioperiod because high flows and Catastrophic durations are limiting.
* GRAF Spawning and Clupeid Spawning bioperiods partly overlap, so durations during this bioperiod begin counting May 5 (previous bioperiod) but apply only during this bioperiod.

Lamprey Protected Instream Flows for Natural Communities, Wildlife Habitats and Rare, Threatened or Endangered Wildlife and Plants	
Wood Turtle - Winter Survival	>130 cfs seasonal mean - December 1 through February 28
Herbaceous Low Riverbank, mannagrass, hempweed - habitat maintenance	>500 cfs for one week or more - December 1 through April 30
Riverweed, Knotty Pondweed - growth and development	>100 cfs seasonal mean - May 1 through June 30
Wood Turtle - avoid nest flooding during management	<500 cfs daily mean - June 1 through October 15, except for natural events
Floodplain vernal pools - protection/isolation	<1,500 cfs daily mean - March 15 through July 31, except for natural events
Herbaceous Low Riverbank - growth and development	< or = 60 cfs daily mean - August through September, except for natural events
Lamprey Protected Instream Flows for Boating	
Boating recreational use	>=275 cfs

LAMPREY RIVER PROTECTED INSTREAM FLOW REPORT

Introduction

Pursuant to the Rivers Management and Protection Program (Section 483:9-c Establishment of Instream Flows), protected instream flows are to be established for each designated river. Chapter 278 (Laws of 2002) created a pilot program to study and establish protected instream flows and adopt water management plans for the Lamprey River and the Souhegan River. This Protected Instream Flow Report describes the scientific methods used to study and develop protected instream flows for the Lamprey Designated River. The findings of this report will be used to formally establish protected instream flows for the Lamprey Designated River and will provide the basis for the development of a Water Management Plan to be completed during the second phase of this project.

This report is the summation of several tasks that have been completed as the first phase of the Lamprey Designated River Protected Instream Flow Study and Water Management Plan pilot project. The tasks performed as part of this study include:

- Task 1 – preliminary identification and listing of river-specific protected entities described categorically in statute RSA 483:1 (Statement of Policy) and 483:9-c as instream public uses, outstanding characteristics, and resources
- Task 3 – an on-stream survey for locating the protected entities on the Lamprey Designated River and the initial report of the survey findings
- Task 4 – a report describing the final list of protected entities and their flow dependent status with the proposed methods for the evaluation of the protected instream flows
- Task 5 – field assessments, data analysis and preparation of the proposed protected instream flows study report
- Task 6 – a public hearing to present the studies findings for comment

Reports documenting these activities can be found at the DES website: http://des.nh.gov/organization/divisions/water/wmb/rivers/instream/lamprey/study.htm.

The development of the protected instream flows for the Lamprey Designated River is based on a multidisciplinary study of a complex system. Due to the technical nature of the methods used and the complexity of the system studied, this report is detailed, lengthy and at times challenging to understand for the non-scientist. For an overview of the material presented in this report the reader is referred to the Executive Summary presented at the beginning of this report.

Part One of this report describes the flow-dependent protected entities, their locations, the methods used to determine their respective PISF goals and the resulting collective PISFs for the Lamprey Designated River.

The Natural Flow Paradigm (Poff et al. 1997) provides the necessary conceptual framework for describing protected instream flows. The Natural Flow Paradigm was developed in recognition that the natural range of flow variability is the most supportive of flow-dependent entities. It also establishes that it is necessary to use a comprehensive set of descriptive terms in order to adequately define this variability in stream flow. Without this framework, the goal of describing protected instream flows to support flexible management providing water for both instream needs and off-stream use would be difficult.

Describing protected stream flows is a difficult process because stream flow is a complex and variable regime. The flow of a river varies on time scales of hours to greater than years. New Hampshire stream flows typically fluctuate over three orders of magnitude (high flows are a thousand times greater than low flows), both during the course of a year and also on individual days over the period of record. Stream flows are highly variable because they are a function of a number of geomorphic and climatic parameters. The natural variability of stream flows determines the stream dimension, pattern, and profile, all of which in turn determine the flora and fauna that can live in the stream and on stream margins. In describing protected flows one must recognize and incorporate this variability in stream flow or risk describing protection in static terms that are overly restrictive or overly lenient.

Furthermore, describing protected flows includes the requirement for a determination of whether a particular day's stream flow is appropriate for meeting ecosystem flow needs. This must be done not only within the context of a variable flow regime, but also relative to the changing needs of the species that rely on stream flow. Native fish and riparian vegetation and wildlife have varying flow needs during the year that complement the river's annual cycles. In describing protected flows for these river species, one must therefore recognize changing seasonal needs of these species' life cycles.

Also, because of stream flow variability within seasonal durations, stream flows are not always optimal for river species, yet these species persist and thrive. Survival can continue at low flows, but not if they persist overlong. High flows are necessary, but can also be harmful if sustained. Even though optimal conditions for these flow-dependent entities do not occur continuously, they must occur long enough and often enough to support life stage needs for spawning, growth of young, and survival. Flows that meet life cycle needs in the summer may not be sufficient to meet different cycles at other times. Determining sufficient stream flow conditions must be placed in the context of previous flows such that flow conditions occur with characteristic frequency and duration as well as in season. In addition, life cycle needs will not be the same for differing species: they may in fact be directly opposite. The variability in a natural flow system provides for entities with opposing flow needs because their flow needs are periodically met.

Describing protected flows therefore requires a description of stream flow that is capable of encompassing a complex flow regime. It must also use a systematic determination of whether the existing conditions within the context of recent flows are supporting flow-dependent entities' needs. The stream flows of the natural flow regime are suited to the river's ecosystem needs, not to just one species. By describing protected flows within the framework of the Natural Flow Paradigm, protected flows meet the flow needs of all the adapted species.

To describe protected instream flows within the Natural Flow Paradigm requires a more comprehensive description of stream flow. Because of the complexity inherent in the flow regime, a single value of magnitude would not adequately describe stream flow. Prescribing a single value as a protected flow wouldn't be sufficient to describe the range of flow needs. The description of flow under the Natural Flow Paradigm uses components of magnitude, frequency, duration, timing and rate of change. A comprehensive description using these components provides a detailed representation of flow and flow needs that allows both for water use and for support of riverine entities.

By framing protected instream flows within the Natural Flow Paradigm, flow dependent entities are protected, yet unrealistic flows are not required because variability is allowed. This description of a complex system describes flow in a way that allows naturally occurring conditions like low flows to occur without considering these events as a crisis, yet limits them in frequency and duration to what the ecosystem has evolved to tolerate. Water for off-stream use is available because the wide range of variability in stream flows, together with the flexibility of instream flow needs, provides space between what is needed instream and what is available for other uses. Management is needed to supply water for off-stream uses when that space is limited or absent. As guidance, the Natural Flow Paradigm provides the framework for defining protected instream flows and for their management.

Part Two of this report presents the results of an assessment of when and where the protected instream flow goals are not met. This assessment is based on the existing water withdrawals and historic watershed hydrology. The existing human uses of stream flow may periodically or continually degrade the biological integrity of the river. Implementation of water management measures may periodically be necessary to protect the biological integrity of the river and maintain the existing human uses. The adoption of appropriate water management measures is a required element of the Instream Flow Pilot Program. Knowing the level of occurrence indicates the level of management that will be required to meet the protected flows.

A draft copy of this report was first presented to the Lamprey River Technical Review Committee (TRC) 9 June 2008. Following their approval, the study findings were then presented to the general public at a hearing held January 14, 2009 in Lee, New Hampshire. Comments and questions on the report and its findings were addressed (Appendix 14) and integrated into the final version of the report.

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Part One – Protected Instream Flow Assessment

A segment of the Lamprey River was designated under RSA 483 in 1990. RSA 483 and the Rules for the Protection of Instream Flow on Designated Rivers (Env-Ws 1900) describe the process by which protected flows are defined and established as water quality standards for the Designated River. The first step in defining protected flows is to identify the river features needing protection. Three methods were selected to define protected flows. Surveys were conducted to identify flow needs for human uses. Flow needs for riparian wildlife and vegetation were determined based on mapping habitat and determining flows using the Floodplain Transect Method. For fish and aquatic life, an incremental model of habitat needs was developed using Mesohabitat Simulation Model (MesoHABSIM), a habitat simulation model. The results of these methods were evaluated to identify the controlling flow needs, where these flows become the protected flows for the Lamprey Designated River.

I. Protected Instream Flow Study Area Description

These protected flows were developed for the protected entities identified in the Lamprey Designated River only. However, the water use and management activities in the upstream watershed area affect the flow in the Designated River segment. As a result, the Protected Instream Flow study focused on the Lamprey Designated River, while in the subsequent phase of the study, the Water Management Plan, will examine affected water users and dam operations in the watershed upstream of the Lamprey Designated River. This combined watershed area is referred to as the Lamprey River Water Management Planning Area.

A. Watershed Description

The Lamprey River watershed drains an area of 549 km2 (212 mi2) in coastal southeast New Hampshire. The river begins in the Saddleback Mountains in Northwood, New Hampshire and travels 76.1 km (47.3 miles) to Great Bay, which empties into the Atlantic Ocean (Figure 1). The watershed's maximum elevation is approximately 348 meters (1142 feet), but the Lamprey River itself drops about 183 meters (600 feet) along its course. Major tributaries include Hartford Brook, North Branch River, Pawtuckaway River, Little River, and North River. The primary towns in the watershed are Candia, Deerfield, Durham, Epping, Lee, Northwood, Nottingham, Newmarket and Raymond.

The land at the headwaters of the Lamprey River is largely undeveloped and forested and the river corridor is relatively undisturbed with the exception of some commercial areas where the river passes through downtown Raymond and Epping. Residential development is the primary form of development elsewhere along the river and there is also some agricultural land use.

Several notable dams exist along the main stem of the Lamprey River. These include the Macallen Dam in Newmarket, Wiswall Dam in Durham, the partially breached Wadleigh Falls Dam in Lee and the Bunker Pond Dam in West Epping. Dams are also found on the major tributaries to the Lamprey River and impound several notable water bodies

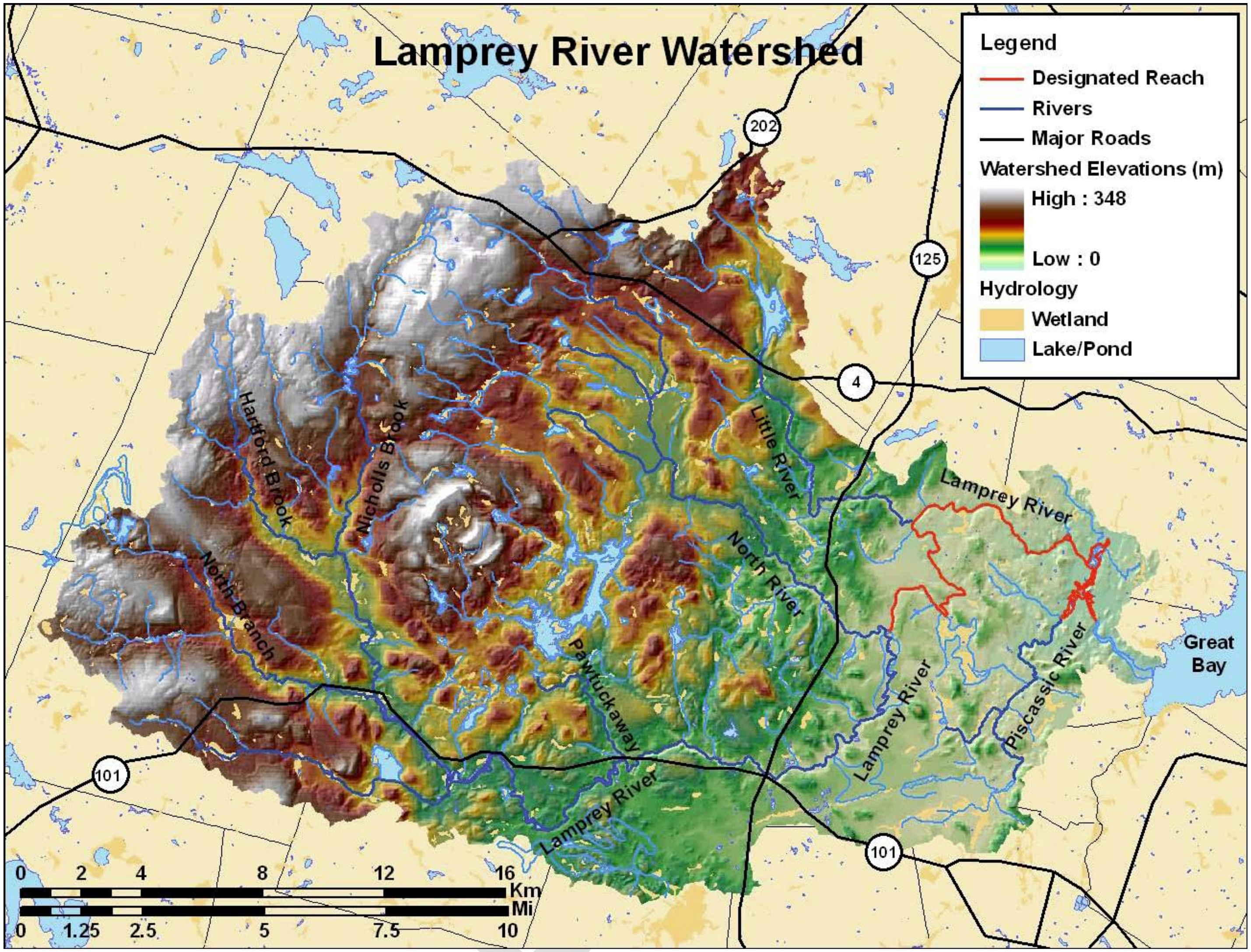

Figure 1 - Lamprey River Watershed.

including; Freese's Pond, Meadow Lake, Mendum's Pond, Nottingham Lake, Onway Lake and the largest water body in the watershed Pawtuckaway Lake in Nottingham.

In November of 1996, Congress amended the National Wild and Scenic Act to include 11.5 miles of the Lamprey River. An additional 12 miles were added in May of 2000. The Lamprey Wild and Scenic designation extends from the Bunker Pond Dam in the town of Epping to the confluence with the Piscassic River in the vicinity of the Durham-Newmarket town line. The federal designation of this part of the Lamprey River means the river will be preserved in its free-flowing condition and additional protections will be applied to the river and its surrounding area.

B. Designated River Description

In June of 1990, New Hampshire designated a portion of the Lamprey River under its Rivers Management and Protection Act. The Lamprey Designated River comprises approximately 19.4 km (12.05 mi) beginning at the Lee-Epping town boundary and continuing through Lee and Durham to the Durham-Newmarket town boundary (Figure 2). The Lamprey flows 2.95 km (1.83 miles) below the head of tide at Macallen Dam to Great Bay. The river in this short section is subject to tidal influences.

The Lamprey Designated River is a low-gradient, coastal stream punctuated with step-like gradient changes caused by the underlying bedrock geology. These geologic underpinnings result in changes in valley width and river gradient. The geology is expressed in the substrate of the relatively dynamic, short sections of river where coarse grained sediment (cobble sized material and larger with sand and gravel) is dominant and bedrock outcrops are abundant. In the sections impounded by bedrock outcrops or dams, the substrate of the channel bed is more fine grained (fine to coarse grained sand and gravel sized sediment) reflecting these low velocity environments.

There are no significant changes in river characteristics over the length of the Lamprey Designated River. The stream order does not change over the designated reach; there are no major tributaries; the impoundments, both natural and otherwise, are spread throughout the designated reach; and the watershed area does not change significantly between the beginning of the Lamprey Designated River near the North River confluence and the end of the designated reach in the Newmarket impoundment.

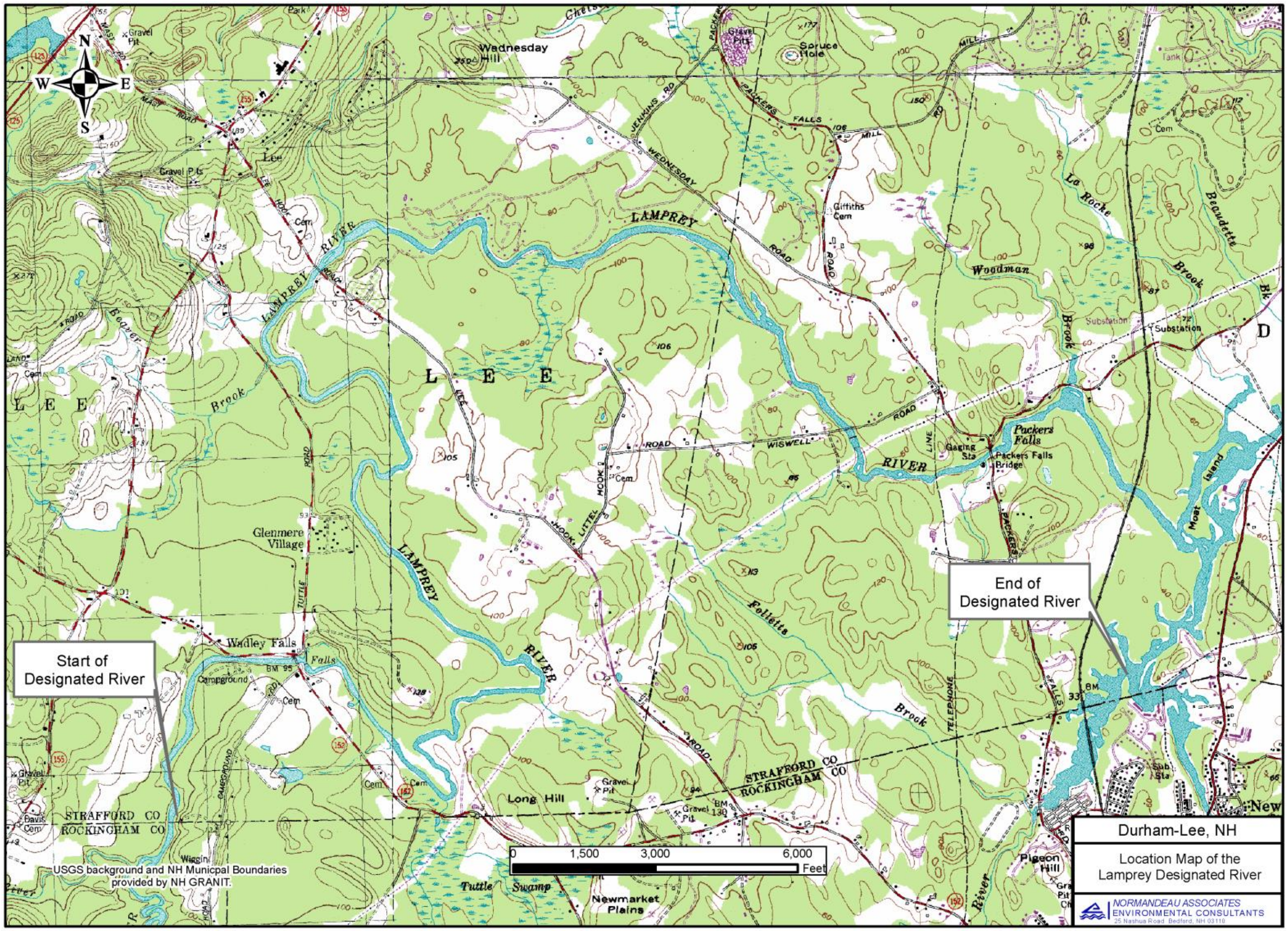

Figure 2 - Location map of Lamprey Designated River.

II. Protected Entities as Protection Goals

The protection goals of the Instream Flows Pilot Program are to maintain water for instream public uses and to protect the resources for which the river or segment is designated and to regulate the quantity and quality of instream flow along designated rivers to conserve and protect outstanding characteristics. Specific categories of the instream public uses, outstanding characteristics and resources are described in RSA 483. Collectively, the instream public uses, outstanding characteristics and resources are called the protected entities in the Instream Flow Program.

The Lamprey Designated River's protected entities were initially identified and listed in Task 1 of the Lamprey Instream Flow Pilot Program project. Their existence was verified by an on-stream survey performed as part of Task 3. The protected entities were assessed for their flow dependence in Task 4, which was documented in a report (DES 2006) where all the specific protected entities were listed (Table 1). Only the flow dependent protected entities were assessed for instream flow protection needs. The determination of whether an identified entity was considered to be flow dependent was based on biological or physical needs. As presented in the Task 4 report (DES 2006), the categories that included specific flow dependent entities were:

- Recreation.
- Public water supply.
- Maintenance and enhancement of aquatic and fish life.
- Fish and wildlife habitat.
- Rare, threatened and endangered species (RTE): fish, wildlife, vegetation and natural/ecological communities.

As shown in Table 1, these categories may include one or several protected entities specifically occurring on the Lamprey Designated River.

Table 1 - Protected entities of the Lamprey Designated River - characteristics and flow assessment methods.

Category	Entity	Location	Flow Dep. Yes, No	Critical Flows High, Avg., Low	Critical Life Stage	Critical Season Sp Su F W	Method of Assessment
Recreation	Boating		Yes	High, Ave		Sp, F	Determine flow needs through observation and boater interviews
	Swimming		Yes			Su	Swimmer interviews
	Shoreline Recreation		No			All	
Storage	Wiswall Dam	Durham	No				
Fishing	Recreational		Yes	Low	Adults	All	MesoHABSIM
Conservation / Open Space			No				
Maintenance and Enhancement of Aquatic Fish and Life	Native Fish		Yes	All	All	All	MesoHABSIM
	Introduced Fish		Yes	All	All	All	Not Assessed
	Anadromous Fish		Yes	All	All	All	MesoHABSIM
	Mussels		Yes	All	All	All	MesoHABSIM
	Insects		Yes	All	All	All	MesoHABSIM
Fish and Wildlife Habitat	Fish Life Stage Habitats		Yes	All	All	All	MesoHABSIM
	Lower Floodplain Forest		Yes	High, Avg.	All	Sp	Floodplain transect
	Higher Floodplain Forest		Yes	High	All	Sp	Floodplain transect
	Alluvial Red Maple Swamp		Yes	Avg, Low	All	Sp, Su	Floodplain transect
	Oxbow and Backwater shrub swamps, marshes, ponds		Yes	All	All	Su	Floodplain transect
	Floodplain Vernal Pool Species		Yes	High, Avg	Eggs, Larvae	Sp, Su	Floodplain transect
	Mesic-Wet High Energy Riverbank		Yes	All	All	Su	Floodplain transect
	River Rapids		Yes	All	All	Su	Floodplain transect

Table 1 (Continued)

Category	Entity	Location	Flow Dep. Yes, No	Critical Flows High, Avg., Low	Critical Life Stage	Critical Season Sp Su F W	Method of Assessment
RTE Fish, Wildlife, Vegetation or Natural/Ecological Communities	Bridle Shiner		Yes	All	All	All	MesoHABSIM
	Banded Sunfish		Yes	All	All	All	MesoHABSIM
	Brook Trout		Yes	All	All	All	MesoHABSIM
	Redfin Pickerel		Yes	All	All	All	MesoHABSIM
	Swamp Darter		Yes	All	All	All	MesoHABSIM
	Brook Floater		Yes	All	All	All	MesoHABSIM
	Blanding’s Turtle		Yes	Avg, Low	Juv, Adult	All	Floodplain transect
	Wood Turtle		Yes	Low, High	Juv, Adult	W, Su	Floodplain transect
	Spotted Turtle		Yes	Avg, Low	Juvenile, Adult	All	Floodplain transect
	Osprey	Newmarket Durham	Yes	Low, Average	Nesting, Adult	Sp, Su	Floodplain transect
	Bald Eagle	Newmarket	Yes	High, Average	All	W, Sp	MesoHABSIM
	Sedge Wren	Durham	Maybe	High, Average	Nesting	Sp, Su	Floodplain transect
	Pied-billed Grebe	Patchy	Yes	High, Average, Low	Nesting	Sp, Su	Floodplain transect
	Climbing Hempweed		Yes	Average, High	All		Floodplain transect
	Small-crested Sedge		Yes		All		Floodplain transect
	Star Duckweed		Yes	Average,	All	Sp, Su	Floodplain transect
	Sharp-flowered Mannagrass		Yes		All		Floodplain transect
	Water Marigold	Newmarket	Yes	High, Low	All	Sp, Su	Floodplain transect
	Small Beggars Tick		Yes		All		Floodplain transect
	Knotty Pondweed		Yes	Low	All	Sp	Floodplain transect
	Slender Blueflag		Yes		All		Floodplain transect
	Swamp White Oak Floodplain Forest		Yes	High	All	Sp	Floodplain transect
	Peregrine Falcon		No				
	Eastern hog-nosed Snake		No				
	Philadelphia Panic Grass		No				
	Northern Blazing Star		No				
	Blunt-lobed Woodsia		No				
	Missouri Rock Cress		No				
	Downy False Foxglove		No				

Table 1 (Continued)

Category	Entity	Location	Flow Dep. Yes, No	Critical Flows High, Avg., Low	Critical Life Stage	Critical Season Sp Su F W	Method of Assessment
Water Quality Protection and Public Health			No				
Public Water Supply	Durham-UNH water withdrawal	Durham	Yes			Su	MesoHABSIM and Floodplain Transect
Pollution Abatement	Epping WWTF	Epping	No				
Aesthetic Beauty / Scenic	Wild and Scenic River Status		No				
Cultural			No				
Historical or Archaeological	Wiswall Falls Mill site Wadleigh Falls	Durham Lee	No				
Community Significance			No				
Hydrological / Geological			No				
Agricultural	Four properties	Lee	No				

III. Occurrence of Protected Entities on the Lamprey Designated River

This section discusses the various protected entities that exist in the Lamprey Designated River, how they were investigated and considered when determining the protected instream flow recommendations.

A. Recreation

In the nomination documents submitted in 1990 for the designation of the Lamprey River under the New Hampshire Rivers Management and Protection Program, the recreational activities; boating, fishing, and swimming were identified as important resources. In a recent survey of citizens within the watershed by Rogers (2007), the recreational activities of boating, fishing and swimming were also identified as uses of the river. Measures to protect these recreational resources and uses have been discussed in the river corridor management plans developed in 1995 and 2007 by the Lamprey River Advisory Committee (1995 and 2007).

The recreational uses of boating, fishing and swimming were identified as flow-dependent protected entities during Tasks 1 and 3 of the Protected Instream Flow (PISF) study. As discussed in the Task 4 report (DES 2006), the evaluation and development of protective flow goals for boating and swimming were to be determined based on a review of existing information, along with field surveys and interviews of resource users. As discussed in the Task 4 report (DES 2006), no assessment of fishing or development of a fishing-specific PISF was proposed. The goal relative to fishing is to have sufficient stream flows to sustain stocked fish during the fishing season. For fishing, a detailed analysis of fish habitat and flow levels was performed and its methodology and results are discussed in Section IV. (D.) of this report.

1. Boating

In the 1990 nomination of the Lamprey River as a Designated River, boating was identified as having both local and statewide significance. Due to the diverse nature of the river, there are many opportunities for recreational flat water and whitewater canoeing and kayaking along the designated segment (Figure 3).

Information regarding recreational boating on the Lamprey Designated River was obtained from a review of published sources, online information and from discussions with individuals familiar with boating on the river. The following section provides a detailed account of the boating conditions along the Lamprey Designated River and the popular boating locations.

A detailed description of the river conditions for boating the Lamprey Designated River is found in the AMC's River Guide (AMC 2007), which divides the river into two sections. The first section includes the portion of the Lamprey Designated River starting at the Epping town line and ending at Wadleigh Falls in Lee (Figure 3). This section is described as a "long, smooth stretch that twists with numerous logjams, through old pastures and woods past the mouth of the North River to the Wadleigh Falls Dam". Depending on flow levels, the boater may experience "quickwater" which is a level of

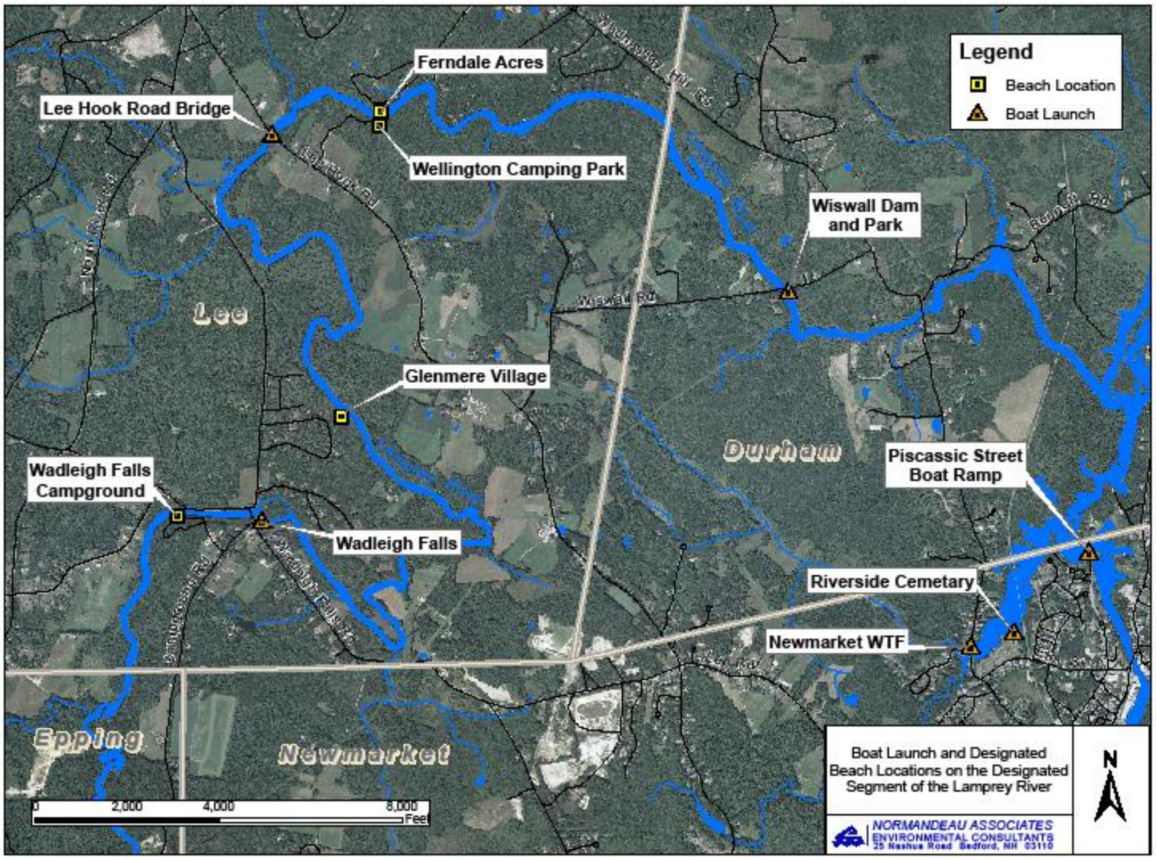

Figure 3 - Lamprey Designated River beach and boat access locations.

difficulty for boating and is defined as fast moving water, "where its surface is nearly smooth at high water levels, but is likely to be choppy at medium water levels and shallow at low water levels" (AMC 2007). This section is described as being navigable during the spring with medium to high water levels (AMC 2007).

The Lamprey Designated River from Wadleigh Falls to the Newmarket town line is described as consisting of flat-water, quickwater and Class I and III white-water (Figure 3). Flat-water is defined as having little to no current, smooth surface and paddling upstream is easy (AMC 2007). Long sections of flat-water are found downstream of Wadleigh Falls to Lee Hook Road Bridge, in the impounded water upstream of Wiswall Dam, the impounded water upstream of Packers Falls, and the impounded water upstream of the Macallen Dam in Newmarket.

Class I to III rapids range from easy to intermediate, where intermediate is described as "rapids with moderate irregular waves which may be difficult to avoid and which can swamp an open canoe" (AMC 2007). Within this section of the Lamprey Designated River, relatively short sections of rapids are found immediately downstream of the Lee Hook Road Bridge, around Hook Island, immediately downstream of Wiswall Dam, at Packers Falls, and between Packers Falls and the confluence of the Lamprey Designated River with Woodman Brook.

The rapids at the Lee Hook Road Bridge are described in the AMC River Guide (2007) as "200 yards of easy Class II rapids with large combers (standing waves) in high water". The guidebook notes "paddlers may have a scratchy time in moderately high water because the rapids starting under the bridge and another shorter one, 1.0 mile farther (Hook Island) need rather high water to run well." Farther downstream there is a 200 yard section of Class II rapids located immediately below Wiswall Dam. Packers Falls are the next series of rapids on the river and they are rated as moderate Class II (summer) to difficult Class III (spring). The AMC River Guide (2007) notes they are "one of the most challenging rapids in the Piscataqua watershed."

Normandeau also performed an online search for information on boating on the Lamprey Designated River. The Lamprey River Advisory Committee website (www.lamprey.org) includes information on recreation opportunities on the Lamprey River. It features a description of the canoeing opportunities on the river, including the Lamprey Designated River (www.lampreyriver.org/recreation/canoeing.htm). Paddling reports for the Lamprey River are also available from a number of websites including those for: Amreican Whitewater (www.americanwhitewater.org), NH AMC Paddlers (www.nhamcpaddlers.org), and Paddling.net (www.paddling.net).

In addition, Normandeau also contacted the Lamprey River Watershed Association (LRWA) and the NH AMC Paddlers group for information on boating on the Lamprey Designated River. Information provided by Fosburgh (personal communication 2006), Genes (personal communication 2006), Lord (personal communication 2006) and Spang (personal communication 2006) provided further insight on the use of the Lamprey Designated River for boating. These individuals confirmed the popular put-in locations along the river including at: Wadleigh Falls, Lee Hook Road Bridge, Wiswall Dam, Packers Falls and the Piscassic Boat Ramp located in Newmarket (Figure 3). They also confirmed its use for both flat-water and whitewater paddling. Flat-water paddling is popular on the section of the river upstream of Wadleigh Falls, the Wiswall Dam and the Macallen Dam. Particular sections of the river noted as being popular for whitewater kayaking and canoeing included: Lee Hook Road Bridge to Hook Island, the rapids downstream of Wiswall Dam, and the reach from Packers Falls to the beginning of the Macallen Dam impoundment.

2. Fishing

The Lamprey River is a popular destination for recreational fishing in southeastern New Hampshire (Klausmeyer 2001). Fishing from the shoreline or by wading is popular at a number of locations on the Lamprey Designated River including: the stretch between the beginning of the designated segment and its confluence with the Little River, the Lee Hook Road / Lamprey River Bridge in Lee, a ¾ mile stretch of the river immediately below Wiswall Dam, and the pool below Packer's Falls in Durham (Figure 3). These reaches are accessible by the public from roads or parks areas and can be fished by wading or from the shoreline. During this study, fly fisherman were frequently observed by field crews at the Lee Hook Road Bridge in Lee, the river reaches above and below Wiswall Dam, and at the pool downstream of Packers Falls in Durham.

The flat-water areas within the upper portion of the Lamprey Designated River provide recreational anglers with opportunities to fish from small boats. In the lower section of the river, where it is impounded by the Macallen Dam, fishing opportunities can be accessed by larger watercraft (powerboats) via the Piscassic Street boat ramp in Newmarket (Figure 3).

The fisheries resource of the Lamprey Designated River includes both coldwater and warm-water species. The fish community of the Lamprey Designated River was evaluated during a Baseline Fish Sampling performed in 2003 (DES 2005). A total of 26 fish species were collected through a number of standard fisheries sampling methods. Among those present were a variety of both native and introduced species popular among recreational anglers. Largemouth bass, smallmouth bass, bluegill, black crappie, rainbow trout, and brown trout are all species that have been either historically or currently introduced to the Lamprey River system and were found within the designated segment during the 2003 baseline survey. A number of native fish species detected during the DES survey within the Lamprey Designated River are also popular with recreational anglers. Included in this group are:

- Redbreast sunfish.
- Pumpkinseed.
- Yellow perch.
- Eastern chain pickerel.
- Atlantic salmon.

Although not observed during the 2003 survey, Eastern brook trout, a fish species native to New Hampshire, do occur within the Lamprey River but appear to be limited in distribution to its headwaters. Except for stocked specimen, there is no expectation of this species occurring within the designated reach.

Although returns are generally small and variable by year, upriver spring movements of Atlantic salmon occur within the Lamprey River. During 2007, a single fish was passed through the fish ladder at Macallen Dam in Newmarket (Dionne, personal communication 2008). In addition to Atlantic salmon, over 55,000 river herring (alewife and blueback herring), 255 sea lamprey and four American shad passed through the Macallen Dam during the spring run and into the lower reach of the Lamprey Designated River (Dionne, personal communication 2008). These fish are currently able to access as far upstream as the Wiswall Dam (approximately three river miles).

Plans to construct a nature-like fishway bypassing the Wiswall Dam have been cancelled due to private land access issues. The Wiswall Dam fish passage committee is currently investigating their secondary option, a Denil fish ladder, and will move forward pending funding (Grout, personal communication 2008). Completion of this project will allow anadromous fish access to an additional 45 miles of riverine habitat in the mainstem of the Lamprey River and its associated tributaries.

Trout are the most targeted fish species within the Lamprey River by recreational anglers. The New Hampshire Fish and Game Department and the Great Bay Chapter of Trout Unlimited both routinely stock trout within the Lamprey River. During 2007, the New Hampshire Fish and Game Department released hatchery-reared trout within the Lamprey River in the towns of Deerfield, Raymond, Epping, Lee, and Durham. Within the Lamprey

Designated River (Lee and Durham), a total of 3,165 Eastern brook trout, 1,775 brown trout, and 890 rainbow trout were released. Table 2 presents the trout releases for 2007 (by species) for the Lamprey River within each of the five towns. Historical fish stocking information for the Lamprey River and other water bodies in the state of New Hampshire is available online at www.wildlife.state.nh.us/Fishing/fishing.htm.

Table 2 - New Hampshire Fish and Game trout stocking records for the Lamprey River during 2007.

Town	Species	Age	# Individuals
Deerfield	Brown trout	1+YR	600
Deerfield	Eastern brook trout	1+YR	80
Deerfield	Rainbow trout	1+YR	1,100
Raymond	Brown trout	1+YR	600
Raymond	Eastern brook trout	1+YR	210
Raymond	Rainbow trout	1+YR	100
Epping	Brown trout	1+YR	630
Epping	Eastern brook trout	1+YR	420
Epping	Rainbow trout	1+YR	1,450
Lee	Brown trout	1+YR	1,010
Lee	Eastern brook trout	1+YR	1,330
Lee	Rainbow trout	1+YR	180
Durham	Brown trout	1+YR	690
Durham	Brown trout	2+YR	75
Durham	Eastern brook trout	1+YR	1,835
Durham	Rainbow trout	1+YR	710

The management goal of the State is to maintain stocked trout during the fishing season. In addition to the New Hampshire Fish and Game Department, the Great Bay Chapter of Trout Unlimited has historically stocked rainbow and brown trout into the designated reach during the fall season in the vicinity of Wiswall Dam and Packers Falls. Due to financial shortages within the organization, Trout Unlimited's future stocking within the Lamprey River will be reduced (Seymour, personal communication 2008).

Fishing regulations for the Lamprey River and other water bodies within the state of New Hampshire are released annually by New Hampshire Fish and Game Department and are available online. For the portion of the designated reach from Wiswall Dam to the first railroad trestle downstream of Packers Falls, the fishery for Eastern brook trout, rainbow trout, brown trout, largemouth bass, smallmouth bass, Eastern chain pickerel, bluegill and black crappie is catch-and-release for the period of 16 October through the 4th Saturday in April with only a single barbless hook and artificial flies/lures. For the remainder of the year, the daily limit set for brook trout is five individuals or five pounds, whichever is reached first. The remainder of the designated reach operates under the general fishing rules specified for rivers and streams in New Hampshire. The open season for those reaches is 1

January through 15 October. Special exceptions exist for parts of the year for the black bass (largemouth and smallmouth), Atlantic salmon, and rainbow smelt fisheries.

Recreational fishing on the Lamprey Designated River is a flow-dependent resource. The protected instream flows that are required to maintain the environmental and fish habitat resource are those that will be adequate to preserve recreational fishing on the Lamprey Designated River. As a result, no assessment of fishing recreation was performed. The methods used to evaluate the instream flows required to protect fish and their habitats and the results of these studies are discussed in detail in Section IV. (D).

3. Swimming

Opportunities for swimming along the Lamprey Designated River are available for almost all of its length with riparian landowners having direct access to the river. Much of the swimming occurs in the impounded sections of the river that are relatively insensitive to flow. These include the river sections upstream of Wadleigh Falls, the Wiswall Dam, below Packers Falls and in the lower section of the river which is impounded by Macallen Dam (Figure 3). During high flow periods, attempting to swim in the fast water, rapids, and falls sections of the river is considered ill-advised and dangerous.

Most of the shoreline along the river is privately owned or undeveloped and public access is limited along those sections. Alternatively, the river may be accessible at three of the four designated beaches located along the Lamprey Designated River. State designated beaches are found at the Wadleigh Falls Campground, Wellington Acres Campground, Ferndale Acres Campground, and Glenmere Village (Figure 3). Under the rules for Public Bathing Places (Chapter Env-Wq 1100) a designated beach means "a public bathing place that comprises an area on a water body and associated buildings and equipment, intended or used for bathing, swimming, or other primary water contact purposes. This term includes, but is not limited to, beaches or other swimming areas at hotels, motels, health facilities, water parks, condominium complexes, apartment complexes, youth recreation camps, public parks, and recreational campgrounds or camping parks" (Env-Wq 1102.14 Designated Beach). Under the Public Bathing rules, a public bathing place is defined as "a place or location, together with buildings and equipment, intended or used for recreational or therapeutic bathing, swimming, or diving, and operated by or for any governmental subdivision, public or private corporation, partnership, association, or educational institution open to the public, members, or students, whether on a fee or free basis" (Env-Wq 1102.38 Public Bathing Place).

Access to the designated beaches depends on the ownership and operation of the campground or association. At Ferndale Acres, Wadleigh Falls and the Wellington Camping Park, only registered campers and their guests are allowed access to the beach area, with the guests having to pay a daily fee. The Glenmere Village Association does not allow public access to its beach and beach use by association members is supposedly limited.

Although not designated by the State as beaches, several popular swimming areas are located along the Lamprey Designated River and include: downstream of Wadleigh Falls in Lee, the impounded area upstream of the Wiswall Dam and downstream of the dam, Packers Falls, and at the railroad trestle crossing located off of Bennett Road in Durham. Two of these locations, Wadleigh Falls and Packers Falls, are posted as New Hampshire Swimming Holes on a website SwimmingHoles.info (www.swimmingholes.org). The land at Wadleigh Falls is privately owned, but access is allowed. The impoundment behind Wiswall Dam is not a town authorized swimming spot and swimming is at one's own risk (Cedarholm, personal communication 2008). The railroad trestle is privately owned and is policed by the Town of Durham. Individuals using the trestle for swimming are considered trespassers and are subject to arrest (Cedarholm, personal communication 2008). Swimming is allowed at the Packers Falls Park, but there are no supporting facilities (baths or toilets), there is no lifeguard on duty, and swimming is at your own risk (on a sign posted by Durham Parks Department). During the field studies, as part of this project, diving off of the Wiswall Road Bridge and off of the railroad trestle appeared to be popular and swimmers were frequently observed at these locations.

B. Public Water Supply

In 1965, the New Hampshire legislature enacted Chapter 332 regarding the use of the Lamprey River as a water supply by the towns of Durham, Epping, Lee, Newmarket, and Raymond. Under this law, all of these towns "shall have the use of the waters of the Lamprey River and its tributaries within said towns for the purpose of public water supplies to the exclusion of all other municipalities". This law also specifies those rights to water for the towns of Durham and Newmarket. Durham has the right to divert water from the Lamprey Designated River at or near the dam at Wiswall Falls, while the town of Newmarket has the right to divert water from the river at or near the Macallen Dam, which is below the designated segment.

In the nomination form submitted supporting the designation of the Lamprey River, it notes that one of the reasons the river was worthy of protection is because it's Durham's reserve water supply. The withdrawal of water from the river was identified as a Managed Resource that was locally significant. The document further identifies the Lamprey River as an "emergency' water supply, citing the findings of a water supply study done for southern New Hampshire in 1979.

The University of New Hampshire/Town of Durham Water System presently withdraws water from the Lamprey Designated River, while the Town of Newmarket Water Works has withdrawn water from tributaries to the Lamprey Designated River in the past. The sources for these public water supplies are briefly discussed in the following sections.

1. University of New Hampshire/Town of Durham Water System (UDWS)

The University of New Hampshire (UNH)/Town of Durham public water supply (aka UDWS) currently is the only public water supply that diverts water directly from the Lamprey Designated River. This diversion is located approximately 0.5 miles upstream of Wiswall Dam (on the left side looking downstream). The water pumped from the Lamprey Designated River at this point is transferred via underground pipeline to a water treatment facility in Durham. The UDWS also obtains water from the Oyster River and from a groundwater well in Lee (the Lee Well). The UDWS provides water both to the University of New Hampshire campus and to the Town of Durham.

Since the UDWS diversion is located within 500 feet of the Designated Lamprey River and the volume of its withdrawal requires registration with and reporting to DES, the water system is considered an Affected Water User (AWU) under the Rules for the Protection of

Instream Flow on Designated Rivers instream flow rules (Chapter Env-Ws 1902.03 Affected Water User). In addition, Wiswall Dam, because it is located in the Lamprey River Water Management Planning Area and because it has an impoundment area greater than 10 acres (reported as 30 acres by the NH Dam Bureau), is considered a dam affected under the Rules for the Protection of Instream Flow on Designated Rivers (Chapter Env-Ws 1902.02 Affected Dam Owner). Thus, the Town of Durham as the dam's owner is an Affected Dam Owner (ADO). Both the operation of the UDWS and Wiswall Dam will be further reviewed and evaluated as part of the development of the Lamprey River Water Management Plan.

2. Newmarket Water Works

The Town of Newmarket Water Works is located in the Lamprey Designated River's Water Management Planning Area. The principal sources of water for Newmarket are two wells (Bennett and Seawall) that are located in the Newmarket Plains aquifer in the northwestern part of town. Since these wells are located over 500 feet from the Lamprey Designated River, they are not considered affected under the Rules for the Protection of Instream Flow on Designated Rivers (Env-Ws 1902.03 Affected Water User). But, the Town of Newmarket has received a Groundwater Discharge Permit (DES Site #200111015-N-001) from the DES for the artificial recharge of the Newmarket Plains aquifer in the vicinity of its Bennett and Sewall water supply wells (Laney, personal communication 2008; Garrett, personal communication 2008). The water recharging the aquifer is proposed to be withdrawn from the Lamprey River. The proposed withdrawal point may be located along the Lamprey Designated River in Lee, nearest the location of its wells.

In the past, Newmarket has also received water from three surface water sources: Folletts Brook, the Piscassic River, and the Lamprey River. Folletts Brook and the Piscassic River are tributaries to the Lamprey Designated River, and under Rules for the Protection of Instream Flow on Designated Rivers (Env-Ws 1902.03 Affected Water User) the Town of Newmarket is considered to be an Affected Water User. Due to the cost of water treatment, the Folletts Brook and the Piscassic River sources haven't been used since 2002 (Laney, Personal communication 2008) and the Lamprey River source at the outlet of the Piscassic River has not been used since 2004. Although, the town reserves the right to use these sources in the future if needed.

Since the Town of Newmarket is considered an Affected Water User, the operations of the town's water system will be further reviewed and evaluated as part of the development of the Lamprey River Water Management Plan.

C. Habitat, Maintenance and Enhancement of Aquatic Life and Fish

This chapter defines the fish and invertebrate species that use the habitat in the river. Fish and invertebrates were sampled within the designated river to assess the status of the fauna communities. Fish collections were conducted by DES in 2003 in the Lamprey Designated River using several methods (DES 2005). Other collections mainly in the headwaters have been made historically. Invertebrates were sampled from representative sites by the Rushing Rivers Institute in fall of 2006 and 2007. This data was used to develop the existing fish and invertebrate community and as a validation of the habitat model outputs. A Target Fish Community was determined describing the native composition and proportions of the fish fauna that should be expected in the designated river. Fish collections from other similar rivers were selected from rivers with the least evidence of impairment and of similar nature to the Lamprey Designated River to determine the Target Fish Community. Comparisons between the existing and expected fish communities of the Lamprey River study area were then made.

1. Lamprey River Fish

This study found 36 fish species from 12 families occurring either historically or currently within the Lamprey Designated River based on a review of fish distribution references, historical records, and recent collection records. These species were compiled into a table organized by taxonomic classes (Table 3). Native or introduced status, habitat use, pollution tolerance, and thermal regime classifications are given for each species. The assemblage contains a variety of species, both native and introduced, with a full range of habitat use, pollution tolerance, and thermal regime classifications.

2. Lamprey Designated River Existing Fish Community

Comprehensive sampling data collected during the Lamprey River Baseline Fish Sampling Survey between August 25 and August 29, 2003 (DES 2005) resulted in a detailed description of the distribution and abundances of fish species throughout the entire Lamprey Designated River. This information was used to define the existing fish community of the Lamprey Designated River. Fish collections were conducted at 43 stations using gill nets, shoreline seining, and backpack, barge, and boat-mounted electrofishing methods. The Lamprey River Baseline Fish Community survey was designed and implemented to collect a complete, representative sample of resident fish species within the Lamprey Designated River and took into account the distribution of available macrohabitat types (DES 2005). The results of the survey are summarized in Table 4.

Table 3 - Fish of the Lamprey Designated River by Family, Genus and Species.

Native (N) or introduced (I) statuses, fluvial specialist (FS), fluvial dependent (FD), or macrohabitat generalist (MG) habitat use classifications, intolerant (I), moderately tolerant (M), or tolerant (T) pollution tolerances, and Cold, Eurythermal, or Warm water thermal regime tolerances are given for each species.

FAMILY Common name	Genus	Species	Native or Introduced	Habitat use classification	Pollution tolerance	Thermal regime
Petromyzontidae						
Sea lamprey	*Petromyzon*	*marinus*	N	FD	M	Eurythermal
Anguillidae						
American eel	*Anguilla*	*rostrata*	N	MG*	T	Eurythermal
Clupeidae						
Blueback herring	*Alosa*	*aestivalis*	N	FD	M	Warm
Alewife	*Alosa*	*pseudoherangus*	N	FD	M	Eurythermal
American shad	*Alosa*	*sapidissima*	N	FD	M	Warm
Salmonidae						
Rainbow trout	*Oncorhynchus*	*mykiss*	I	FD	I	Cold
Atlantic salmon	*Salmo*	*salar*	N	FS	I	Cold
Brown trout	*Salmo*	*trutta*	I	FD	I	Cold
Brook trout (char)	*Salvelinus*	*fontinalis*	N	FS	I	Cold
Escocidae						
Redfin pickerel	*Esox*	*americanus*	N	MG	M	Warm
Chain pickerel	*Esox*	*niger*	N	MG	M	Warm
Cyprinidae						
Common shiner	*Luxilus*	*cornutus*	N	FD	M	Eurythermal
Golden shiner	*Notemigonus*	*crysoleucas*	N	MG	T	Eurythermal
Bridle shiner	*Notropis*	*bifrenatus*	N	MG	I	Warm
Spottail shiner	*Notropis*	*hudsonius*	I	MG	M	Eurythermal
Blacknose dace	*Rhinichthys*	*atratulus*	N	FS	T	Eurythermal
Longnose dace	*Rhinichthys*	*cataractae*	N	FS	M	Eurythermal
Creek chub	*Semotilus*	*atromaculatus*	N	FS	T	Eurythermal
Fallfish	*Semotilus*	*corporalis*	N	FS	M	Eurythermal
Catostomidae						
Common white sucker	*Catostomus*	*commersoni*	N	FD	T	Eurythermal
Creek chubsucker	*Erimyzon*	*oblongus*	N	FS	I	Eurythermal
Ictaluridae						
Yellow bullhead	*Ameiurus*	*natalis*	I	MG	T	Warm
Brown bullhead	*Ameiurus*	*nebulosus*	N	MG	T	Warm
Cyprinodontidae						
Banded killifish	*Fundulus*	*diaphanus*	N	MG	T	Warm
Moronidae						
White perch	*Morone*	*americana*	N	MG	M	Eurythermal
Striped bass	*Morone*	*saxitilis*	N	FD	M	Warm
Centrarchidae						
Rock bass	*Amblopites*	*rupestris*	I	MG	M	Eurythermal
Banded sunfish	*Enneacanthus*	*obesus*	N	MG	M	Warm
Redbreast sunfish	*Lepomis*	*auritus*	N	MG	M	Warm
Pumpkinseed	*Lepomis*	*gibbosus*	N	MG	M	Warm
Bluegill	*Lepomis*	*macrochirus*	I	MG	T	Warm
Smallmouth bass	*Micropterus*	*dolomieu*	I	MG	M	Eurythermal
Largemouth bass	*Micropterus*	*salmoides*	I	MG	M	Warm
Black crappie	*Pomoxis*	*nigromaculatus*	I	MG	M	Warm
Percidae						
Swamp darter	*Etheostoma*	*fusiforme*	N	MG	M	Warm
Yellow perch	*Perca*	*flavescens*	N	MG	M	Eurythermal

Table 4 - Lamprey Designated River Baseline Fish Community Survey data by river section.

Section I.D. **Common Name**	**Section 1**	**Section 2**	**Section 3**	**Section 4**	**Section 5**	**Section 6**	**Section 7**	**Section 8**	**Existing Proportion**
Common Shiner	275	613	512	325	359	9	47		34%
Redbreast Sunfish	97	226	179	109	59	84	184	10	15%
Fallfish	37	301	94	94	130	35	76		12%
Pumpkinseed	87	60	104	24	51		4	47	6%
Bluegill		1	16					341	6%
Common White Sucker	134	59	85	17	24	2	1	2	5%
American Eel	9	45	37	22	9	45	104	17	5%
Longnose Dace		90	3	126	53	12	3		5%
Golden Shiner	120	26	42		47			4	4%
Smallmouth Bass		10	24	42	33	13	3	3	2%
Largemouth Bass	1	3	4	3	35	4	1	44	2%
Yellow Perch	1	15	19	6	16			20	1%
Bridle Shiner	39	13	2						1%
Yellow Bullhead	9	19	5	2	16				1%
Chain Pickerel	1	3	13		11			10	1%
Creek Chubsucker	9	1	12						<1%
Alewife	2	1			18				<1%
Blacknose Dace	19								<1%
Black Crappie								18	<1%
Rock Bass	18								<1%
Atlantic Salmon		5		5	3				<1%
Brown Bullhead			5	4	2				<1%
Redfin Pickerel	3		1					2	<1%
Brown Trout				1	2				<1%
Blueback Herring	1		1						<1%
Rainbow Trout			1						<1%
Totals:	862	1491	1159	780	868	204	423	518	100%

Source: DES 2005.

The existing fish community of the Lamprey Designated River, as sampled during the Lamprey River Baseline Fish Sampling Survey of August 25-29, 2003 (DES 2005), consisted of common shiner (34 percent), redbreast sunfish (15 percent), fallfish (12 percent), pumpkinseed (6 percent), bluegill (6 percent), common white sucker (5 percent), American eel (5 percent), longnose dace (5 percent), golden shiner (4 percent), smallmouth bass (2 percent), largemouth bass (2 percent), yellow perch (1 percent), bridle shiner (1 percent), yellow bullhead (1 percent), chain pickerel (1 percent), and 11 other species (creek chubsucker, alewife, blacknose dace, black crappie, rock bass, Atlantic salmon, brown bullhead, redfin pickerel, brown trout, blueback herring, and rainbow trout) comprising the remaining 2 percent of the community (Table 4, Figure 4).

The existing fish community consisted of 18 percent fluvial specialists, 39 percent fluvial dependent, and 43 percent macrohabitat generalists (Figure 5). A total of 26 different fish species were sampled from the Lamprey River, 18 of which were native. Eight non-native fish species, bluegill, black crappie, brown trout, largemouth bass, rainbow trout, rock bass, smallmouth bass, and yellow bullhead were sampled and accounted for a combined 11 percent of the community.

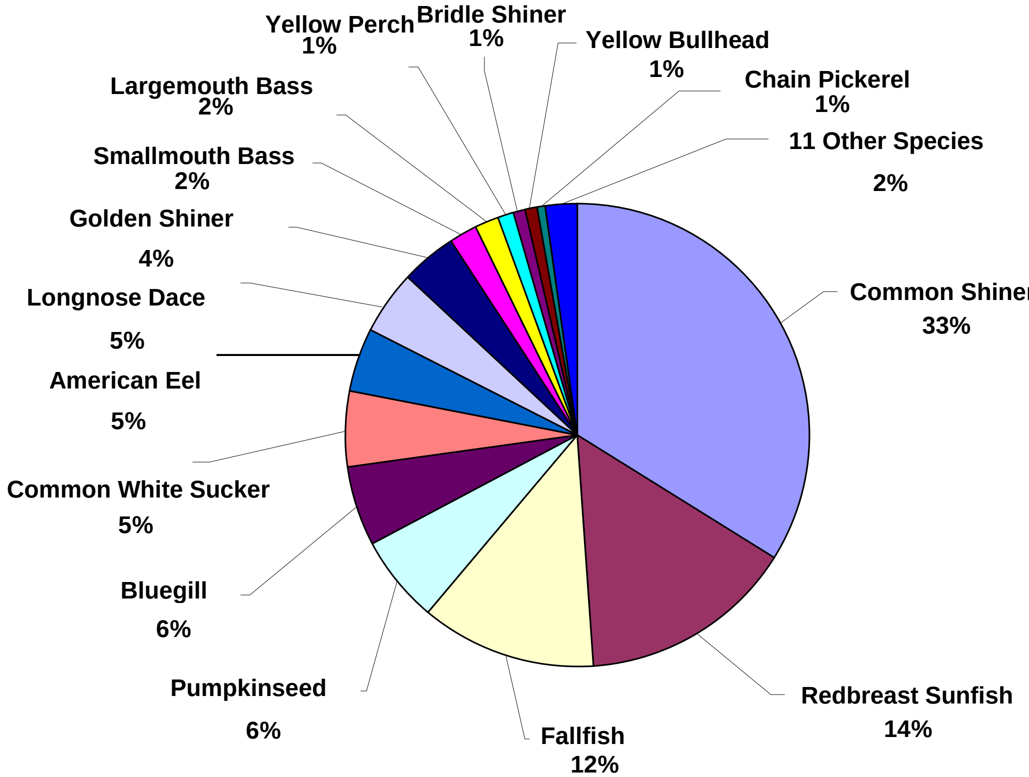

Figure 4 - Lamprey Designated River existing fish community.

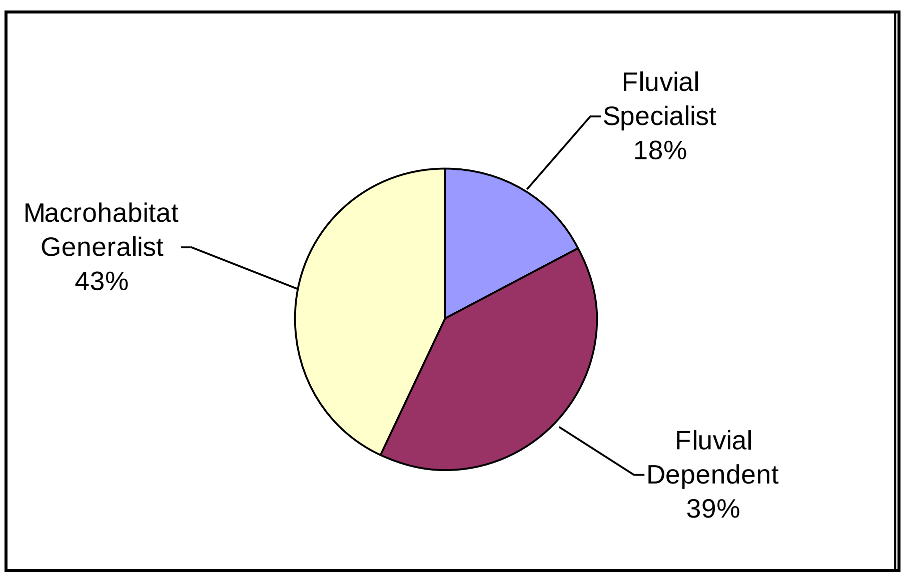

Figure 5 - Lamprey Designated River existing fish community composition by habitat-use classification guilds.

3. Existing Benthic Macro-Invertebrate Community

In the autumns of 2006 and 2007, benthic macro-invertebrates were collected from multiple habitat types within the Lamprey Designated River. Benthic macro-invertebrate samples were collected, during September 28-29, 2006, from 38 1-meter by 1-meter (3.28 ft x 3.28 ft) quadrates using a stratified random sampling technique. Quadrates were randomly placed on the stream bottom within multiple hydromorphologic units (i.e. areas defined by their structure such as pools, rapids, glides, riffles, etc.) of the upper part of Site 2 (downstream of Wadleigh Falls) and a sample of the benthic macro-invertebrates within each quadrate was collected from the substrate and swept into a micromesh drift net. This same method was repeated on November 1, 2007 below Lee Hook Road and invertebrates were collected from quadrates at an additional 14 sampling locations (see Appendix 5).

Benthic macro-invertebrates were identified in the laboratory by technicians from the Northeast Instream Habitat Program and Rushing Rivers Institute. Due to the extensive effort involved in sorting and identifying macro-invertebrate samples this study focused on a family-level identification of the Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies or EPT) taxa because these families are expected to show the highest sensitivity to flows. Because many endangered dragonflies and damselflies were observed on the river, Odonata were selected as indicator animals. The difficulty is that the members of this Order occupy a wide variability of habitats. In order to find those members that are the most flow sensitive, all of the Odonata were identified to the species-level. However, the samples consisted of many species with a very low number of individuals, so flow dependence could not be determined at the species level. Therefore, the habitat model uses the collection at the taxonomic level of order Odonata. The detailed data are presented in Appendix 5.

D. Rare, Threatened and Endangered: Wildlife, Vegetation, and Natural/Ecological Communities

The riparian wildlife and vegetation includes rare, threatened and endangered (RTE) species and natural communities. The riparian wildlife and vegetation evaluated for protected flows are the flow-dependent subset of those listed in the Lamprey Protected Entities-Preliminary List (DES 2004). Flow dependency of riparian wildlife and vegetation varies seasonally. Critical bioperiods occur during spring for floodplain-adapted species and communities; during summer low flows for breeding and nesting wildlife, and during winter for hibernating turtles (Figure 6). The flow dependent riparian wildlife and vegetation communities evaluated are listed in Table 5. Their distribution and the evaluation methods used to generate the protective flow requirements are described in more detail in the following sections.

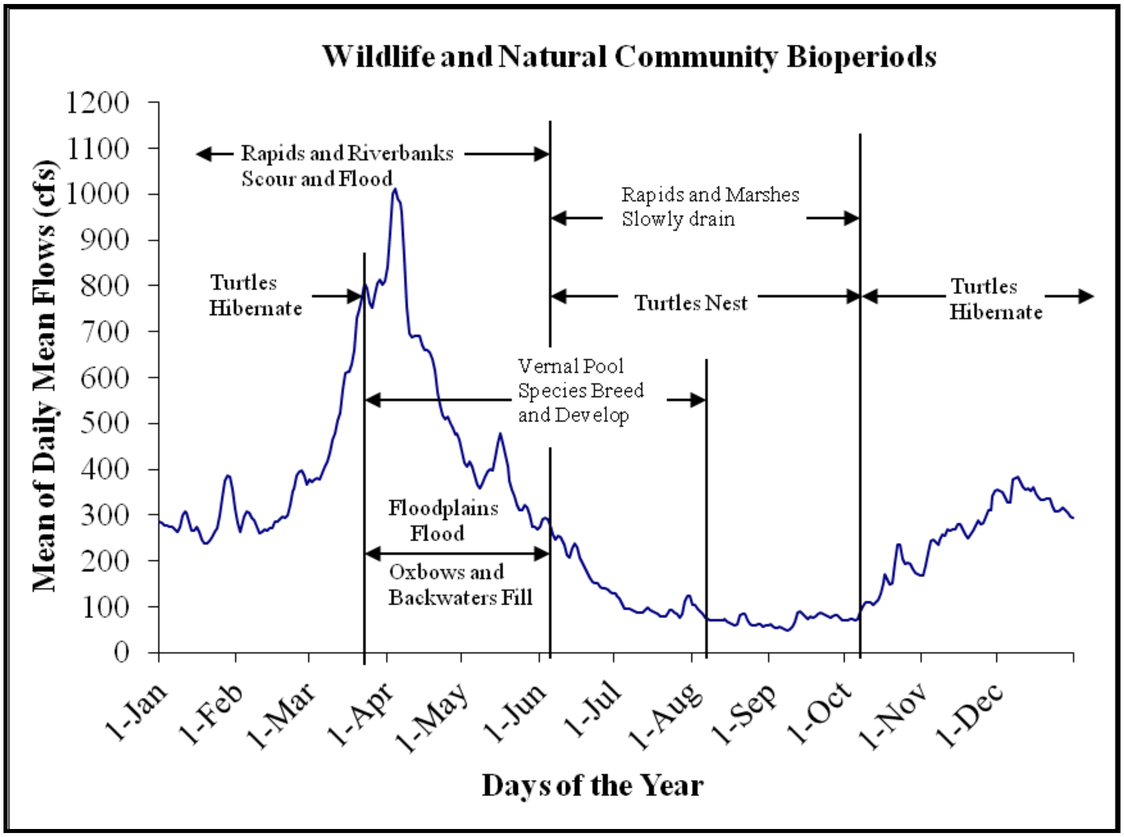

Figure 6. - Wildlife and natural community bioperiods. Mean of mean daily flows based on 73-year record for USGS Lamprey River gage at Packers Falls.

Table 5. - Flow-dependent riparian wildlife and vegetation on the Lamprey Designated River.

Protected Entities	Conservation Status[1]	General Location	Sensitive Bioperiod(s)
Low Floodplain Forest	S2	Newmarket pool, scattered elsewhere	Growing season
High Floodplain Forest (incl. Swamp White Oak *Quercus bicolor*)	S2S3 S1	Narrow band along most of Lamprey, wider at tributaries and oxbows.	Growing season
Oxbow/Backwater Swamp	S3	North of Glenmere Village	Growing season
Herbaceous Low Riverbank	S3/S4	Near Lee Hook Road and other locations	Winter/spring dormancy Late summer flowering

Table 5 (Continued)

Protected Entities	Conservation Status[1]	General Location	Sensitive Bioperiod(s)
Riverweed River Rapid	S2S3	Near Lee Hook Road and other locations	Spring growth
			Late summer flowering
Deep and Shallow Marsh	S4S5	Along tributaries and in pools above dams	Early-mid growing season
Vernal Floodplain Pool	S2	Near Wiswall Rd and Glenmere Village	Early spring to mid-summer breeding season
			Early spring to mid-summer breeding season
Climbing Hempweed *Mikania scandens*	G5S2	Tributary stream floodplain	Spring/summer growing season
Star Duckweed *Lemna trisulca*	G5S1	Tributary stream	Summer growing season
Water Marigold *Megalodonta beckii*	G4G5S1	River/tributary impoundments	Summer growing season
Knotty Pondweed *Potamogeton nodosus*	G5S1	Fast shallow water	Early summer growth
			Late summer flowering
Slender Blueflag *Iris prismatica*	G4G5S2	Floodplains, riverbanks	Growing season
Sharp-flowered Mannagrass *Glyceria acutiflora*	G5S1	Fast shallow water	Growing season
Blanding's Turtle *Emydoidea blandingii*	G4S3 State-Endangered[2]	Uplands near backwater/oxbow wetland complex	Spring-summer nesting period
Wood Turtle *Clemmys insculpta*	G4S3 State Special Concern	Uplands and floodplains near tributary streams	Spring-summer nesting
		Lamprey River and tributary streams	Winter hibernation

Table 5 (Continued)

Protected Entities	Conservation Status[1]	General Location	Sensitive Bioperiod(s)
Spotted Turtle *Clemmys guttata*	G5S3 State-Threatened[2]	Uplands near backwater/oxbow/VP wetland complex	Spring-summer nesting
Osprey *Pandion haliaetus*	G5S2B[2]	Pools in lower Designated River	Spring-summer nesting-rearing
Bald Eagle *Haliaeetus leucocephalus*	G5S1 State-Threatened[2]	Pools in lower Designated River	Any time of year
Pied-billed Grebe *Podilymbus podiceps*	G5S1B State-Threatened[2]	Newmarket Pool – presence unlikely	Spring-summer nesting
Sedge Wren *Cistothorus platensis*	G5S1 State-Endangered	Wet meadows near Newmarket Pool	Spring-summer nesting

1 – Conservation Status

Code	Description
1	Critically imperiled because extreme rarity (generally one to five occurrences) or some factor of its biology makes it particularly vulnerable to extinction.
2	Imperiled because rarity (generally six to 20 occurrences) or other factors demonstrably make it very vulnerable to extinction.
3	Either very rare and local throughout its range (generally 21 to 100 occurrences), or found locally (even abundantly at some of its locations) in a restricted range, or vulnerable to extinction because of other factors.
4	Widespread and apparently secure, although the species may be quite rare in parts of its range, especially at the periphery.
5	Demonstrably widespread and secure, although the species may be quite rare in parts of its range, particularly at the periphery.

2 – In 2008 the New Hampshire Fish and Game Department made the following changes to the state protection status for these (and other) species:

Blanding's Turtle – added to the Endangered Species List
Spotted Turtle – added to the Threatened Species List
Osprey – removed from the Threatened Species List
Bald Eagle – down listed from Endangered to Threatened
Pied-billed Grebe – down listed from Endangered to Threatened

1. Natural Communities and Rare, Threatened, and Endangered Plants

Much of the existing information regarding Natural Communities and RTE vegetation was obtained from records provided by the New Hampshire Natural Heritage Bureau in 2005 and from a comprehensive report prepared by Sperduto and Crow (1994) of the Natural Heritage Bureau. From these records and reports, one Exemplary Natural Community and eight RTE plants were identified as flow dependent species in the Instream Public Uses, Outstanding Characteristics, and Resources of the Lamprey River and Proposed Protective Flow Measures for Flow Dependent Resources Report (DES 2006). After discussions with the Natural Heritage Bureau, three of the eight RTE plants were eliminated from further evaluation due to the age of the records, change of protection status, and/or the likelihood that the record is a misidentification.

Natural Communities

Floodplain Forests

Relative to some other coastal rivers, such as the Exeter River, the Lamprey Designated River has a rather narrow floodplain (Sperduto and Crow 1994), especially below Wadleigh Falls. However, these small floodplain areas provide important habitats. Floodplain communities are divided into two main types based on landscape position. Lower floodplain forests are typically three to five feet above summer river levels and one to two feet above average spring high water (Sperduto and Nichols 2004). These forests probably flood annually during peak flood flows and many of these communities are jurisdictional wetlands. Higher floodplain forests, positioned approximately one to three feet higher than lower floodplain forests, generally flood in two to 100 year cycles and are usually uplands. These forests are often present adjacent to the lower floodplains, either further back from the river or on naturally higher banks along the river edge. Floodplain vegetation response to floodwater varies with species, degree of soil saturation, water temperature, frequency, duration, and water depth. The flood intensity and duration of flooding on smaller rivers are typically lower than for extensive floodplain forests on larger rivers and the flooding may occur earlier in the year.

Dominant tree canopy species of lower floodplains along the Lamprey Designated River include red maple (*Acer rubrum*), red oak (*Quercus rubra*), American elm (*Ulmus Americana*), black cherry (*Prunus serotina*), and shagbark hickory (*Carya ovata*). Ironwood (*Carpinus caroliniana*) is a common understory tree, and shrubs, including several species of viburnum, are common. The ground cover is a mixture of ferns, sedges and other forbs. Lower floodplain forests were observed above Wadleigh Falls and in small, scattered locations below this. Silver maple (*Acer saccharinum*) is found along the river occasionally in narrow bands or with other lower floodplain species, generally about one to two feet below the other lower floodplain forests, and was most abundant below Packers Falls, particularly near Moat Island. The flood tolerance of most of the dominant trees in the Lamprey Designated River’s low floodplain forests, based on studies of flooded rivers, ranges from slightly tolerant to tolerant. Most of the trees will survive more than 50 days of flooding during the growing season (Whitlow and Harris 1979; Bell and Johnson 1974).

The amount of low floodplain forest along the Lamprey Designated River was estimated by computing the overlapping acreage of forested wetlands, as determined from National Wetland Inventory Maps, and the 100-year Floodplain, as mapped by the Federal Emergency

Management Agency on the Flood Insurance Rate Maps. This value is approximately 207 acres, which is higher than the approximately 160 acres of forested wetlands mapped from the aerial photographs that were taken for this study.

Higher floodplain forests support many of the lower floodplain species listed above, although black cherry and elm are uncommon, and hemlock (*Tsuga canadensis*) or white pine (*Pinus strobus*) can be abundant. These forests are also reminiscent of mesic mixed forests, and are comprised of more flood intolerant species. The area of high floodplain forest was estimated by subtracting the NWI wetlands (approximately 507 acres) and estimated non-forested areas (app. 120 acres) from the mapped 100-year floodplain (1,626 acres). This value is approximately 1,000 acres.

Swamp White Oak (Quercus bicolor) Floodplain Forest (S1)

One notable swamp white oak floodplain forest community along a tributary to the Lamprey River was described by Sperduto and Crow (1994). Floodplain forests dominated or co-dominated by swamp white oak are state and regionally rare, classified as S1 (Sperduto and Nichols 2004). These floodplain communities average approximately one to six feet above the main river channel, and therefore, there are lower and higher floodplain variants. A small stand of swamp white oaks near the confluence of the Lamprey and a tributary stream was evaluated to represent this floodplain type. Dominant plants occurring with the swamp white oak include shagbark hickory, green ash (*Fraxinus pennsylvanica*), hazelnut (*Corylus*), and ironwood. Slightly higher elevations support northern red oak, white pine, and paper birch (*Betula papyrifera*) , while silver maple and red maple occur at slightly lower elevations on the floodplain.

Oxbow Swamps – Seasonally Flooded Red Maple Swamp (S4S5)

Alluvial swamps on organic soils dominated by red maple can develop within old oxbows, meander scrolls, or tributary pools protected from swift water and scour under common flows. These swamps are similar to other swamps not located in the floodplain of the Lamprey Designated River, but may contain vegetation and wildlife characteristics slightly different due to the spring flooding regime. Depending on water depth and canopy opening size, the swamps may be forested or shrubby, and may have associated emergent marshes. Those within the floodplain of the Lamprey are considered partially flow dependent, as they flood during some flood events, although beaver dams, natural levees, and tributary streams may maintain water levels and reduce their dependency on Lamprey River flows.

There are relatively few oxbow swamps along the Lamprey Designated River. Within the study area, the wetland complex north of Glenmere Village is notable for its size (approximately 45 acres) and variety of cover types. This swamp is separated from the Lamprey Designated River by sand levees and beaver dams. Three overflow channels through the levee are currently present, two of which are blocked by beaver dams. Summer water levels in the swamp were observed to be approximately three feet higher than in the river and surface water enters from at least one intermittent stream and possible groundwater discharge. The hummocky red maple swamps also support winterberry (*Ilex verticillata*), arrowwood (*Viburnum dentatum*), high bush blueberry (*Vaccinium corymbosum*), alder (*Alnus incana*), sensitive and royal ferns (*Onoclea sensibilis; Osmunda regalis*), skunk cabbage (*Symplocarpus foetidus*), and sedges (*Carex* spp.). Wood ducks (*Aix sponsa*), snapping turtles (*Chelydra serpentina*), and bullfrogs (*Rana catesbeiana*) were observed. On the forested terrace above the swamp, dominant trees include red maple, white pine, red oak, black cherry, American beech (*Fagus grandifolia*), black gum (*Nyssa sylvatica*), and eastern hemlock. The shrub layer includes high bush blueberry and seedlings of the trees, and the ground cover is partridgeberry (*Epigea repens*), Canada mayflower (*Maianthemum canadense*), bracken and hay-scented ferns (*Pteridium aquilinum*; *Dennstaedtia punctilobula*), and cinquefoils. The topography is rolling, with muck and peat soils in the deeper depressions and sandy ridges. Several depressions on the floodplain function as vernal pools.

Although forest and shrub swamps are not uncommon, this community is associated with an important wildlife habitat area along the Lamprey River (Carroll 1998). Transect 4 – Glenmere Village Swamp - was established within this swamp and marsh complex. There is an estimated 200 acres of forested and shrub backwater swamp habitat along the Lamprey Designated River.

Herbaceous Low Riverbank (S3S4)

The Herbaceous Low Riverbank community is located in high- to moderate-energy river banks subject to ice and flood scour in winter and spring (Sperduto and Crow 1994; Sperduto and Nichols 2004). The alluvial bar on the Lamprey Designated River directly downstream of the Lee Hook Road in Newmarket has characteristics of this community. The narrow island has a few silver maple trees at its center and shrubs and herbaceous plants on the sand/cobbles near the channel. The community extends from the summer river channel up to a point approximately three feet above summer water levels, where the hydrology ranges from flooded to hydric to mesic as water levels fall during the growing season. Species richness is often high, as plants may be emergent, aquatic or moist site species. The substrate may be very fine, or coarse, including alluvial sand or cobble bars and banks (Sperduto and Crow 1994; Sperduto and Nichols 2004). Plants observed that are typical of this community include cardinal flower (*Lobelia cardinalis*), water hemlock (*Cicuta maculata*), sensitive fern (*Onoclea sensibilis*), marsh fern (*Thelypteris palustris*), royal fern (*Osmunda regalis*), false nettle (*Boehmeria cylindrica*), and water pepper (*Polygonum hydropiperoides*). The length of the Herbaceous Low Riverbank community along the high energy reaches of the Lamprey Designated River was assumed to be similar to the length of River Rapid community. This was estimated, through review of photos, reports, and field notes, to be approximately 8,000 linear feet (1.5 miles).

Riverweed River Rapid (S2S3)

The riverweed river rapid plant community has been described only in the Lamprey River and can be found there in several locations (Sperduto and Nichols 2004), although it may be found on other rivers with the characteristic vegetation. This plant community is adapted to semi-permanently to permanently flooded conditions at high energy sites, such as falls and rapids. The characteristic vegetation includes riverweed (*Podostemum ceratophyllum*), an obligate wetland plant worthy of consideration as a Special Concern species (Sperduto and Crow 1994) which forms a low mat on submerged rocks. Riverweeds occur in rivers and streams that have distinct high-low water periods, remaining vegetative when the water level is high and plants are submersed, then flowering when exposed as the water level drops (Philbrick ND). Other plants associated with this community include white water crowfoot (*Ranunculus tricophyllus*) and knotty pondweed (*Potamogeton nodosus*), which is described further in the Rare, Threatened and Endangered Plants section of this report. Algae may also be a component of this community. Other species of plants may appear as water levels drop through the growing season.

The length of the Lamprey Designated River with river rapid community was estimated, through a review of photos, reports and field notes, to be approximately 8,000 linear feet (1.5 miles). The riverweed river rapid community is represented on Transect 2, downstream of the Lee Hook Road Bridge near the channel island. On the northwest side of the island this plant community occupies 25-50 percent of the channel near the transect, and on the southeast side of the island, where the water is deeper and there is more shade, the transect has less than 5 percent riverweed rapid vegetation. Algae were observed on many of the channel rocks along the surveyed transect. Pastures upstream of the bridge are fenced in a manner that allows farm animals (and manure) to enter the river, a potential contributing factor to algae growth.

Deep and Shallow Marshes (S3)

Deep and shallow marshes develop in locations with slow moving water and sufficient sun exposure. Often they are found in a mosaic pattern with other floodplain wetlands and channel formations. Marshes are present along the low-gradient, pooled portions of the Lamprey Designated River, particularly above Wiswall Dam, and from below Packers Falls to the Macallen Dam, including the Moat Island area. Smaller marshes are found at stream confluences, along the river shore, in shallow embayments, or behind natural levees. Marshes are often partially filled in with fine sediments and shallower than the adjacent river channel and may be connected to the channel through partially constricted outlets.

Marshes along the Lamprey are classified into three broad categories: lacustrine, riverine, and palustrine. Lacustrine marshes are located within impoundments (lacustrine) and are dominated by plants that are non-persistent (not visible after the growing season), such as water lilies and arrowheads. Artificially created marshes located above dams have relatively stable water levels, particularly at low flows. Variations in flow do not cause significant changes in water levels, as was determined by aerial photo review of the Moat Island impoundment and transect work in the Wiswall Dam impoundment. The result of stable water levels, however, is very minor elevation differences between wetland plant communities. Riverine marshes have similar vegetation, but are located along free-flowing portions of the river or its tributaries. Palustrine marshes have persistent vegetation (such as grasses, sedges, or cattails) and may grow anywhere along the channel or in backwater areas.

Concentric rings of vegetation were commonly observed to correspond to the water level gradient. On Transect 3, upstream of Wiswall Dam, the deep marsh included a central channel of submerged aquatics, primarily coontail (*Ceratophyllum demersum*). Fringing the central channel is white water lily (*Nymphaea odorata*), cow lily (*Nuphar lutea*), pickerelweed (*Pontederia cordata*), and burreed (*Sparganium* sp.). This deep marsh is a riverine wetland, typically inundated throughout the growing season, and the plants are non-persistent. It extends from the bottom of the backwater channel up approximately three feet. The intermediate marsh that extends one foot higher is dominated by three-way sedge (*Dulichium arundinaceum*), arrowhead (*Sagittaria latifolia*), spikerush (*Eleocharis* sp.), and woolgrass (*Scirpus cyperinus*), and may retain shallow water throughout the growing season. Numerous small fish, painted turtles (*Chrysemys p. picta*), green frogs (*Rana clamitans melanota)*, and aquatic macroinvertebrates were observed in these marshes. Part of this community is a floating mat. Extending 0.5 feet above the intermediate marsh is a seasonally flooded palustrine shallow marsh and shrub swamps comprised of buttonbush (*Cephalanthus occidentalis*), tussock sedge (*Carex stricta*), marsh fern (*Thelypteris palustris*), and royal fern (*Osmunda regalis*). This was bordered by a forested or shrub swamp margin of maleberry (*Lyonia ligustrina*), red maple (*Acer rubrum*), sweet pepperbush (*Clethra alnifolia*), speckled alder (*Alnus incana*), winterberry (*Ilex verticillata*), arrowwood (*Viburnum dentatum*), buckthorn (*Rhamnus* sp.), cinnamon fern (*Osmunda cinnamomea*), and tussock sedge. Soil in the shallow marsh and bordering shrub/forest community is typically saturated throughout the growing season.

In the Moat Island portion of the Lamprey Designated River, which is impounded by the Macallen Dam, the deep marsh aquatic plant community falls in the lacustrine classification, and includes many additional submerged species, including water marigold (*Megalodonta beckii*) (Sperduto and Crow, 1994). This aquatic member of the composite family is found in ponds, streams and slow rivers, blooming in August to September. It is currently listed as an endangered species in New Hampshire. This species was not observed in the field, but that may have been due to having missed its flowering period. The water depth in much of this impounded marsh is approximately 0.5 to three feet deep.

Marshes typically fill in spring as the lower floodplain floods, draining slowly during the summer months until only the deeper marshes contain standing water and surface connections to the river may be temporarily lost. Since rivers are dynamic, both water levels and the arrangement of sediments and plants may frequently change. Marsh vegetation is generally well adapted to occasional short-term and long-term water level fluctuations. While plants are susceptible to drowning or desiccation during floods or droughts, there is often a seed bank in the sediment or sources upstream that can initiate vegetation recovery if water levels are restored to a stable level. Frequent water level fluctuations may exhaust a seed bank and prolonged winter drawdowns may kill dormant plant rootstocks.

Vernal Floodplain Pool (S2)

Shaded floodplain or oxbow pools typically have sparse vegetation, but can have similar hydrology to open oxbow marshes and ponds; those with direct or unconstricted connections are most dependent on river flow, while others have a surface water connection to the river only at high flows. Some of these pools function as vernal pools, important breeding areas for amphibians and invertebrates and feeding areas for many wildlife species. They may differ from vernal pools in upland areas, as fish may be periodically washed in during river flooding, or substrates scoured of organic debris in high flows.

Vernal pools in their broadest sense are fishless pools of water that dry out at least some years, usually in late summer, and support breeding wood frogs, mole salamanders, and/or fairy shrimp. Generally speaking, pools with longer hydroperiods have greater species diversity than those that dry quickly, and wood frogs (*Rana sylvatica*), having one of the shortest hydroperiod requirements of the obligate amphibian vernal pool breeders, require about 145 days of continuous standing water for eggs to hatch and larvae to transform to terrestrial adults (RIVP). The eggs of wood frogs and spotted salamanders can survive temporary stranding (caused by receding water levels) for up to one week, and potentially longer when clustered with other egg masses, as the gelatinous covering protects from immediate desiccation (Green Futures). Vernal pools also provide food and water to numerous other species of wildlife, including spotted and Blanding's turtles.

New England vernal pools fill in fall, winter or early spring, and this normally occurs through rain and snowmelt. Water levels decline until fall as evapotranspiration exceeds precipitation (Brooks 2004). On floodplains, flooding may fill pools in winter or spring, while flooding in April through July may wash away amphibian egg masses or introduce predatory fish, thereby reducing pool productivity. Lower than normal fall/winter/spring flows may fail to fill pools, leaving them unusable by vernal pool species if precipitation is also low. Variability in pool success is not uncommon and ideal conditions may not be present in every pool each year. By definition, flooding of pools in floodplains (and consequent loss of vernal pool species) will occur one or more times in every hundred years.

Fourteen confirmed vernal pools were observed within the floodplain of the designated reach, based on field investigations by various researchers. More likely exist in areas not searched on foot. Carroll (1994) noted several vernal pools in the floodplain above Lee Hook Road and in the swamp north of Glenmere Village. Transect 4 crosses an oxbow swamp and floodplain forest with floodplain pools, which may support vernal pool species. Another group of vernal pools are present in the floodplain above Wiswall Dam, some with direct and deep/wide connections to the river and others with minimal surface connections. Wood ducks, painted turtles, and frogs were observed in the pools, and heron, deer, muskrat, and beaver tracks were seen. Otter scat was also observed. This group was surveyed in mid-April 2006 during the drawdown for the Wiswall Dam inspection when water levels were approximately 30 inches below the spillway. No transects were established in this area. Water levels in the isolated vernal pools were low, about one foot below full pond, which appeared to be the case with most vernal pools in early spring 2006. Pools with deep connections to the river were draining and were well below their full spring levels. Several spotted salamander egg masses were observed hanging on branches above the water, while others were still submerged. Snails and mussels were exposed on the riverbanks. Some minor amounts of silt were washing into the river from a small tributary stream.

Rare, Threatened, and Endangered Plants

Climbing Hempweed (*Mikania scandens*)

This state-listed threatened plant species was found by Sperduto and Crow in 1994 along a tributary to the Lamprey River. This climbing, facultative-wetland plant (FACW+) is most commonly found in wetlands along water bodies and is likely flow dependent to the extent that the wetland floodplains it inhabits are flow dependent. This population was located near a tributary stream and during most of the growing season; the primary hydrologic influence in this species' habitat is the tributary stream and adjacent wetland, which is above the influence of the Lamprey River at low flows. However, it is located within the 100-year floodplain of the Lamprey Designated River and may be influenced by the river during large flood events.

Star Duckweed (*Lemna trisulca*)

Historical records indicate this floating leaved aquatic bed species was collected from a tributary stream to the Lamprey River, but it was not observed in this location or elsewhere in the river in 1994 (Sperduto and Crow 1994) or during 2006-2007 field investigations. This obligate, state endangered species is most likely to be found in quiet backwaters and slow moving streams where water velocity is always low. Water depth is not an issue, as the plants float on the water surface, obtain nutrients from the water column, and primarily reproduce vegetatively.

Water Marigold (*Megalodonta beckii*)
This aquatic member of the composite family is found in ponds, streams and slow rivers, blooming in August to September. It is currently listed as an endangered species in New Hampshire. It has been recorded from one particular impoundment in the Lamprey Designated River where it was locally abundant in 1994 and was also observed in a tributary stream above a culvert that hydrologically separates the plant community from the river during most flows. The habitat for this species has been artificially created in the study area. This species was not observed in the field in 2005, which may have been the result of missing its period of flowering, which occurs sometime from July to September. This plant is one member of a submerged and floating leaved deep marsh community. According to the Robert W. Freckmann Herbarium website of the University of Wisconsin - Stevens Point (Judziewicz and Freire ND), water marigold can grow in clear water up to 12 feet deep.

Knotty Pondweed (*Potamogeton nodosus*)
This state endangered aquatic plant is found in shallow to deep ponds and streams. In 1994, the historic record was reconfirmed and found to be locally abundant in river rapids throughout the study area, typically associated with riverweed (*Podostemum ceratophyllum)* and white water crowfoot *(Ranunculus trichophyllus*). It was located also in 2004 in the same portion of the Lamprey Designated River and was identified by Normandeau during the initial field survey (DES 2006). Knotty pondweed is near its northern limit in New Hampshire, but common elsewhere in North America.

Like many pondweeds, this species has submerged leaves and floating leaves, and late in the growing season sends flowers above the water surface. As with riverweed, low flows early in the season could adversely affect plant development and high water levels during flowering could affect reproduction. However, like riverweed, knotty pondweed also reproduces vegetatively, and therefore, may tolerate a year of high flows during late summer.

Slender Blueflag *(Iris prismatica)*
This obligate wetland plant is found in brackish to fresh wet meadows, bogs, pond margins, and wooded swamps. It blooms in June and July. Although slender blueflag is a state-listed threatened species on the Natural Heritage Bureau list for the study area, this species was not mentioned in the 1994 survey by the NHNHB, nor was it observed by Normandeau in the study area. Slender blueflag may be flow dependent if it inhabits shallow marshes or swamps within the floodplain or channel of the Lamprey River.

Sharp-flowered Mannagrass (*Glyceria acutiflora*)
This state listed endangered grass species is found in shallow water in ponds and streams, and blooms in June and July. The Natural Heritage Bureau database indicates that it was last observed in the Lamprey in 1942 in fast-flowing shallow water. A related species was observed at this location in 1994, but not the target plant. This plant species may or may not be extirpated from this site. As an emergent plant growing in shallow water, it is most likely to be associated with the herbaceous low riverbank community.

2. Wildlife

Habitats with a direct hydrological connection (groundwater or surface water) to the river at some time during the growing season are potentially susceptible to changes induced by prolonged changes in flow. Prolonged flooding and/or prolonged low water during the growing season both alter plant communities and microhabitats for plants, fish and wildlife, causing losses of foraging opportunities and nesting/denning sites for wetland dependent wildlife. Wildlife species that have an aquatic life phase for which water levels are critical, such as frogs, and those that normally consume flow-dependent plants or animals, such as ducks, swallows, kingfishers and bats, are more flow dependent than mobile terrestrial species that forage opportunistically in wetlands (e.g. deer, chipmunks).

Wildlife species observed by Normandeau or others in the Lamprey Designated River corridor that are directly or indirectly flow dependent include:

- **Amphibians** - spring peeper, gray treefrog, bullfrog, green frog, wood frog, northern leopard frog, pickerel frog, American toad, Jefferson salamander, spotted salamander, northern two-lined salamander, and red-spotted newt.
- **Turtles** – spotted, Blanding's, snapping, wood, painted, and musk.
- **Mammals** – otter, muskrat, and beaver.
- **Birds** – Great blue heron, green heron, American bittern, mallard, black duck, Canada goose, wood duck, cormorant, osprey, spotted sandpiper, belted kingfisher, and bank swallow.

Several of the turtles (wood, spotted, and Blanding's) and birds (black duck, great blue heron, and bittern) are also State-Threatened, Species of Special Concern or Species of Greatest Conservation Need (NHF&G 2005).

Flows that deviate substantially from the Natural Flow Paradigm during the growing season (April through October) will have the most significant effects on flow-dependent wildlife, as the adaptive behaviors and food chains may be upset. For example, higher than "normal" flows in early summer may destroy turtle or waterfowl nests, while lower flood levels in spring may fail to fill oxbow marshes where amphibians breed. Exceptionally low flows during critical life stages of some species can result in direct freezing, desiccation, or increased predation. Examples include loss of water during aquatic egg and larval stages of amphibians; exposure of overwintering turtles in the river channel; and dewatering of mink, muskrat, and otter burrows in channel walls.

Protective flows for many wildlife species using wetlands and floodplains are represented by protective flows determined for the wood turtle and oxbow marshes, as described in Section IV. (C) of this report. Water temperature changes that alter the timing of macroinvertebrate life cycles (for example, emergence of insects important to breeding or migrating songbirds) could also adversely affect wildlife. Protective flows for aquatic/emerging insects are represented by those identified for odonates. Several floodplain wetland complexes within the study area representing combinations of plant community types were noted by various investigators for their habitat value. One of these, an area just north of Glenmere Village, was noted for excellent bird habitat; vernal pools; emergent, forested and shrub wetlands; beaver dams; musk, painted, snapping turtles, and potentially other turtle species. This wetland complex is represented by Transect 4, but valuable wildlife habitat is present along the other transects also.

It should be noted that loss of habitat from development is still considered the greatest threat to many species of wildlife in NH (NHF&G 2005), so even under the natural flow paradigm, wildlife along the Lamprey Designated River may be adversely affected by habitat loss.

Table 6 lists the wildlife species, both flow dependent and non flow dependent, observed during the field reconnaissance and transect surveys. Although the list is not a complete list of species potentially using the river, it includes some of the more common species and those easily detectable by song or track.

Rare, Threatened, and Endangered Wildlife

The New Hampshire Natural Heritage Bureau provided information regarding rare, threatened, and endangered species, species of concern, and exemplary natural communities along the Lamprey River study corridor. The New Hampshire Wildlife Action Plan (NHF&G 2005) was also consulted for current information regarding species of greatest conservation need (SGCN) and their status. Field investigations previously performed by wildlife specialists, in part for the Wild and Scenic study, were also consulted for additional information regarding RTE species and their habitats.

Blanding's Turtle (*Emydoidea blandingii*)

Blanding's turtles are a wetland-dependent NH Endangered Species and Regional Conservation Species. Blanding's turtle populations are threatened by loss of wetland and nesting habitat, road kill, and collection (NHF&G 2005). This turtle prefers permanent shallow dark waters of bogs, swamps, ponds and slow moving rivers and coves, and the adjacent vegetation. They require shallow water with soft mud bottoms, but do not seem to make sustained use of river channels, using them primarily during long-term dispersal. Vernal pools can be important foraging sites in spring (DeGraaf and Yamasaki 2001).

Adjacent terrestrial habitat, typically mixed or coniferous forests, is also important as Blanding's turtles will nest up to 1,115 m (3,657 ft) from the nearest water source (Congdon et al. 1983), and frequently nest in plowed fields near wetlands (DeGraaf and Yamasaki 2001). Blanding's turtles reach reproductive maturity around 12-15 years and lay 6-17 eggs (DeGraaf and Yamasaki 2001) once (and sometimes twice) every one to two years (Congdon et al. 1983). In the northeast, eggs are laid from late May to early July (NHF&G 2005). These eggs hatch in fall and nestlings may remain in the nest until spring (DeGraaf and Yamasaki 2001). Blanding's turtle eggs are not highly susceptible to drowning and are also able to withstand fairly dry conditions (Packard et al. 1982). However, lakeshore nests are at risk of extended flooding during relatively wet summers (COSEWIC 2005) and in 2003, all lakeshore nests in Kejimkujik N.P. were lost as a result of late summer flooding (COSEWIC 2005; McNeil, personal communication 2005; Herman, personal communication 2005). Researchers believed that extensive seasonal flooding of the Ottawa River may have lead to Blanding's turtle nests being submerged for up to seven days, which would likely prove fatal to the developing embryos (COSEWIC 2005).

Blanding's turtles overwinter in permanent bodies of water (Joyal et al. 2001) and, in some cases, seasonally isolated wet depressions or ponds (Power 1989). Turtles will densely aggregate in overwintering sites in Québec (St-Hilaire 2003) and in Nova Scotia, with up to

Table 6 - Wildlife species observed in and near the Lamprey Designated River during 2005-2007.

Common Name	Scientific Name	Habitat Observed in
Reptiles and Amphibians		
Green Frog	*Rana clamitans melanota*	Back swamps
Pickerel Frog	*Rana palustris*	Floodplain
Wood Frog	*Rana sylvatica*	Floodplain pools
Spring Peeper	*Hyla crucifer*	Back swamps, pools
Gray Tree Frog	*Hyla versicolor*	Floodplain pools
Bull Frog	*Rana catesbeiana*	Channel
Spotted Salamander	*Ambytsoma maculatum*	Floodplain pools
Red-spotted Newt	*Notophthalmus v. viridescens*	Backwater marsh
Snapping Turtle	*Chelydra s. serpentine*	Backwater swamp
Eastern Painted Turtle	*Chrysemys p. picta*	Channel, oxbow, pools
Common Musk Turtle	*Sternotherus odoratus*	Back swamps
Wood Turtle (SC)	*Clemmys insculpta*	Tributary channel
Common Garter Snake	*Thamnophis sirtalis*	Riparian forest
Mammals		
Meadow Jumping Mouse	*Zapus hudsonius*	Floodplain forest
Eastern Chipmunk	*Tamias striatus*	Riparian edge
Red Squirrel	*Tamiasciurus hudsonicus*	Riparian edge
Gray Squirrel	*Sciurus carolinensis*	Floodplain forest
River Otter	*Lontra Canadensis*	Riverbank and channel
Muskrat	*Ondatra zibethicus*	Channel, oxbow
Raccoon	*Procyon lotor*	Oxbow, bank
Beaver	*Castor Canadensis*	Channel, bank
Red Fox	*Vulpes vulpes*	Floodplain thicket
Coyote	*Canis latrans*	Floodplain forest
White-tailed Deer	*Odocoileus virginianus*	Oxbow, floodplain
Birds		
Great Blue Heron (SGCN)	*Ardea Herodias*	Channel, bank
American Bittern (RC, SGCN)	*Botaurus lentiginosus*	Channel marsh
Green Heron	*Butorides virescens*	Bank

Table 6 (Continued)

Common Name	Scientific Name	Habitat Observed in
Birds		
Turkey Vulture	*Cathartes aura*	Floodplain forest
Canada Goose	*Branta Canadensis*	Channel
Mallard	*Anas platyrhynchos*	Channel
Wood Duck	*Aix sponsa*	Floodplain pool
American Black Duck (SGCN)	*Anas rubripes*	Channel
Double-crested Cormorant	*Phalacrocorax auritus*	Channel
Osprey	*Pandion haliaetus*	Channel, floodplain
Sharp-shinned Hawk cf.	*Accipiter striatus*	Floodplain
Broad-winged Hawk	*Buteo platypterus*	Floodplain forest
Red-tailed Hawk	*Buteo jamaicensis*	Channel, floodplain
Ruffed Grouse (SGCN)	*Bonasa umbellus*	Floodplain old-field
Spotted Sandpiper	*Actitis macularia*	Gravel bars
Rock Dove	*Columba livia*	Bridges
Mourning Dove	*Zenaida macroura*	Floodplain
Belted Kingfisher	*Ceryle alcyon*	Channel
Ruby-throated Hummingbird	*Archilochus colubris*	Channel island
Northern Flicker	*Colaptes auratus*	Floodplain forest
Eastern Wood Pewee	*Contopus virens*	Floodplain Forest
Great Crested Flycatcher	*Myiarchus crinitus*	Floodplain
Eastern Kingbird	*Tyrannus tyrannus*	Riparian edge
Red-eyed Vireo	*Vireo olivaceus*	Floodplain
Blue-headed Vireo	*Vireo solitaries*	Floodplain
Blue Jay	*Cyanocitta cristata*	Floodplain forest
American Crow	*Corvus brachyrhynchos*	Floodplain
Barn Swallow	*Hirundo rustica*	Channel
Tufted titmouse	*Baeolophus bicolor*	Floodplain forest
Black-capped Chickadee	*Poecile atricapilla*	Wooded eastern edge
White-breasted Nuthatch	*Sitta carolinensis*	Floodplain forest
Brown Creeper	*Certhia Americana*	Floodplain forest

Table 6 (Continued)

Common Name	**Scientific Name**	**Habitat Observed in**
Birds		
Eastern Bluebird	*Sialia sialis*	Floodplain forest
Veery (SGCN)	*Catharus fuscescens*	Forest
Hermit Thrush	*Catharus guttatus*	Forest
Wood thrush (SGCN)	*Hylocichla mustelina*	Forest
American Robin	*Turdus migratorius*	Floodplain
Mockingbird	*Mimus polyglottos*	Riparian edge
Gray Catbird	*Dumetella carolinensis*	Riparian edge
Cedar Waxwing	*Bombycilla cedrorum*	Channel, riparian edge
Common Yellowthroat	*Geothlypis trichas*	Riparian edge
Pine Warbler	*Dendroica pinus*	Forest
Ovenbird	*Seiurus aurocapillus*	Forest
Yellow Warbler	*Dendroica petechia*	Riparian edge
Chestnut-sided Warbler	*Dendroica pensylvanica*	Floodplain
Scarlet Tanager	*Piranga olivacea*	Floodplain
Song Sparrow	*Melospiza melodia*	Floodplain field
Chipping Sparrow	*Spizella passerine*	Floodplain field
Dark-eyed Junco	*Junco hyemalis*	Floodplain forest
Northern Cardinal	*Cardinalis cardinalis*	Floodplain
Indigo Bunting	*Passerina cyanea*	Floodplain meadow
Brown-headed Cowbird	*Molothrus ater*	Riparian edge
Red-winged Blackbird	*Agelaius phoeniceus*	Oxbow, back swamp
Common Grackle	*Quiscalus quiscula*	Channel
Baltimore Oriole	*Icterus galbula*	Floodplain
American Goldfinch	*Carduelis tristis*	Floodplain

Note:

SC – NH Special Concern (NHF&G 2005)
SGCN – Species of Greatest Conservation Need (NHF&G 2005)
RC – Regional Concern (NHF&G 2005)

14 individuals at a single site (Herman et al. 2003). In Nova Scotia, individuals tend to return to the same sites each year (Herman et al 2003). During the winter months, the Blanding's turtles move, although only a few meters (Ernst et al. 1994). Over the majority of the range very little is known about the overwintering requirements of the Blanding's turtle.

Although Blanding's turtles were not observed during this study, most of those reported from near the Lamprey River have been in wetlands upstream of the project area. However, several properties within the study area are known to support Blanding's turtles and there are additional suitable habitats in the study area without confirmed Blanding's turtle sightings (Carroll 1998). The primary Blanding's habitat in the project area includes large wetland complexes with documented beaver influences along tributary streams within the floodplain of the Lamprey Designated River. The turtles are adapted to the shifting mosaic of wetlands types modified by beaver activity.

Reductions in low flow that cause wetlands to drain or expose the bottom of water bodies for prolonged periods in winter and spring could cause stress or mortality of Blanding's turtles, but this is unlikely in the known and potential Blanding's turtle habitat along the Lamprey Designated River due to modifying effects of tributaries and beaver dams. However, the dams will not protect nests from flooding of the Lamprey Designated River in all instances. It was assumed that potential nest sites for Blanding's turtles are more likely to be in the high floodplain (upland) terrace of the Lamprey Designated River adjacent to the tributary wetlands, as Blanding's turtles are not as likely as wood turtles to use the river channel and associated sand bars/banks in the low floodplain. Summer floods of one or more weeks in duration can destroy eggs or nestlings. Flows associated with flooding of the high floodplain of the Lamprey Designated River were assessed using the Floodplain Transect Method (see Section IV (C)).

Wood Turtle (*Clemmys insculpta*)

The wood turtle, a NH Species of Special Concern and Regional Conservation Species, has been classified as flow dependent species due to its reliance on riverine habitats in spring and summer for feeding and cover, and also for overwintering. The wood turtle overwinters in rivers and streams and feeds both on land and in the water (NHF&G 2005) eating aquatic and upland plants and animals. Instream and riparian cover are extremely important for wood turtles (Carroll 2000). Instream cover includes deadfalls and debris drifts and dams, and cobbles and boulders. Cover for hatchlings through adults is provided by natural wetland shrub borders along the river, herb cover, vines, and debris and detritus. Because of this, wide, undeveloped riparian areas are most suitable.

The wood turtle excavates a nest in dry, sandy banks, sandbars, or adjacent farm fields, laying 4 to 18 eggs in late May to early July. Flooding of nests by high summer flows before the hatchlings leave (in August to early October) can cause direct mortality (NHF&G 2005). Sometime in October or November, depending on weather, the wood turtle returns to the water until spring and may enter hibernation. Some wood turtles return to the same hibernacula each year (Ernst, et al 1994; NHF&G 2005). The wood turtle typically hibernates underwater in undercut banks or burrows, beaver lodges, on the river bottom in pools, or under submerged debris piles/logs in the river channel. In Massachusetts they have been observed hibernating in 0.3 to 0.6 meters (1 to 2 ft) of water in flowing streams (Ernst, et al 1994). Some turtles continue to be alert and mobile in the winter under river ice and show little sign of hibernating (Hanson, ND). Many turtle activities appear to be temperature dependent, and therefore, dates vary from year to year. Hibernating turtles may be susceptible to injury or death if exposed to ice or below freezing air temperatures after settling into hibernation sites in autumn. However, non-hibernating wood turtles may relocate as needed if water levels decline in winter.

Suitable wood turtle habitat has been observed along the Lamprey River and several of the larger tributary streams (Carroll 2000). Most of the wood turtles observed during David Carroll's studies on the Lamprey River were located upstream of the project area. However, suitable habitat appears to exist within the project area, particularly on the tributary streams, though angling and other human activity may limit suitability by diminishing bank cover and flushing turtles from basking sites.

While habitat loss, road kill, mowing injuries, and collection are probably the greatest threats to wood turtles in NH, there are also hydrological threats. Drops in river flow after the start of hibernation could expose hibernating turtles to ice or scour and could result in direct mortality. Flooding of nest sites in the floodplain in late spring or summer can cause egg or nestling mortality. Such flooding events occur naturally on rare occasions and the continued presence of wood turtles indicates an adaptation to periodic flooding during these critical bioperiods. Construction of dams that reduce scouring flows may eliminate nest sites downstream, flood nest sites upstream, or flood downstream nests with sudden releases of flow (NHF&G 2005). This species is reported to be intolerant of pollution (DeGraaf and Yamasaki 2001) and is therefore also indirectly flow dependent.

Spotted Turtle (*Clemmys guttata*)

Spotted turtles, a NH Threatened Species and Regional Conservation Species, prefer heavily vegetated wetlands surrounding small, shallow bodies of water, such as small streams, ponds, vernal pools, and swamps. Their habitat use may overlap with Blanding's turtles in southern New Hampshire (NHF&G 2005). In June, female spotted turtles travel overland as much as 120 m (394 ft) to nest (Joyal 1996). Nest sites are generally located in open, upland habitats including, for example, open fields, along gravel roads, lawns. Females typically lay three to seven eggs every other year. Hatchlings may emerge in late summer to fall, depending on the weather, and some hatchlings may overwinter in the nest and emerge instead the following spring (Center for Reptile and Amphibian Conservation and Management). Spotted turtles may aestivate (a metabolic state similar to hibernation) in wetlands (NHF&G 2005) or adjacent upland forests (DeGraaf and Yamasaki 2001) during the dry summer months.

In winter, spotted turtles hibernate in the shelter of dense clumps of cattails, grasses and sedges, submerged cavities created by tree or shrub roots, and hummocks created by trees or shrubs. Hibernation throughout elevated mats of sphagnum at the bases of tree and shrub roots has also been observed. Water depths between 20 and 50 cm (7.9 and 19.7 in) were noted at spotted turtle hibernation sites in Maine by Joyal and Barlow also recorded depths less than 50 cm (19.7 in) in Indiana (Center for Reptile and Amphibian Conservation and Management, ND). Spotted turtles may hibernate both solitarily and communally, and have been observed to return to the same hibernacula on a yearly basis, or to ones occupied by other spotted turtles during the previous winter.

Habitat for spotted turtles appears to be present in forested floodplains with pools and swamps and oxbow marshes, and historical observations of spotted turtles exist in the study area (Carroll 2000). Reductions in flow that drain wetlands or expose the bottom of water bodies for prolonged periods in winter and spring could cause stress or mortality of spotted turtles. This is unlikely to occur in wetlands with beaver dams and sufficient groundwater or tributary stream flow to counteract a reduction in river flow. Marshes and vernal pools with direct connections to the Lamprey Designated River will drain in low flow conditions, but spotted turtles are mobile and often use a wetland complex that will include alternative locations with more favorable conditions.

Osprey (*Pandion haliaetus*)
The osprey was removed from the state threatened list in 2008. The osprey is a bird of prey that was observed foraging over the Lamprey Designated River during the August 2005 reconnaissance survey. Ospreys are known to nest in Great Bay and may forage up to seven miles away (Vana-Miller 1987), putting the whole study area potentially within range of a resident bird. Ospreys observed along the Lamprey River in summer could also be transient individuals. Ospreys consume fish primarily from clear, unobstructed water bodies. They dive up to three feet into the water, so they are most likely to feed in pools and reservoirs, not shallow riffle areas. With the exception of a few pools, most of the project area above Moat Island would not provide ideal foraging habitat, particularly compared with the nearby Great Bay and Piscataqua River. Only changes in flow that eliminate pools, reduce fish abundance, increase turbidity, or increase aquatic plant cover are likely to affect ospreys.

Bald Eagle (*Haliaeetus leucocephalus*)
Bald eagles are a state threatened species recolonizing their historic range. Eagles nested in New Hampshire in 1989 after a 40-year absence and continue to nest in several New Hampshire locations each year. In New Hampshire, bald eagles occur in relatively undisturbed forests along major rivers and lakes or near the coast. Eagles perch, hunt from, and nest on tall, coniferous and deciduous trees or snags near water. They prey primarily on fish and waterfowl, but are also noted for their scavenging. In winter, they leave the breeding areas and congregate in areas with large expanses of unfrozen, open water. A forest stand that offers protection from inclement winter weather is needed for communal night roosting. Night roosts are most often found near foraging areas, but may be further away if the roost is more protected. Bald eagles are observed each winter in the Androscoggin, Connecticut, and Merrimack River Valleys, on Great Bay, and in the Lakes Region. Non-breeding adults and immature eagles are observed sporadically throughout the state year-round, including Great Bay. The Lamprey Designated River may provide eagle foraging habitat at various times of the year. Flow changes in the river that affect fish populations would probably have little impact on this very mobile bird of prey, but flow requirements to maintain basic fish habitat were interpreted from the MesoHABSIM model.

Sedge Wren (*Cistothorus platensis*)
The sedge wren, a state endangered species, uses densely vegetated sedge meadows, wet hayfields, upland margins of ponds and marshes, and coastal brackish marshes, preferring drier marshes or wet meadows where there is little standing water and the ground is damp (U.S. Fish and Wildlife Service 2001). Sedge wrens have low fidelity to both breeding and wintering sites, and readily abandon areas that become too wet or too dry through water level fluctuation (DeGraaf and Yamasaki 2001). Meadows greater than two acres are preferred. Nesting in the northeast is low to the ground (within a foot) and initiated in late June or July, and may coincide with seasonal stability of water levels in preferred habitats.

Agricultural land borders the Lamprey in several locations, with the most suitable habitat comprised of several un-mown wet pockets in a hayfield north of Moat Island. Attempts to locate sedge wrens in this area in 2007 using call playbacks were not successful. Water levels in the large reservoir around Moat Island will be evaluated using the aerial photo modeling approach. Significant fluctuations are not expected due to the volume of water in this basin.

Pied-billed Grebe (*Podolymbus podiceps*)
Preferred habitat for the state threatened pied-billed grebe is densely vegetated emergent and deep marsh interspersed with open water that is more than 12 acres in size (Degraaf and Yamasaki 2001; Banner 1998). To the extent that such a marsh is dependent on river flow, this marsh bird species would be flow dependent. A preliminary inspection of aerial photos of the Lamprey Designated River floodplain indicates that emergent marshes large enough for grebes may be located around Moat Island within the Newmarket reservoir (aka the pool) of the Lamprey Designated River. Although there is good vegetation/water interspersion in these shallow and deep marshes, the vegetation type is not ideal for grebes, being of the floating-leaved variety, not the preferred emergent type such as cattail. No response was obtained from grebe call playbacks in this area and it is unlikely that pie-billed grebes are nesting here.

3. Exotic/Invasive Species

There are numerous exotic and invasive species of vegetation and invertebrates present in New Hampshire that have the potential to occur in the Lamprey River watershed. These species can be found listed on the DES website. For the purposes of this project, these species are not protected entities, although some are flow dependent. Rather, these species are threats to a protected entity – namely the communities of native plants and their habitat value. Maintenance and protection of these natural communities (and control of invasives) are assumed to be facilitated under the Natural Flow Paradigm (NFP), which should favor the adapted native plants. But invasive species may be favored when disturbances, including prolonged deviations from the NFP, occur.

Purple loosestrife (*Lythrum salicaria*), an invasive wetland plant, was observed during the field reconnaissance. The small seed of this prolific seeder is often transported by water and wildlife. The seed germinates on seasonally exposed mudflats, and seed can remain dormant in the sediment for years until conditions for germination are suitable. Prolonged periods of low flow during spring and summer would promote germination and seedling survival. Once mature, this perennial plant can tolerate fluctuating water levels. Purple loosestrife was observed in the northern reaches of the Newmarket pool, where water levels are normally quite stable. Any significant reduction in water levels could favor germination of colonies of purple loosestrife on exposed mudflats.

Japanese knotweed (*Polygonum cuspidatum*) is a persistent perennial that spreads rapidly by rhizomes, fragments of which are often transported by water. Though such transport is possible at any flow, it is most likely to occur at high flows. The wind dispersed seed rarely germinates. This plant was observed on the riverbank near Wadleigh Dam, and now that it is in the watershed, is likely to spread regardless of flow.

Several other invasive species, including common barberry (*Berberis vulgaris*) and European buckthorn (*Frangula alnus*), were observed during the detailed vegetation assessments performed in 1993 and 1994 for the National Park Service (Chase 1993, Sperduto and Crow 1994). The seed of these two species are spread by non-flow-dependent birds. While their distribution is not limited to riparian areas, birds may drop the seeds while travelling along a riparian corridor, and the seedlings thrive in moist soils and canopy openings, conditions often present on stream banks and floodplains. Flow management is not likely to have an effect on the abundance of these species.

No invasive submerged aquatic macrophytes were recorded during the field studies. A flow regime that encourages a healthy native community of flora and fauna in the Lamprey Designated River will discourage the spread of exotic/invasive species.

IV. Assessment of Protected Flows

Protected flows were developed for specific human instream uses, riparian wildlife and vegetation, and fish and aquatic life. Each of these three groupings of flow-dependent uses was assessed using methods appropriate for their flow needs as described in Instream Public Uses, Outstanding Characteristics, and Resources of the Lamprey River and Proposed Protective Flow Measures for Flow Dependent Resources (DES, 2006). Human instream uses were assessed using surveys and questionnaires. A floodplain transect method was used to assess riparian wildlife and vegetation. Fish and aquatic life were assessed using an incremental model that evaluates habitat quality versus streamflow.

A. Survey Methods for Recreational Uses

Flow-dependent instream human uses of the Lamprey Designated River include recreational boating, fishing, and swimming. Of these, boating and swimming uses of the river were assessed by literature survey, field observations, surveys and interviews, and by contacting local and regional user groups for information. These methods are commonly used in the evaluation of river recreation uses and instream flow (Whittaker et al. 2005).

Although recreational fishing is a flow-dependent instream use, it was not directly assessed during this study. The protected instream flows that are required to maintain the environmental and fish habitat resources are those that will be adequate to preserve recreational fishing on the Lamprey Designated River. As a result, recreational fishing was not assessed and the instream flows required to protect fish and their habitats are considered to also be protective for this flow-dependent instream human use.

1. Boating

As part of the protected instream flow study, boating flows for the Lamprey Designated River were evaluated qualitatively through a combination of field observations and surveys of boaters during various river flow stages including low summer flows and high spring flows . The surveys included questions regarding the boater’s use of the river (season run, frequency of visits and favorite sections), flow conditions (preferred flow levels, maximum and minimum flows run), and sources of information on flow conditions.

Several variations of a survey form were used during the course of the study. In general, the survey included questions on:

- Location of boat put in.
- Frequency of paddling and time of year.
- The town or city and state where the boater was from.
- How they monitored flow conditions.
- The sections of the Lamprey they typically boated or paddled.
- The flow range or water level that was best to paddle the river.
- The minimum flow they would attempt to paddle the river.
- The things they found attractive about the Lamprey for boating or paddling.

The completed survey forms are included in Appendix 1 for reference.

Surveys of boating preferences were performed on April 16 and 29, July 1, 3, and 20, October 8, 2006, and May 27, 2007. On April 16, 2006, Normandeau personnel met with a group of paddlers running a section of the river above the Lamprey Designated River from Mary E. Folsom Blair Park to the Route 87 fishing access. The trip was sponsored by the Merrimack River Watershed Council Inc. and the NH Rivers Council. Normandeau personnel also distributed surveys on April 29 at the Lamprey River Canoe (and Kayak) Race. This race covered the same 6.8 miles of river as did the April 16 trip. Although not within the Lamprey Designated River, these two events provided the opportunity to meet with individuals having experience paddling the Lamprey River during spring flow conditions. During these two events, 60 survey forms were distributed and 15 were returned completed. After meeting with the boaters at Mary E. Folsom Blair Park, visits were also made to boat launching locations on the upper portion of the Lamprey Designated River including: Wadleigh Falls, Lee Hook Road Bridge, Wiswall Dam, and Packers Falls Park to distribute surveys, but no boaters were observed at those locations on those two days.

Three visits were made during July 2006 to the boat launch sites on the upper portion of the Lamprey Designated River and in its' lower section where it is impounded by the Macallen Dam to document boating use during summer flow conditions. Boat launching points in the lower section include an area next to the Town of Newmarket's water treatment facility on Packers Falls Road and the Riverside Cemetery. Both of these are unmarked and unimproved launch sites. A third site, the Piscassic Street Boat Ramp (also referred to as the Twin Rivers Condo boat launch by some survey respondents) was also visited. The upper and lower sites were revisited in October 2006 and May 2007 to gather more survey information. Survey forms (with return postage provided) were placed on vehicles with boat racks or trailers. A total of 15 surveys were distributed and six were returned completed.

During swimming surveys on July 29 and August 5, 2006, 15 of the 24 people surveyed mentioned that they also canoe the river. These included individuals staying at the Ferndale Acres Campground, Wadleigh Falls Campground, and the Wellington Camping Park. These campgrounds are located along flat-water sections of the river that are formed either by bedrock controlled waterfalls (Wadleigh) or Wiswall Dam (Ferndale Acres and Wellington Camping Park).

It should be noted that a survey of the riparian landowners was not proposed or performed as part of the protected instream flow project. During the field studies, boating by riparian landowners was noted. The greatest number of homes with boats was located along the impounded flat-water section upstream of the Macallen Dam.

From the answers provided by the respondents to the boating and swimming surveys, the following conclusions can be reached relative to boating on the Lamprey Designated River:

- **River access:** Popular locations for putting in boats are the three campgrounds, Wadleigh Falls, and the Piscassic Street Boat Ramp in Newmarket. Information from the AMC River Guide (2007) and members of the Lamprey River Watershed Association also indicate access at Lee Hook Road Bridge, Packers Falls, and Wiswall Dam.
- **Frequency of paddling and time of year:** Survey respondents indicated that they boated or paddled the river from a couple of times a year to over a dozen times a year.

Their trips on the river occurred from spring into the fall. Individuals who ran the entire river indicated that they would only do so during high flows in the spring, whereas individuals that boated on the flat-water sections used it from spring to fall.

- **Where the boaters were from:** The answer to this question depended upon where the survey was performed. Of the individuals that mentioned during the swimming interview that they also boated, the majority were from out of state (Massachusetts). Individuals that were surveyed on the lower portion of the Lamprey Designated River were local (Dover, Durham, and Newmarket).
- **How they monitored flow conditions:** Most of the surveyed boaters monitored the river for boating based on driving by the river or to the boat ramps or by word of mouth. A few respondents mentioned the USGS gage at Packers Falls and a few mentioned the New Hampshire Fish and Game website.
- **The sections of the Lamprey they typically boated or paddled:** The majority of the individuals surveyed (boating and swimming surveys) on the Lamprey Designated River indicated that they canoed or boated on the flat-water sections of the river. These included the sections near the three campgrounds and in the impounded section upstream of the Macallen Dam. As indicated by the inclusion of the Lamprey Designated River in the AMC River Guide (2007) and based on information provided by members of the Lamprey River Watershed Association, white-water paddling is also popular, but only one of the surveyed parties in the Lamprey Designated River indicated that they paddle the entire designated segment, and only at high flows.
- **The things they found attractive about the Lamprey for boating or paddling:** The survey also provided insight on the characteristics that attract boaters and paddlers to the river. Attractive features of the river mentioned by the respondents include how quiet the river is, the lack of development, the quality of fishing, the beautiful scenery, and the opportunities to observe and photograph wildlife.

The focus of the boating survey was to determine from the responses of recreational boaters what the best flows and the minimum flows are needed to boat or paddle the river. To document different flow conditions, the surveys were performed in the spring, summer and fall. The April 16 and 29 survey events in 2006 were expected to coincide with spring runoff and the high flows needed to run the whitewater sections of the river. As shown in the Table 7 below, the measured flows at the USGS gage at Packers Falls on these two dates were well below historical mean flows.

No boaters were found on the Lamprey Designated River during the two April survey dates, but the survey results from the upper section provide some insight into the relationship between flow level and navigability of the river. Nine of the 15 respondents (60 percent) indicated that the flows on April 16 and 29 should have been higher to run the river. These conditions may have also limited the navigability of the rapids on the Lamprey Designated River, as evidenced by the lack of boaters observed on the two survey dates.

The flows experienced during July 2006 ranged from above average (on the 1st and 20th) to below average (on the 3rd). Boaters were only found on the lower section of the river that is impounded by the Macallen Dam and only over the Fourth of July holiday period. No boaters were encountered on July 20th. Flow on the October 8, 2006 survey date was below the historical mean and boaters again were only observed on the lower impounded section.

Table 7 - Discharge at the time of boating surveys.

Date	Mean Daily Discharge		Historical Mean Discharge (in CFS)
	CFS	CFSM	
April 16 2006	185	1.01	698
April 29 2006	154	0.84	477
July 1 2006	249	1.36	127
July 3 2006	177	0.97	292
July 20 2006	100	0.55	80
October 8 2006	64	0.35	99
May 26 2007	353	1.93	322

Where:

cfs = cubic feet per second

cfsm = cubic feet per second per square mile drainage area (183 sq. mi.).

Historical mean discharge period of record from 10/1/1933 to 9/30/2007.

On May 26, 2007, when flow was near its historical mean and more representative of a typical late spring flow level, boaters were observed on both the upper and lower sections of the river.

In general, excluding periods of extremely high flows, such as those experienced during the flooding events of May 2006 and April 2007, boating conditions in the impounded sections are less flow dependent than the rapids sections of the river. The lower variability and greater reliability of water level conditions of the impounded sections on the Lamprey Designated River are the major reason why they attract the greatest number of recreational boaters during the spring, summer and fall.

In addition to the boating surveys performed as part of this study, an interview was performed with a representative of the only commercial business directly associated with water recreation on the Lamprey Designated River. This business is the Durham Boat Company (DBC), which is located on the lower impounded section of the river off of Newmarket Road (Route 108) in Durham. The DBC manufactures sculling boats in addition to providing lessons and hosting a local boating club. Mr. Jordan Hicks, an employee of the DBC, was interviewed in May 2006 by Shannon Rogers of the University of New Hampshire (UNH). In this interview, Mr. Hicks mentioned that the water levels in the lower impounded section of the river need to be high enough to be rowable and deep enough so they can put their docks in along with their motorboat. The motorboat is used a safety feature when they give sculling lessons. The water levels also cannot get too high, as experienced during the floods. Overall, Mr. Hicks commented that the river has been fairly consistent in its water level and subsequent ability to provide for the company’s needs.

Unfortunately, the respondents to the recreational boating surveys failed to provide a recommended flow level for the free-flowing rapids sections of the Lamprey Designated River. They typically responded that they would only run the designated segment during a period of high flow as long as it wasn’t a flood flow. Since a recommended protected instream flow magnitude for boating was not obtained by surveying users, other sources of information were consulted. The results of an online search for paddling reports on the Lamprey Designated River uncovered a day trip report at Paddling.net (www.paddling.net) from July 2004. The report described the boating conditions from Wadleigh (aka Wadley) Falls to the Wiswall Dam. The reported flow for that day was was 69 cfs (0.38 cfsm, relative to Packers Falls' gage). They noted that this flow was the absolute minimum for the "scratchy areas" (rapids). In particular, the rapids below the Lee Hook Road Bridge were the "roughest, scratchiest section of this trip."

As part of Task 3 of the protected instream flow study, an on-stream survey of protected entities was performed by boat on August 25 and 26 of 2005 (DES 2006). On these two days, daily mean discharge at the USGS Packers Falls gage ranged from 19 to 22 cfs (0.10 to 0.12 cfsm). These flows were below normal for this period. As a result of these low flows, the rapids below Wadleigh Falls and Packers Falls were impassable by boat.

An additional source of information regarding recommended flows on the Lamprey River for boating is the publication titled "Discover Southern New Hampshire: AMC Guide to the Best Hiking, Biking and Paddling" (Monkman and Monkman 2002). In the description of the Lamprey River, the authors note that the section of the river from the Mary Blair Recreation Park to the Route 87 access point in Epping, which is located above the designated segment), should not be attempted if flows are below 200 cfs, as measured at the USGS 01073500 LAMPREY RIVER NEAR NEWMARKET, NH gage located near Packers Falls.

Mr. Jamie Fosburgh (personal communication 2006) of the National Park Service mentioned that, as a general rule of thumb for running the entire length of the Lamprey Designated River, if the water levels are high enough to run the rapids downstream of Lee Hook Road Bridge, they are sufficient for the entire segment. Based on observations made by field crew members during the fish habitat assessment performed as part of this study (Rogers personal communication 2008), a minimum flow of 275 cfs (1.5 cfsm) is required to cleanly paddle this reach of the river. A review of photographs taken by Normandeau personnel of this reach of the river from the Lee Hook Road Bridge over a range of flows (10 cfs to 1,670 cfs) also supports this conclusion.

Flows above 275 cfs (1.5 cfsm) normally occur during the spring (March through May) in response to snowmelt and/or rainfall, or at other times of the year due to storm runoff, and during the fall in response to the release of water stored in Pawtuckaway Lake. At this flow level, a paddler should be able to negotiate the Lamprey Designated River, but may still encounter fallen trees or other obstructions (dams or falls) that would require some portaging.

Both flat-water and whitewater boating on the Lamprey Designated River are flow-dependent resources. Flat-water boating primarily occurs on sections of the river that are either artificially or naturally impounded. Based on the information gathered during this study, boaters using these reaches of the Lamprey Designated River are more sensitive to higher flows, which potentially pose a safety hazard, than do lower flows. For whitewater paddling, the limitation on this activity is the minimum flow necessary to run the rapids of the Lamprey Designated River. Based on the results of this study the protected instream flow for this activity is 275 cfs (1.5 cfsm).

In either case, the opportunity to engage in boating on the river is dependent upon the availability of flow. The availability of flow is directly dependent on runoff from rainfall and or snowmelt, along with recharge by groundwater. The availability of flow may also be affected by dam operations and/or water withdrawals along portions of the designated segment. The impact of any water uses on the magnitude, frequency, and timing of flows that might affect boating recreation will be further investigated as part of the Water Management Plan (WMP) process.

2. Swimming

As proposed in the Task 4 Report (DES 2006), swimmers using designated beaches were interviewed as they were encountered on the river during the summer and the results evaluated qualitatively. The interviews included a survey of the swimmer's use of the river (frequency of visits and favorite swimming areas), flow conditions (preferred flow levels), and sources of information on flow conditions.

A swimming recreation survey consisting of personnel interviews was performed on July 29 and August 5, 2006 by Ms. Kimberly Peace of Normandeau. The interviews were performed at the four designated beach sites: Ferndale Acres Campground, Glenmere Village Association, Wadleigh Falls Campground, and the Wellington Camping Park. In response to comments received during the interviews, the survey was widened slightly to include responses from swimmers who were found using two "swimming holes": the road bridge above the Wiswall Dam, and the area located immediately below the ruins of Wadleigh Dam, also referred to as Wadleigh Falls.

Each of these locations can be characterized as being impounded backwater due to natural or artificial controls. The state designated beaches are found on sections of the river that are impounded by natural controls such as bedrock outcrops or rapids, while the reach of the river at Wiswall Road bridge is impounded by Wiswall Dam. The swimming hole located below the breached dam at Wadleigh Falls is a scour pool below the falls and is upstream of rapids that partially impound water at this location. The impoundment of water at each of these locations creates a low velocity flow environment and deep water when compared with the free flowing rapids sections of the river and are the conditions that are supportive for recreational swimming.

The swimming surveys were conducted via walking among the beach and beach-associated campsites and verbally inquiring of the campers if they used the Lamprey Designated River for swimming. If they answered affirmatively, and they also answered affirmatively to a request to ask them some survey questions, then questions from the survey form were asked and the responses were recorded. The survey included the following questions:

- How often do you swim in the Lamprey River?
- What months do you typically swim in the Lamprey?
- Where do you live?
- What conditions make you choose the Lamprey River for a swimming location?
- Do you look at the flow conditions on the Lamprey for swimming before you come? If so, how do you check conditions?
- What is the best flow range or level to swim the river?
- What is the minimum or maximum flow you would consider for swimming? How would you decide this?

- In which sections of the Lamprey do you typically swim?
- Can you name other swimming areas or places where you can access the river for swimming?
- What do you find attractive about the Lamprey River for swimming?
- Do you use the Lamprey River for other recreation, such as fishing or boating and if so where?
- Do you belong to any sporting, outdoor recreation or environmental organizations? If yes, please list the organizations.

The completed survey forms are included in Appendix 2 for reference.

The Glenmere Village Association site (located off of Tuttle Road in Lee) is a residential development with a private beach. However, inspection of the beach indicated that it was not in use. Grass had grown around it, the water's edge was overgrown, and access was limited. Residents of Glenmere Village volunteered that the beach was no longer used. They reported that the residents were unable to maintain the beach in accordance with NH regulations and that the current residents did not have an "age-cohort" that swam. Because Glenmere Village is private property and access to the beach area is supervised by the residents, it is unlikely that non-residents would use this location for swimming access.

The Ferndale Acres Campground and the Wellington Camping Park are largely semi-residential, with campers occupying trailer homes or recreational vehicles for long periods during the camping season. Survey respondents shared that many of them were seasonal residents of the camps, returning for weekends, weeks at a time, or the entire season, and had been doing so in many cases for years and even decades. There were a few open locations among these campgrounds for non-residential or transitory campers. The Wadleigh Falls Campground is a mix of transitory and semi-residential campers. Both the Ferndale Acres and the Wadleigh Falls campgrounds have large in-ground pools as an alternative to swimming in the river.

A total of 24 surveys were completed with the following breakdown in the number of surveys per location and the total number of individuals associated with the respondents:

- Ferndale Acres Campground – seven interviews, 32 party members.
- Glenmere Village Association – one interview, one party member.
- Wadleigh Falls Campground – four interviews, 18 party members.
- Wellington Camping Park – eight interviews, 26 party members.
- Wadleigh Falls Swimming Hole – two interviews, seven party members.
- Wiswall Dam Swimming Hole – two interviews, seven party members.

Many of the respondents answered the questions similarly and this was identified as being a possible artifact of the survey process (e.g., people who camp in a similar location and style tend to have similar views and responses).

From the answers provided by the respondents the following conclusions can be reached relative to swimming on the Lamprey Designated River:

- **Frequency of Use:** The most frequent users (several times a week) were individuals that were camped at Ferndale Acres or were swimming at Wiswall Dam. This response is interesting because most of the campers were not local, while the individuals at Wiswall Dam were local. Frequent use of the river by campers was most likely because they were there, while frequent use of Wiswall Dam by locals was most likely due to convenience.
- **Time of Use:** Swimming typically occurs in summer months from June to September, generally during the warmest months.
- **Where did they come from:** The majority of the individuals at the campgrounds were not local and were from out of state (mostly Massachusetts), while swimmers at the Wadleigh Falls and Wiswall Dam swimming holes were from local communities (Epping, Lee, and Newmarket).
- **Conditions favoring swimming in Lamprey:** Most individuals responded that they chose the Lamprey Designated River for swimming because it was close to where they were staying (campground) or living. Warm or hot weather was also a factor taken into consideration.
- **Monitoring flow conditions:** Few people monitor the flow conditions other than driving by occasionally or looking at them when they arrive at their campsite.
- **Best flow range or level to swim in the river:** Seven of the respondents said that the flow on the day they were interviewed was just fine, while seven said higher flow would be better. Only two responded that the flow should be lower. The surveys were performed on 29 July and 5 August, 2006 when the flow of the Lamprey River as measured at the USGS gaging station at Packers Falls was 235 and 173 cfs (1.28 cfsm and 0.95 cfsm) respectively. Compared with the long term record (1933 to 2007) these flows are roughly 2.1 times greater than the mean daily flow for these days.
- **The maximum and minimum flows for swimming:** Respondents did not give relative values for these flows, but they did provide conditions that would affect their decision to swim. Strong currents and flooding conditions limit swimming at maximum flow, while depth of water in pools or rapids, the ability to walk across the channel along with warm murky water conditions are factors limiting swimming at minimum flows.
- **Popular swimming locations:** Popular swimming locations included areas in the vicinity of the campgrounds, Wadleigh Falls, Wiswall Road Bridge, Packers Falls, and the railroad trestle. Most other swimming locations discussed were accessed via canoe from campgrounds. Of these, only three locations are associated with campgrounds and they are considered inactive designated beaches since water quality samples are not collected at these locations (Carlson, personal communication 2008).
- **Factors contributing to the attractiveness of the river for swimming:** clean, cool, fresh water.
- **Other uses:** Respondents indicated that the Lamprey River supported several other recreational activities including boating and fishing. All of these recreational resources add to the value of the river.

Based on the results of the interviews, the conditions favoring the use of the Lamprey Designated River for swimming include: warm weather, safe flow velocities, and sufficient depth. Relative to temperature, most of the swimmers indicated that they used the river during the summer months. Although they could not provide specific flow values as representative of preferred swimming conditions, many did note that strong currents and high flows pose safety hazards, while lower flow levels with warm murky water are less desirable for swimming.

Most of the individuals surveyed responded that flows on the day of the survey should have been higher than they were for swimming. The flows on the days of the interviews ranged from 173 cfs (0.95 cfsm) to 235 cfs (1.28 cfsm), which when compared with the long term flow records were roughly 2.1 times greater than the mean daily flow for these two days. Only two of the persons interviewed said that the flows should have actually been lower to make conditions better for swimming.

Based on the results of the interviews, swimming at the designated beaches along the Lamprey Designated River is dependent upon water levels, flow velocities, certain water quality criteria (temperature and appearance), and weather conditions (air temperature). As a result, this recreational use is considered to be opportunistic, in that all of the supporting conditions (air and water temperature, water depth, and flow velocity) must be in place to favor the use of the river for swimming. Since the depth and velocity of flow in the river is site specific and since existence of suitable swimming conditions is highly dependent upon an individuals' perception and personal preferences, a specific instream flow value for swimming recreation cannot be established for the Lamprey Designated River.

3. Summary of Recreational Flow Assessments

The results of the surveys show that the Lamprey Designated River is an important recreational resource, one that attracts individuals from afar and locally. Boating, along with fishing and swimming, are important recreational uses of the river and contribute to its overall attractiveness and value.

Both flat-water and whitewater boating are popular activities on the Lamprey Designated River and are considered to be flow-dependent resources. Flat-water boating primarily occurs on sections of the river that are either artificially impounded by dams or naturally impounded by bedrock or rapids. Based on the information gathered during this study, flat-water boating is more sensitive to high flow (flood) events rather than low flow events because of safety issues. Numerous dams exist within the watershed and provide some flood storage, but management of high flows for boating is not proposed by this study.

For whitewater paddling, the limitation on this activity is the minimum flow necessary to run the rapids of the designated segment. Based on the information obtained during this study, a minimum flow of 275 cfs (1.5 cfsm) is sufficient to cleanly paddle the length of the Lamprey Designated River.

Recreational fishing on the Lamprey Designated River is also a flow-dependent resource. The protected instream flows that are required to maintain the environmental and fish habitat resource are those that will be adequate to preserve recreational fishing on the Lamprey Designated River. As a result, no assessment of fishing recreation was performed. The proposed instream flow values believed to be protective of the fishing resource are discussed in Section IV (C) (MesoHABSIM Incremental Flow Model for Aquatic Life and Fish) of this report.

Swimming is also considered a flow-dependent resource of the Lamprey Designated River. Based on the responses of swimmers surveyed for this study swimming on the Lamprey Designated River is dependent upon water levels, flow velocities, certain water quality (water temperature and appearance), and weather conditions (air temperature). As a result, this recreational use is considered to be opportunistic, in that all of the supporting conditions (air and water temperature, water depth and flow velocity) must be in place to favor the use of the river for swimming. Since the depth and velocity of flow in the river is site specific, and since the existence of suitable swimming conditions is highly dependent upon an individuals' perception and personal preferences, a specific protected instream flow value cannot be established for swimming for the Lamprey Designated River.

B. Survey of Public Water Supplies

Two public water supplies are included within the Lamprey Designated River study area; the University of New Hampshire/Town of Durham Water System (UDWS) and the Town of Newmarket Water Works. The UDWS currently withdraws water from the impoundment upstream of Wiswall Dam and was identified in the Task 4 report as a flow-dependent protected entity. The Town of Newmarket Water Works was not identified as a flow-dependent entity in the Task 4 report because its withdrawal points are not located on the Lamprey Designated River, but on several of its' tributaries. Since both the UDWS and the Town of Newmarket Water Works are registered water users, and have reported water use to DES, they were both surveyed as part of this study to assess their use of water from the Lamprey Designated River or its tributaries.

To assess their water use, both the UDWS and the Town of Newmarket Water Works were sent a water use questionnaire. A questionnaire was sent to and completed by Mr. Wesley East of the UDWS and one was sent to and completed by Mr. George Laney (now retired) of the Town of Newmarket Water Works. The questionnaire requested information on:

- Whether they used water from the Lamprey River, tributary streams or from adjacent wells
- How water from the Lamprey River, tributary streams or adjacent wells is used
- When they use this water
- How their facilities are staffed
- How their water use is measured
- How much water they return to the river
- If they have historic water use records
- If they plan to modify their water use in the future
- The depth and configuration of any water intakes
- Whether they maintain a stream gage or if they were aware of stream gaging data in the vicinity of their facility
- Any water conservation measures that they employ or have considered
- How much water they can store

- Their reuse of water
- If they have planned shutdowns

Using the information provided in the returned questionnaires an Affected Water Users profile was developed for each of these Public Water Supplies. This information will be used in the second phase of this project for the development of a Water Management Plan for the Lamprey Designated River. Information from these questionnaires was also used in the assessment of their water use as part of this study.

In addition to the questionnaires, a survey and interview of representatives of these two Public Water Supplies was performed by Ms. Shannon Rogers of the University. The information collected by Ms. Rogers was as part of her graduate research work (Rogers 2007), but was also obtained for use in the development of the Water Management Plan for the Lamprey Designated River. Information from the survey and the interviews was also used in the assessment of their water use as part of this study. The stakeholder survey included questions on the possible conflicts associated with the management of the water resources of the Lamprey River. Ten of the 14 stakeholders returned a completed survey.

Ms. Rogers also performed structured interviews with Mr. David Cedarholm (Durham Town Engineer on June 14, 2006), Mr. Wesley East (University of New Hampshire Water Works on June 26, 2006) and Mr. George Laney (Newmarket Water Works on June 20, 2006). The structured interview consisted of the four following questions:

- What is important about the Lamprey River?
- How do they know when the river is able to provide what is important to them?
- What do their customers/citizens tell them about the river?
- How they would anticipate responding to management alternatives proposed by the water management plan and do they have suggestions or recommendations for such alternatives?

Each of the stakeholders was also given the opportunity to provide any additional comments.

Lastly, to comply with the requirements of RSA Chapter 488 Title L (Water Management and Protection) both the UDWS and the Town of Newmarket have registered their water use and report their monthly withdrawals to DES on a quarterly basis. The reported water use records on file with DES and daily water use data obtained from the UDWS for its' withdrawals were reviewed as part of this assessment.

1. University of New Hampshire/Town of Durham (UDWS)

Using the existing diversion in the Wiswall Dam impoundment, the UDWS can withdraw up to one million gallons of water a day (East, personal communication 2006) from the Lamprey Designated River. When compared with the capacity of its' other two water sources (Oyster River and the Lee Well) the withdrawals from the Lamprey River can represent close to half of the UDWS maximum water supply capacity (Metcalf 2007). The actual amount of water withdrawn from the impoundment depends on demand and the availability of water from the Oyster River or the Lee Well (East, personal communication 2008).

Based on the monthly water use values that the UDWS has reported to DES (2000 to 2005), water is not continuously pumped from the Lamprey River during the entire year. During this six year period no water was diverted from the Lamprey River during the months of January and February, while water was typically pumped from the river during the period of July through December. The demand during this period is driven by seasonal low flows on the Oyster River along with the return of students to UNH in the fall, which significantly increases the demand for water from the UDWS. It is in response to these periods of increased and or the reduced availability of water from its' other supply sources that make the Lamprey Designated River such an important source of water for the UDWS.

When the UDWS has withdrawn water from the Lamprey River its' monthly pumping (excluding months without any pumping during the 2000 to 2005 reporting period) have ranged from 23,000 gallons in June 2000 to 21,480,000 gallons in October 2003. Using adjusted average use values calculated by DES (from actual monthly values and excluding months with zero values) the amount of water pumped from the river by the UDWS ranges from 10,267 gallons per day (June 2000) to 492,141 gallons per day (October 2003). These flow volumes can also be expressed in cubic feet per second (cfs) so that they can be compared with recorded flows in the Lamprey River. Using a conversion of 1 cfs equaling 646,320 gallons per day, the equivalent range of flows would be from 0.02 cfs (June 2000) to 0.76 cfs (October 2003). Comparatively, based on the flow records of the USGS Packers Falls gaging station, mean monthly streamflow in June 2000 was 190 cfs, while in October 2003 it was 206 cfs. When the UDWS withdrawals are compared with the mean daily discharge for the months of June 2000 and October 2003, they represent 0.01 percent and 0.37 percent of the flow.

The daily water withdrawal data recorded by the UDWS provides a more detailed view of the range of the withdrawal values and their magnitude relative to the flow of the Lamprey River. During 2002, the Lamprey River experienced a period of low flows during the late summer and into the fall. During this period, streamflow recorded at the USGS Packers Falls gage fell below either the 99 percent flow duration or the 7-day 10-year low flow (7Q10). On August 20, 2002 UDWS pumped 514,000 gallons (0.8 cfs) from the Lamprey River. Although the magnitude of this withdrawal isn't the highest recorded for 2002, relative to the flow in the Lamprey River at the time (1.8 cfs) it represents the highest withdrawal as a percentage (44 percent) of flow. The highest magnitude withdrawal during 2002 was 1,085,700 gallons (1.68 cfs) recorded on November 14, 2002. But, as a percentage of the flow of the Lamprey River on that day (197 cfs) this withdrawal represented only 0.85 percent of the flow. So as shown in these examples, the highest withdrawals may not always represent the highest percentage of river flow, while lower magnitude withdrawals may represent a greater percentage of flow, especially during periods of low flow. Relative to the average daily withdrawals recorded during the period of 2002 to 2007, the average withdrawal from the Lamprey River was 0.93 cfs, while the average percentage of Lamprey River flow was 3.9 percent.

So the UDWS withdrawals from the Lamprey Designated River can range from the tens of thousands of gallons per day to just over one million gallons per day. These withdrawals represent a transfer of water from the Lamprey River basin to the Oyster River basin.

Wastewater at the University of New Hampshire and the Town of Durham is collected via sanitary sewers and piped to the wastewater treatment facility located off of Route 4. The treated wastewater is then discharged into the tidally influenced portion of the lower Oyster River. Since the water pumped by the UDWS from the Lamprey Designated River is not returned to the Lamprey River basin, this withdrawal represents a 100 percent consumptive use (loss) of this water.

The withdrawals made by UDWS from the Lamprey Designated River are presently subject to the terms of a Section 401 Water Quality Certification (#2001-001). Under this certification, the withdrawals of water from the Lamprey River during the summer via the pump station and flow downstream of Wiswall Dam are subject to conditions based on flow in the river. Specifically:

- When river flow at the Packers Falls gaging station is between 45 and 21 cfs (0.25 and 0.11 cfsm), outflow from the Wiswall Dam (owned by the Town of Durham) shall be maintained at no less than inflow minus 1.8 cfs (0.01 cfsm or 1.2 million gallons per day).
- When river flow at the Packers Falls gaging station is between 21 and 13 cfs (0.11 and 0.07 cfsm), outflow from the Wiswall Dam shall be maintained at no less than inflow minus 0.4 cfs (0.002 cfsm or 259 thousand gallons per day).
- When river flow at the Packers Falls gaging station is less than 13 cfs (0.07 cfsm), outflow from the Wiswall Dam shall be maintained equal to inflow. When flow is less than 13 cfs (0.07 cfsm), withdrawals can only be made from the water stored by the dam.

The certification also has a condition pertaining to the drawdown of the impoundment (reservoir). The pool elevation in the Wiswall Dam reservoir cannot be drawn down more than 0.5 inches in any 24-hour period and the maximum drawdown of the pool elevation cannot exceed six inches below the crest of the dam. The Town of Durham has approached the DES for a modification of the certificate to increase the allowable drawdown to 18 inches below the crest of the dam to increase its potential withdrawals from storage. This proposal is currently under consideration by the DES pending the outcome of the PISF study.

2. Town of Newmarket

The Town of Newmarket Water Works does not presently withdraw water directly from the Lamprey Designated River or its tributaries, but it has done so in the past. Surface water withdrawals have been made from Folletts Brook (#20057-S01), the Piscassic River (#20057-S05) and the Lamprey River (#20057-S02). The last reported withdrawals from these surface water sources were in 2002 for Folletts Brook and the Piscassic River and 2004 for the Lamprey River. These surface water supplies are not currently used as water sources because the quality of the water requires treatment and the existing water treatment facility cannot meet current water quality standards without an upgrade. Although these sources are not currently being used, the Town of Newmarket does reserve the right to use them in the case of an emergency.

The existing sources of water for the Town of Newmarket are two ground water supply wells (Bennett and Seawall) that are located in the Newmarket Plains aquifer. Reported total annual water production (1989 to 2007) from these wells has ranged from 29,554,000 gallons to 77,971,000 gallons for the Bennett Well and 43,738,000 gallons to 107,098,000 gallons for the Sewall Well.

With the limitation of using only these two wells as the Town's water supply, a stage three water conservation plan is currently in effect for the Town. This plan restricts the outdoor use of water and during dry periods outdoor water use is banned. So in effect, the Town is meeting its water demands through water conservation.

To supplement the existing water supply, the Town is proceeding with an artificial recharge project in the Newmarket Plains Aquifer. The Town has received a Groundwater Discharge Permit (GWP-200111015-N-001) for this project. The project will include the withdrawal of water from the Lamprey Designated River, at a point near the Bennett and Sewall Wells, and then artificially recharge the aquifer. The water withdrawals for the artificial recharge project would occur during periods of high flow and are limited to 500,000 gallons per day (0.77 cfs). A provision in the project's permit is that it can be rescinded or revised if the aquifer recharge activities cause a violation of surface water quality standards. Since the protected instream flows recommended in this report are to be established by the DES and will be considered as water quality standards, the surface water withdrawals must not cause a violation of the protected instream flows.

3. Summary of Public Water Supply Flow Assessment

The Lamprey Designated River represents an important source of water for both the UDWS and the Town of Newmarket Water Works. Under existing New Hampshire law (Chapter 332 Laws of 1965) the towns of Durham and Newmarket have the right to use the waters of the Lamprey River and its tributaries (in their respective borders) for public water supplies.

Provisions in the existing 401 Water Quality Certificate for the UDWS withdrawals from the Lamprey Designated River and the conditions included in the Groundwater Discharge Permit for the Town of Newmarket's artificial recharge water diversion project already establish limitations for the amount of water that can be withdrawn from the Lamprey Designated River. The diversion of water by these public water supplies will be further governed by the proposed protected instream flows for instream fauna as discussed later in this report. The rationale for this recommendation is that in order to maintain and enhance aquatic and fish life along with fish and wildlife habitat (Chapter 483:9-c, Establishment of Protected Instream Flows) sufficient flow must be available in the Lamprey Designated River during specific bioperiods for these protected entities. Whereas, the public water systems would have options to reduce water withdrawals through adaptive management practices (artificial recharge, conservation, development of alternative water sources, off-stream storage, etc.), the instream fauna and their supporting habitat would not. They would potentially be at risk if water withdrawals resulted in flows below the protected instream flow levels.

Water use by the UDWS and the Town of Newmarket Water Works and other Affected Water Users in the Water Management Planning Area (WMPA) will be further evaluated during the development of the Water Management Plan following the establishment of the protected instream flows by the Commissioner of DES. As part of the Water Management Plan, both a Conservation Plan and Water Use Plan will be prepared for both the UDWS and the Town of Newmarket Water Works. In addition, Wiswall Dam, because it is located in the WMPA and since it has an impoundment area greater than 10 acres (30 acres), it is considered a dam affected under the Rules for the Protection of Instream Flow on Designated River (Chapter Env-Ws 1902.02 Affected Dam Owner). Thus, the Town of Durham, as the dam's owner, is an Affected Dam Owner. As part of the Water Management Plan process, the operation of Wiswall Dam will be reviewed and a Dam Management Plan will be prepared.

In the instance that water withdrawals from the Lamprey Designated River are needed to alleviate emergency conditions, Chapter 483 (New Hampshire Rivers Management and Protection Program) includes provisions for this emergency use. Specifically, Chapter 483:9-c states that "*the protected instream flow levels established under this section shall be maintained at all times, except when inflow is less than the protected instream flow level as a result of natural causes or when the commissioner determines that a public water supply emergency exists which affects public health and safety.*" Provisions for the emergency use of water by the UDWS are also included in its existing 401 Water Quality Certificate.

C. Floodplain Transect Methods for Riparian Wildlife and Vegetation

Field studies were conducted during the summer and fall of 2006 and 2007, and though not all listed plant and wildlife protected entities were observed during these field studies, those with some likelihood of being present were kept on the list for further evaluation. High water levels throughout the 2006 growing season complicated the field investigations. Several other natural communities were evaluated that were not identified as Exemplary Natural Communities by the Natural Heritage Bureau, but were considered flow dependent and which supported flow dependent wildlife or RTE plants. All of these communities and plants are located either in the channel or floodplain of the Lamprey Designated River. Riparian plants and communities were evaluated using the Floodplain Transect Method (FTM) as described below. This model also applies to the evaluation of some of the flow dependent wildlife species, as described in Section III (D). Plant names follow Magee and Ahles (1999).

The FTM relates the elevation of plant communities along transects to inundation of these communities at observed flows referenced to the USGS Packers Falls Gaging Station. The necessary frequency and duration of inundation associated with these plant communities under the Natural Flow Paradigm was estimated based on community type descriptions in the literature.

To determine flow requirements for wetland, floodplain, and channel habitats and their associated flora and fauna, four transects (Table 8) across the river floodplain and channel were surveyed. Transects were chosen to overlap with several flow dependent species or communities wherever possible. The boundaries of plant communities and the observed elevation of water at various flows were plotted on the transect cross sections. Water level elevations were correlated with flows recorded at the USGS gaging station at Packers Falls.

Plant community boundaries were transferred to a baseline cover type map developed from aerial photographs obtained for this study. For modeled flow scenarios, the change in habitat suitability area was calculated for a given segment of the river and extrapolated to other relevant reaches. The relative loss or gain of plant community types serves as a measure of impact to the adapted flora and fauna. Where available, habitat suitability data was integrated into the assessment. The steps are as follows:

- Conduct a topographic survey of floodplain, wetland and adjacent river channel along transects.
- Identify primary vegetation types (emergent, floating leaved or submergent) in the wetland plotted along transects.
- Document the elevation of water along the transect habitats simultaneously with gage data documenting flow rates and elevations; including, as possible, seasonal low flow (or as determined by historical data), average, and high flows.
- Use a stage-discharge relationship and topography at each transect to determine profiles of water levels along each cross section at representative flows.
- Estimate the flows associated with water levels at particular habitat elevations that are critical during the life cycles of sensitive flora and fauna such as:
    - Standing water in marshes for emergent, floating-leaved, and submergent plants during growing season low flow.
    - Filling to the elevation of levees and floodplains around oxbow/backwater marshes, swamps, and floodplain pools in spring for plant development and breeding wildlife.
    - Flooding of low and high terrace floodplains at the natural frequency and season to maintain community vigor.
    - Water levels below forested floodplain elevations during turtle and bird nesting seasons.
    - Standing water cover in the channel and backwaters over hibernating turtles.

Table 9 shows the relationship between recorded flows in the Lamprey River at the USGS Packers Falls gaging station and the observed inundation of plant communities in the river channel and adjacent floodplain at the four selected transect locations. Some of the plant communities on Transects 3 and 4 are not adjacent to free-flowing portions of the Lamprey Designated River, and the flow ranges inundating these communities may vary due to dam control. Plant communities, and therefore inundating flows, may overlap in elevation, as hydrology is but one factor that determines plant community distribution. Substrate, disturbance patterns, flow velocity, etc. will also affect distribution.

Though the analyses of flow effects on protected entities may focus on particular transect locations, the floodplain and channel habitats discussed are part of an integrated and shifting mosaic, changed by river processes and beaver activity, with each habitat type important in

Table 8 - Summary of transect information for the Floodplain Transect Method.

Transect	Transect Location	Protected Entities Represented
Transect 1 Tuttle Swamp Outlet	4,000 feet below Wadley Falls at the confluence of the Tuttle Swamp stream and the Lamprey River in Lee.	*Potamogeton nodosus* Swamp White Oak Floodplain High and Low Floodplain Terrace Potential Wood Turtle Habitat
Transect 2 Lee Hook Road Rapids	250 feet downstream of the Lee Hook Road bridge at the northern tip of the channel island in Lee.	Riverweed River Rapid Herbaceous Low Riverbank (High Energy) Low and High Floodplain Terrace
Transect 3 UNH Pump Station Marsh	3,300 feet upstream of Wiswall Dam and 600 feet upstream of the UNH Pump Station in Durham.	Shallow and Deep Marsh Low Floodplain Forest Potential Rare Plant Habitat Wildlife Habitat
Transect 4 Glenmere Village Swamp	500 feet north of Glenmere Village, Tuttle Road in Lee.	Potential Blanding's and Spotted Turtle Habitat; Oxbow Swamp Floodplain Vernal Pool High Floodplain Terrace Wildlife Habitat

Table 9 - Flows associated with observed inundation of community types in the Lamprey Designated River channel and floodplain.

Plant Community* in order by descending elevation	Flow in CFS that begins to Inundate the Community				
	Transect 1	Transect 2	Transect 3 Wiswall Dam	Transect 4 levee/beaver dam	Comments
High Floodplain UPL	>1,200	>1,690	>1,670	>1,670	T1 has a slightly lower high floodplain terrace
Low Floodplain PFO1	520	520	>157<543	520	Elevation differences between plant communities less on T3
PSS1	-	520	157	40	T3 and T4 water held up by dams
PEM1	157	58	47 (Floating)	40	
R2BB	-	58	-	-	

Table 9 (Continued)

Plant Community* in order by descending elevation	Flow in CFS that begins to Inundate the Community				
	Transect 1	Transect 2	Transect 3 Wiswall Dam	Transect 4 levee/beaver dam	Comments
R2EM2	-	-	<10	-	T3 water held by dam
R2AB4	<10	10	<10	-	
R2UB or R2AB2	<10	<10	<10	10	Lowest channel points still inundated at <10 cfs

*Cowardin et al. 1979 Classification:

- UPL – upland
- PFO1 – Palustrine forested wetland, broad-leaved deciduous
- PSS1 – Palustrine scrub-shrub wetland, broad-leaved deciduous
- PEM1 – Palustrine emergent wetland, persistent
- R2BB – Riverine, lower perennial, beach bar
- R2EM2 – Riverine, lower perennial, emergent non-persistent
- R2AB4 – Riverine, lower perennial, aquatic bed, rooted floating-leaved
- R2UB – Riverine, lower perennial, unconsolidated bottom
- R2AB2 – Riverine, lower perennial, aquatic bed, submergent

NOTE: Flow in CFS recorded at USGS Packers Falls gaging station.

the overall landscape for any number of wildlife species at a particular season or life stage. Many wildlife species likely to use floodplain habitats may also need adjacent undeveloped uplands or hydrologically-independent wetlands to sustain their populations. The periods of greatest flow sensitivity for the protected entities have been identified as bioperiods.

The Moat Island area of the Newmarket pool includes deep marsh community, water marigold (*Megalodontia beckii)* habitat, and waterfowl/shorebird habitat, and potential habitats for sedge wren, pied-billed grebe, osprey, and bald eagle. This habitat was created by the impoundment of the Lamprey Designated River and is artificially maintained, and would be much reduced in area or absent, but for the Macallen Dam. Nevertheless, the adapted species are flow-dependent to the extent that water levels are reliant on flow. Aerial photographs taken at various flows throughout the growing season were examined to determine the extent of standing water at important habitats during critical bioperiods for these species: wet meadows for sedge wrens during the nesting season, and open pools of water for the piscivorous raptors from spring through fall. It became apparent that there was very little observable change in water level over the range of flows surveyed by aerial photography (approximately 13 cfs to 264 cfs) due to the impoundment of water by the Macallen Dam. The habitat dependent species (water marigold, sedge wren, and pied-billed grebe) were therefore not assigned PISF values. The eagle and osprey are flow dependent only due to reliance on fish as prey, and therefore the PISF for fish was assigned to them. Table 10 summarizes the protective flows for the protected entities.

Table 10 - Flow-Dependent RTE wildlife, RTE vegetation, and natural/ecological communities on the Lamprey Designated River and their protected instream flows (PISFs).

Protected Entities	Sensitive Bioperiod(s)	General Flow Requirements.	PISF (at Lamprey Gage)
Low Floodplain Forest	Growing season	One to three year flooding (< two yr return flood)	>500 cfs every one to three years for five to 50 days.
High Floodplain Forest (incl. Swamp White Oak *Quercus bicolor*)	Growing season	Two to 100 year flooding (>two-year return flood)	> 1,500 cfs every two to 100 years for five to 30 days.
Oxbow/Backwater Swamp	Growing season	Flooding of backwaters/oxbows	>1,500 cfs every one to five years
Herbaceous Low Riverbank	Winter/spring dormancy	Flood/ice scour of channel	December 1 to April 30 >500 cfs for one week
	Late summer flowering	Low flow to expose substrate	August 1 to September 30 ≤ 60 cfs mean daily flow
Riverweed River Rapid	Spring growth	Flooding of riffles	May 1 to June 30 >100 cfs mean monthly flow
	Late summer flowering	Low flow to expose riffles	August 1 to September 30 < 100 cfs mean monthly flow
Deep and Shallow Marsh	Early-mid growing season	Flooding of marsh for dependent fauna	April 1 to July 31 >10 cfs daily mean flow
Vernal Floodplain Pool	Early spring to mid-summer breeding season	Hydrologic isolation of pools in high floodplain	March 15-July 31 <1,500 cfs every day most years
	Early spring to mid-summer breeding season	Maintain hydrology of river-connected pools in low floodplain	March 15-July 31 No impoundment draw downs > six inches for seven or more consecutive days

Table 10 (Continued)

Protected Entities	Sensitive Bioperiod(s)	General Flow Requirements.	PISF (at Lamprey Gage)
Climbing Hempweed *Mikania scandens*	Spring/summer growing season	Forested wetland hydrology	April 1 to October 31 >500 cfs for 10 days (non-consecutive)
Star Duckweed *Lemna trisulca*	Summer growing season	Maintain standing water or saturation	No PISF[1]
Water Marigold *Megalodonta beckii*	Summer growing season	Maintain standing water or saturation	No PISF[1] Maintain summer water levels within two feet of mean elevation.
Knotty Pondweed *Potamogeton nodosus*	Early summer growth	Maintain flowing water	May 1 to June 30 >100 cfs mean monthly
	Late summer flowering	Low flowing water	August 1 to September 30 <100 cfs mean monthly
Slender Blueflag *Iris prismatica*	Growing season	Maintain wetland hydrology	See requirements for shallow marsh
Sharp-flowered Mannagrass *Glyceria acutiflora*	Growing season	Maintain wetland hydrology	See requirements for herbaceous low riverbank
Blanding's Turtle *Emydoidea blandingii*	Spring-summer nesting period	No flooding of high floodplain nest sites	June 1 to October 31 <1,500 cfs daily flow
Wood Turtle *Clemmys insculpta*	Spring-summer nesting	No flooding during nesting in mid to high floodplain	June 1 to October 15 <500 cfs daily flow
	Winter hibernation	Avoid dewatering of in-channel hibernation sites	December 1 to February 28 >130 cfs seasonal mean >50 cfs daily mean most days

Table 10 (Continued)

Protected Entities	Sensitive Bioperiod(s)	General Flow Requirements.	PISF (at Lamprey Gage)
Spotted Turtle *Clemmys guttata*	Spring-summer nesting	No flooding of high floodplain nest sites	June 1 to October 31 <1,500 cfs daily flow
Osprey *Pandion haliaetus*	Spring-summer nesting-rearing	Sufficient flows to protect prey (fish) in channel	Support prey fisheries (see GRAF Fish recommended flows)
Bald Eagle *Haliaeetus leucocephalus*	Any time of year	Sufficient flows to protect prey (fish) in channel	Support prey fisheries (see GRAF Fish recommended flows)
Pied-billed Grebe *Podilymbus podiceps*	Spring-summer nesting	Maintain water levels during nesting season	No PISF[1]. Maintain summer water levels within two feet of mean elevation.
Sedge Wren *Cistothorus platensis*	Spring-summer nesting	Maintain water levels during nesting season	No PISF[1]. Maintain summer water levels within 18 inches of mean elevation.

1 – These species are dependent on minimal standing water or water levels that are not greatly altered by changes in flow, and therefore, no PISF was assigned to them. They may, however, be vulnerable to rapid or prolonged changes in water levels associated with dam management. See text for more details.

NOTE: PISF referenced to recorded flow of the Lamprey River at the USGS Packers Falls gaging station.

1. Natural Community Flow Requirements

Floodplain Forests

Small portions of higher and lower floodplain forests (Swamp White Oak, Silver Maple, and Red Maple Floodplain Forests) are represented on each of the four transects. Summer flows, when river levels are typically three to eight feet below the floodplain, have little influence on the floodplain community and mesic to saturated conditions prevail. Floodplain forests are dependent on spring floods to provide nutrients and discourage colonization of upland species, so they are considered flow dependent at high flows. Reduction in spring floods over long periods or increases in flooding intensity or duration may alter the plant community. Modeling the effects of dam impoundment on floodplains, Nislow et al. (2002) found that dams decreased the frequency of flooding in the higher floodplain terraces particularly on the upper Connecticut River.

The elevation of water expected to flood the two floodplain forest types on each transect was determined through the Floodplain Transect Method. The 100-year return event (8,560 cfs) occurred in May 2006 and all transects, including high and low floodplain forests, were completely submerged and inaccessible during this event. Therefore, this elevation does not appear on the transect figures.

The lowest observed flow which resulted in partial flooding of the low silver maple and swamp white oak/red maple floodplain forests was between approximately 150 and 500 cfs along Transect 3. This transect is above the Wiswall Dam, which keeps water levels artificially high. On free-flowing portions of the Lamprey Designated River, the low terrace floodplain forest typically begins to flood at about 500 cfs. Mean monthly flows in the Lamprey River over the 73 years of record typically exceed 500 cfs in March and April, and therefore, the low floodplain typically floods every year. Review of the daily data for three dry years (1965, 1985, 2002) indicates that flows above 500 cfs typically last no more than one week in duration, but occur several times, though generally not during the growing season (May through October). In wet years (e.g. 1938, 1984, 2006), growing season flows above 500 cfs occur for one to four weeks duration several times in a year, including the growing season, and for shorter durations also.

Flows of 1,200 to 1,600 cfs (averaged to about 1,500 cfs) were associated with observed flooding in the lower portions of the higher terrace floodplain forests. This flow is well above the seasonal mean in almost all years of record (three exceptions), but does occur for a week at a time during most normal and wet years. For example, flows of 1,500 cfs or higher were recorded for at least five consecutive days in each of the last five years. The two-year return event for the Lamprey River is given as 2,170 cfs (Olson 2007). Low portions of the high terrace may therefore flood at intervals of less than two years, but higher portions of the floodplain flood much less frequently.

Flows that are protective of low floodplain forests along the Lamprey Designated River are high flows >500 cfs every one to three years for five to 50 consecutive days. For high floodplains, the protective flows would be > 1,500 cfs for five to 30 days during the growing season. These stream flow levels are typically associated with spring flood events, which are unlikely to be greatly reduced under most river management scenarios, nor is there any capacity to create or increase the frequency of such a flooding event given the water management infrastructure in place. Therefore, there will be no management recommendations associated with the high floodplain forest. The loss of floodplain habitat associated with loss of flood flows would be slow, but could eventually affect 1,200 acres. There are no minimum flow requirements for floodplain forest communities during low flow seasons, as they are hydrologically supported by precipitation or groundwater when river levels are low, as are upland forests above the floodplain.

Seasonally Flooded Red Maple Oxbow Swamp

These wetlands are not dependent on river flow during low and median flows, since water enters from other (stream and groundwater) sources, and is detained and perched above the river levels by constricted outlets in the sand levee. The outlet elevations were not surveyed, and are subject to frequent alteration from beaver activity and sand deposition on the levee. However, these old oxbow wetlands are within the floodplain, and therefore subject to flooding. During the 100-year return flood event in May 2006 the entire floodplain along Transect 4 was flooded (observed May 16, 2006 at 8,400 cfs). The levees and upland floodplain communities were not observed to flood when flow in the Lamprey River was 1,620 cfs, but all floodplain wetlands and vernal pools were inundated and flow may have occurred into the complex from the river through one or more of the outlets (levee breaks) and also from a rise in the regional groundwater levels. At 220 cfs, water levels in the Lamprey Designated River were six feet below the river bank and three feet below the water levels in the swamp, and the swamp was draining to the river. At a flow of 10 cfs, the river was eight feet below the top of the bank, only the deepest channels in the oxbows were inundated (and still supporting fish), and most surface flow out of the swamp had ceased.

This dynamic wetland complex is subject to periodic flooding associated with high flows in the Lamprey River. This periodic flooding likely influences vegetation composition, wildlife habitat, and flood flow alteration functions of the wetland. However, because the outlet elevations are subject to frequent alteration, a flood flow protective of this resource is difficult to determine. Other sources of water influencing the wetland hydrology include groundwater, intermittent streams, and residual flood waters impounded by beaver dams. This wetland complex is located in a free-flowing reach of the Lamprey, and is not influenced by a downstream dam, but it may be affected by flows resulting from management of the dams in the watershed upstream. This resource should be adequately protected by the frequent small flood events (one to five-year return) that allow the normal floodplain flooding (>1,500 cfs every one to five years). Even with the loss of these flood events, changes in composition of the community might be slow and modest given the alternate sources of hydrology.

Herbaceous Low Riverbank

This herbaceous community is dependent on ice scour and relatively high-velocity spring flow to prevent the accumulation of organic material, fine sediment and successional woody plants along the channel margins. Since the community is found within the bankfull channel, it is assumed that annual flooding and scour is required for this community. On Transect 2 where this community is represented, flows of approximately 500 cfs resulted in flooding most of the herbaceous, rocky shore of the island. Flows in the range should occur for several days annually during winter and spring (December to April) to maintain this community. Based on 73 years of record, mean monthly discharge in March and April exceeds 500 cfs. The daily mean discharge exceeds 520 cfs for about 40 days from mid-March through late April. Flows of approximately 58 cfs coincided with the lower elevation of this community. The mean low summer flow over this time frame is approximately 70 cfs.

The community is less dependent on summer low flows, as the plant assemblage would respond to modest, short- and long-term water level changes with shifting dominance of species based on their hydrologic adaptations. Low summer flows are necessary for plant flowering and seed production, so this community would be sensitive to prolonged flooding during the summer months. Prolonged reduction in low summer flows (for one or more years) may actually extend the Herbaceous Low Riverbank community further into the channel, with a shift of dominance at the highest elevations toward mesic species, but not necessarily a loss of habitat, as all portions would still be within the three-foot elevational range of the community. Lowering of both summer low flows *and* winter or spring floods would reduce the areal extent of this plant community.

Riverweed River Rapid

Riverweed and associated plants in the Riverweed River Rapid Community have peak development in spring and early summer when water levels are high; then they flower, fruit, and die back in late summer and fall when their rocky substrate is exposed by declining water levels (Sperduto and Crow 1994). It is predictable that riverweeds are adversely affected by factors that influence the seasonality of the water level, attachment to solid substrata, and light availability. Such factors could include flooding from dam building, sedimentation, and nutrient pollution, which leads to increased algae and decreased light availability (Philbrick ND).

Maintenance of sufficient flow to submerge the rocky channel substrate is necessary for most of the year through early summer (July) and lower flows are necessary during the latter part of the growing season for reproduction. Prolonged exposure to air and sun in winter or early in the growing season (May through July) could adversely affect plant growth and development and prolonged flooding late in the season (August through September) could adversely affect reproduction, although riverweed can reproduce vegetatively.

In the Lamprey River, mean monthly flow in May, June, and July is 371, 206, and 94 cfs respectively, and in August and September the mean is approximately 70 cfs. However, there is considerable variation in monthly flow in any given year. For example, mean September flows varied from 3.8 cfs in 1995 to 650 cfs in 1954. During the field visits, it was observed that all rock surfaces upon which riverweed was growing were submerged at flows above 100 cfs, and approximately 40-50 percent of the rocks supporting riverweed along Transect 2 were exposed at flows of 10 cfs. Based on these observations, mean monthly flow of approximately 100 cfs should be exceeded in May and June, with daily flow remaining naturally variable but not falling below 10 cfs for more than five consecutive days. In August and September, mean monthly flow should not be artificially raised above 100 cfs and daily flows should not be artificially raised above 70 cfs for more than five consecutive days. Assuming that the Lamprey River averages 75 feet wide, there is an estimated 10 to 15 acres of potential riverweed community in the designated river.

Deep and Shallow Marsh

Changes in river water levels would affect primarily those wetlands with direct and unrestricted surface water connections to the river and would have the most immediate effect on marsh-dependent animals. The magnitude of the impact would depend, in part, on the elevation of the marsh relative to the river channel, the constriction of the surface water connection, the season and duration of water level change, the rate of the water level change, and the frequency of water level fluctuations.

The results of a rapid decline in water levels on marsh biota were observed during the Wiswall Dam inspection in mid-April 2006. The Wiswall Dam gates were opened on the morning of April 10th. While the water appeared to be approximately 6 to 12 inches below the dam spillway, shallow marsh communities were already drained, and only narrow channels of water remained in the deep marsh channel. Water was still draining out of the unconstricted outlet. While wetland plants were not harmed by the short-term event, fish and amphibians were stranded in mud by the rapid drop of the water surface. Mussels were present on the exposed river shoreline, and beaver and muskrat bank burrow entrance holes were exposed. When the water was approximately 18 inches below the spillway, water, invertebrates, and amphibians were flowing out of a backwater marsh near Transect 3, including: adult red-spotted newts, bullfrog or greenfrog tadpoles, various odonate larvae, caddisfly larvae, small fish, crayfish, diving beetles, water scorpions, and others. These animals lost their cover and habitat and became available to predators in the river channel.

The following general long-term conditions were considered necessary to maintain the current quantity and distribution of marsh vegetation and dependent aquatic life in the deep and shallow marshes assuming the existing dams in place:

- High spring water levels to fill the marshes (minimum of 50 cfs for wetlands with direct connections).
- Standing water April through July in deep marshes and standing water and/or soil saturation April through July in shallow marshes (>10 cfs at least one day every week).
- Avoidance of rapid water elevation declines of >six inches from April 1 through June 30 (regardless of flow).

Prolonged decreases in water levels on the magnitude of six inches or more associated with a permanent reduction in impoundment levels may result in a shift of wetland cover types, with deep marshes becoming shallow marsh, shallow marsh becoming shrub or forested swamps, and forested swamps becoming uplands. Increases in impoundment levels would shift the communities the other way.

The potential shifts in cover type areas associated with reduced impoundment water levels at Wiswall Dam were calculated from the communities along Transect 3 and extrapolated to the rest of the impoundment using wetland mapping from the photogrammetric study:

- Deep marsh conversion to shallow marsh: 0.5 acres (0.21 ha)
- Shallow marsh conversion to shrub/forested wetland: 1.25 acres (0.50 ha)
- Shrub/forested wetland converted to upland: 1.35 acres shrub/7.75 acres forested (0.54/3.1 ha)

Limitations to the accuracy of this assessment include:

- Each marsh has a unique river connection and landscape position that may make it more or less flow dependent than the evaluated marshes and changes would be expressed differently at each particular location.
- Small wetland vegetation increases in shallow channel margins may partially offset losses.

Vernal Floodplain Pool

Most vernal pools will fill with water during years with normal precipitation patterns, assuming there is not a residual water deficit (Brooks 2004). Floodwaters may contribute water in fall, winter, or spring. However, flooding during the breeding season (April through July) could wash away vernal pool species and/or introduce predatory fish. Ideally, the pools will remain isolated from river flow during the egg and larval stage of obligate amphibians during most years. This would require water levels to remain below the floodplain flood stage. Species like spotted salamanders (*Ambystoma maculata*) may not breed every year (Degraaf and Yamasaki 2001). Summer flows below 1,500 cfs from mid-March through July would be necessary to maintain annual vernal pool breeding success in the high floodplains. Although management of naturally occurring floodwaters during this period is not being suggested, nor should flow management that results in flooding during this period be considered without also considering the potential effects on vernal pool breeding species. Water levels should also not be lowered by six inches or more in dam impoundments during this period for more than one week duration. Even slow rates of water level decline may expose salamander egg masses, as they are typically anchored to twigs and may therefore be suspended as water level drop.

2. Rare, Threatened, and Endangered Plant Flow Requirements

Climbing Hempweed *(Mikania scandens)*

Climbing Hempweed was considered dependent on high flows (100-year flood). This flow on the Lamprey is approximately 8,560 cfs. In the event that this plant is also an inhabitant of wetlands directly on the Lamprey, then flows sufficient to support forested wetlands on the low floodplain, as defined by the US Army Corps of Engineers (Environmental Laboratory 1987) will be protective of this plant. That would be 500-1,500 cfs for at least 5 percent of the growing season (approximately 10 days) in most years (>50 percent of the years).

Star Duckweed *(Lemna trisulca)*

Only prolonged desiccation of a river or tributary impoundment would be detrimental to star duckweed, an event that is unlikely under any flow regime, even extreme low flow, except in the case of dam removal. Therefore, no protective flow was assigned to this species, only a protective low water level of 0 to 0.5 feet in areas where duckweed can be found.

Water Marigold *(Megalodonta beckii)*

Prolonged and significant reductions in water levels within man-made impoundments would need to occur before adverse effects on water marigold result. Due to the size and volume of impoundments, water level changes associated with weather events tend to be minor and reductions in water levels substantial enough to affect water marigold would be associated only with an event that eliminated standing water in the deep marsh habitat (a three-foot or greater reduction in water levels) for a prolonged period (one or more growing seasons).

Knotty Pondweed ***(Potamogeton nodosus)***

Water flows that are protective of the Riverweed River Rapid community should be protective of knotty pondweed. Mean monthly flow of approximately 100 cfs should be exceeded in May and June, with daily flow remaining naturally variable but not falling below 10 cfs for more than five consecutive days. In August and September, mean monthly flow should not be artificially raised above 100 cfs and daily flows should not be artificially raised above 70 cfs for more than five consecutive days.

Slender Blueflag ***(Iris prismatica)***

As an obligate wetland plant, slender blueflag would require saturated soils throughout the growing season and would be adapted to shallow flooding. Meeting protected flow requirements for the shallow marsh (Section IV (C)) would be protective of slender blueflag. This flow is > 10 cfs mean daily flow during the early and middle growing season.

Sharp-flowered Mannagrass ***(Glyceria acutiflora)***

Flows that are protective of the Herbaceous Low Riverbank community would be protective of sharp-flowered mannagrass. This flow is at least 500 cfs early in the growing season and a daily mean of 60 cfs or less most days late in the growing season.

3. Rare, Threatened, and Endangered Wildlife Flow Requirements

Blanding's Turtle (*Emydoidea blandingii*)

Water level changes assumed to be adverse to Blanding's Turtle are:

- Release of water in June, July, August or September that floods turtle nests in the high floodplain.

The median daily stream flow curve for the Lamprey River based on 73 years of data indicates that water levels are typically lowest in August through September, gradually rising in October and November and remaining fairly stable until rising in March through April. Deviations from the norm have occurred.

Based on observations, flows of about 1,500 cfs begin flood the upland floodplain terraces that may contain turtle nests. Since the mean daily stream flow in the River for 73 years of record is less than 300 cfs during this period, only an infrequent storm event, dam failure, or planned release would likely cause such a flow. Mean flow in June of 1998 reached 1,117 and exceeded 500 cfs in July and August of 1938, June of 1982, and June of 2006. During these months, flow above 1,500 may have occurred for several consecutive days or weeks. Although the duration of inundation that causes egg mortality is not known, deliberate management practices that result in daily flow above 1,500 cfs during June through October should be avoided or minimized. Natural flood events may still occur, with no expected management to control such flows.

Wood Turtle ***(Clemmys insculpta)***

Water level changes (aside from those created by new dam construction) assumed to be adverse to wood turtles are:

- Low winter flows (Dec – Feb) that drop below the November levels, potentially exposing hibernating turtles in stream banks or pools; and/or

- Release of water in June, July, August or September that floods turtle nests in the low and high floodplain.

Low Winter Flows

The median daily stream flow curve for the Lamprey River, based on 73 years of data, indicates that water levels are typically lowest in August and September, gradually rising in October and November and remaining fairly stable until rising in March through April. If it is assumed that most wood turtle hibernacula are below the elevation inundated by the mean November flow (264 cfs), when wood turtles typically enter hibernation, then the years in which flow drops significantly below this level in December, January or February could put wood turtles at risk for exposure and freezing in their hibernacula. A review of monthly mean stream flow over this 73-year data set indicates that mean December flows were lower than mean November flows in 20 of 72 years, with six of those years (8 percent of total years of record) having mean December flow significantly (>50 percent) lower than the mean monthly November discharge of 264 cfs. In most cases, flows then rose in January. Since wood turtles are known to inhabit the Lamprey and its tributaries, it is assumed that this population of long-lived reptiles has adapted to some level of periodic low flows in winter.

In winter of 1948-49, flows were below mean monthly November flows by 66 percent to 92 percent from October through January. In such a case, it is possible that turtles selected channel bottom hibernacula that were submerged in the fall and remained so through the winter. However, in the case of the winter of 1943-44, flows were near average in November, but then dropped 53 percent to 83 percent below average in December through February, potentially leaving wood turtles exposed to freezing conditions. Several factors might ameliorate the danger in such a situation, including very short duration of low flow; concurrent high air temperatures allowing turtles to survive exposure; gradual decrease in flow potentially allowing turtles time to respond and move to different hibernacula; and use of hibernation sites in the tributary streams, rather than in the Lamprey channel.

An accurate determination of protective flows for the wood turtle would require mapping of hibernacula locations and turtle movements through radio-telemetry (well beyond this study). A protective flow should also be one relative to flow associated with the onset of hibernation for that winter and include correlations with air temperatures. This is not easily accommodated in a Water Management Plan, which should be straightforward to apply on a daily basis. Therefore, a simple estimate of protective flow for the wood turtle, based on observations and the historical flow record was established. It was observed that in free-flowing portions of the river associated with Transect 1, flows below 300 cfs exposed undercut banks, and flows below 50 cfs exposed river banks almost completely, but retained good cover in channel pools. Low winter flows that fall within this range would retain complete inundation of channel pools, as well as at least partial bank cover, and therefore protect some hibernacula for wood turtles, and would be met in most (but not all) winters under the natural flow paradigm. For simplicity, a seasonal mean flow of 130 cfs or more in December, January, and February (50 percent of the mean monthly November flow) and a daily low flow that does not drop below 50 cfs for more than one consecutive day during this period was established for the protection of wood turtles.

High Summer Flows

Based on observations, flows of approximately 500 cfs are just contained within the river channel, and the forested floodplains and higher sandbars remain exposed. Partial flooding of the low floodplain occurs with flows above 500 cfs in some locations, and if such flows occur in June, July, August, September, or early October, there is the potential to flood turtle nests. Since the mean daily and mean monthly stream flow in the River for 73 years of record is less than 300 cfs during this period, only an infrequent storm event, dam failure, or planned release would likely cause such a flow. Management activities, such as a dam release, that result in flows above 500 cfs should be avoided during June through mid-October.

Spotted Turtle *(Clemmys guttata)*

As with Blanding's turtles, the known spotted turtle habitats in the Lamprey floodplain are backwater swamps with beaver activity and tributary streams, as well as floodplain vernal pools that may or may not be dependent on Lamprey River low flows in summer and winter. Water level changes that are assumed to be adverse to spotted turtles are:

- Release of water in June, July, August, or September that floods turtle nests in the high floodplain.

The median daily stream flow curve for the Lamprey River based on 73 years of data indicates that water levels are typically lowest in August through September, gradually rising in October and November, and remaining fairly stable until rising in March through April. Deviations from the norm have occurred.

Based on observations, flows of about 1,500 cfs begin to flood the upland floodplain terraces that may contain turtle nests. Since the mean daily stream flow in the River for 73 years of record is less than 300 cfs during this period, only an infrequent storm event, dam failure, or planned release would likely cause such a flow. Mean flow in June of 1998 reached 1,117, and exceeded 500 cfs in July and August of 1938, June of 1982, and June of 2006. During these months, flow above 1,500 may have occurred for several consecutive days or weeks during these months. Although the duration of inundation that causes egg mortality is not known, deliberate management activities that cause daily flow above 1,500 cfs during June through October should consider the potential effects on turtle nests.

Osprey *(Pandion haliaetus)*

Flows that are protective of a healthy fish community will be protective of this species, so the PISF for GRAF fish (see Section IV (D) (18)) as determined through the MesoHABSIM model was interpreted for osprey.

Bald Eagle (*Haliaeetus leucocephalus)*

Flows that are protective of a healthy fish community will be protective of this species, so the PISF for GRAF fish (see Section IV (D) (18)) as determined through the MesoHABSIM model was interpreted for the bald eagle

Sedge Wren *(Cistothorus platensis)*

Based on a review of aerial photographs taken at the following flows, it appears that water levels in the Moat Island portion of the designated reach vary minimally under the flow range. The wetlands adjacent to this part of the Newmarket Pool are also influenced by several tributary streams, which further reduce the effect of Lamprey flow on impoundment water levels. A permanent or prolonged drop in summer water levels of 18 inches or more would likely convert wet meadow habitat to upland habitat and reduce potential habitat for sedge wren in this area. However, given that no sedge wrens have been observed in this area, actual impacts to the species is unlikely

Pied-billed Grebe (Podolymbus podiceps)

Despite the apparent absence of grebes in the Lamprey Designated River, flow changes that alter shallow and deep marsh habitats would affect deep and shallow marsh habitat. The aerial photo modeling approach was used to identify water level variations associated with flows in the Moat Island impoundment. The results of this analysis indicate that water levels in this large basin vary very little with changes in flow of 250 cfs during the growing season. Therefore, only a substantial modification of the water levels (a two to three-foot reduction) that might occur with a drawdown or permanent change in spillway height would alter shallow and deep marshes to an extent that potentially dependent wildlife, such as pied-billed grebes, would be affected.

D. MesoHABSIM Incremental Flow Model for Aquatic Life and Fish

The next step of this study is to define how much habitat is available to support the fauna and how instream flow influences habitat availability. A computer model of fish habitat conditions relative to flow, MesoHABSIM, was developed for this purpose (Parasiewicz 2001, 2007a and b, 2008a and b). The model evaluates the physical settings of the river channel at a number of flows in terms of suitability for selected fish and invertebrates.

For the model, the study area is divided into spatial units (called hydromorphologic units or HMUs) that are at the scale at which biota react to their environments (e.g. pools or riffles). Within each unit the arrangement of physical attributes such as flow velocity, water depth, substrate, and cover are noted at different flows. The habitat suitability functions developed from fish observations at several rivers are applied to determine the value of each unit in terms of habitat availability. The area of units with high habitat value are then summarized over the entire study area and used as a metric for habitat availability. In order to complete the habitat mapping the entire study area is divided to self-similar sections and each section is represented by representative site, which is mapped five times.

1. Study Areas of the Lamprey Designated River

The Lamprey Designated River provides several different types of habitat throughout its 19.4 km (12.05 mi) length. For this study, the Lamprey Designated River was divided into sections based on similarity of features (Figure 7). A representative site was then selected in each section for habitat mapping and evaluated under the MesoHABSIM method.

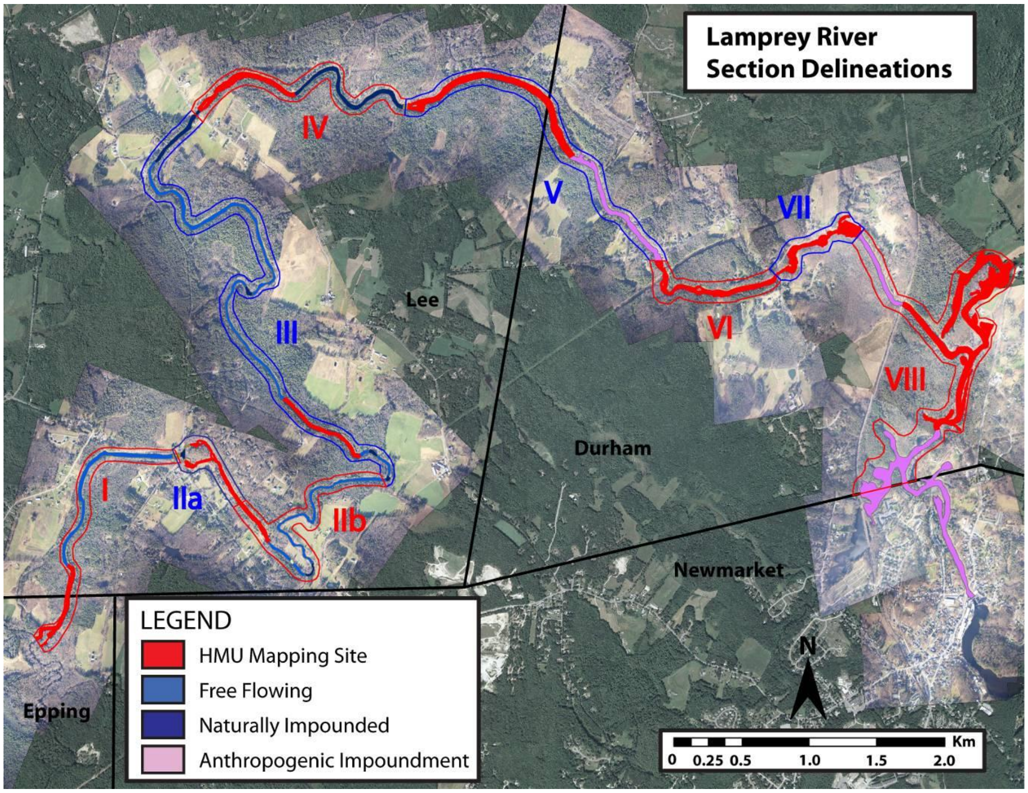

Figure 7 - Map of Lamprey Designated River study area.

2. River Sections and Representative Sites

The river was divided into eight sections using changes in gradient, hydromorphologic assemblages, and cover attributes, which are described below. By prioritizing the mapping to the higher gradient, and thus dynamically changing, portions of the river, the majority of changing HMU assemblages on the designated river were captured. During the reconnaissance survey almost no riffles, ruffles, or rapids were observed outside of these areas. The stepped nature of the Lamprey Designated River between these high-gradient sections made for natural divisions between the areas of interest, where slower moving and impounded areas could be sampled as well.

Representative sites (hydromorphologic unit mapping sites) were then selected in each of these sections for habitat mapping surveys. The habitat mappings conducted in each of the representative sites divides each section of river into meso-scale components based on the morphological character of the river and the physical attributes within them. The MesoHABSIM method uses 11 categories of riverine habitat, which are based on the structure of the channel and the distribution of flow, called hydromorphological units (see Appendix 7). Within every HMU, a record of the presence, absence, or abundance of cover type and choriotop (substrate) features is determined and later applied to develop habitat suitability for that unit. For choriotop and cover type definitions see Appendix 7.

In two cases the representative site includes nearly the total length of that section. The many natural and human-made impoundments--approximately 45 percent of the Lamprey Designated River is impounded-- made the selection of representative sites more difficult. The higher gradient portions of the river sections were included in order to model the reaches most sensitive to flow. Adjacent portions of the naturally or human-made impoundments were included in the representative sites to assess the slack water conditions which exist in the many impounded areas.

A mapping site (site 8) was added after the completion of field mapping to characterize the largest impoundment in the study reach created by the Macallen Dam. During the field surveys and subsequent analysis, it was determined that there was a significant change in the character of Section II between the upstream portion near Wadleigh Falls and the reach near and downstream of the 180° bend in the river. This led to the division of this section into two subsections. The upstream portion of Section II contained a wide variety of hydromorphological unit type and represented an area of relatively high gradient. This reach became Section IIa. The lower portion of the section transitioned into a low gradient slow stream with higher impacts from bank erosion and less diversity in hydromorphological types. This reach became Section IIb. This division proved to be necessary since Section IIb represents habitat which were not observed often in the other sections and marked an area of transition between Sections IIa and III.

In Figure 7, the Lamprey Designated River is divided into sections outlined in alternating red and blue lines. Representative mapping sites within each section are highlighted in red. Of the reaches not included in the representative sites, the free-flowing river reaches are shown highlighted in light blue, naturally impounded reaches in dark blue and dam impounded reaches in purple.

Section I

Section I (length 2.18 km (1.35 mi)) begins 400 m (0.25 mi) upstream of the start of the designated reach where the North River enters the Lamprey River and ends at the Route 152 Bridge just upstream of Wadleigh Falls. The proximity of a significant tributary so close to the town boundary and the official start of the Lamprey Designated River made for a definitive and more natural upstream boundary for the study. This section can be characterized as a free-flowing, but slow-moving section of river. It is dominated by slow runs and pool hydromorphological units (for definitions of hydromorphologic units see Appendix 7) and includes the most extensive backwater complex in the free-flowing portions of the study reach. Choriotops are mostly psammal, but there are sections of mesolithal and some gigalithal. Canopy ranges from extremely dense at the upstream end of the section to simply present at the downstream end. Where the Lamprey Designated River makes a bend and comes close to Riverside Farm Drive and Rt. 152 the steep hills recede from the river's edge and a low-lying flood plain opens up on both sides of the river. In this same area, there is an increase in human uses along the river with many clearings associated with house lots and a substantial campground (Wadleigh Falls). The section ends with a small ruffle area associated with the split flow around a small island and support caisson for the Rt. 152, Wadleigh Falls Bridge.

Representative Site 1

This representative site (length 702 m (0.44 mi)) begins at the North River confluence upstream of the start of the Lamprey Designated River. This upper portion of the site begins with a deep run that has abundant canopy cover and extraordinary amounts of woody structure in the stream. Even disregarding areas with downed trees and their associated snares, this upper section contains a much higher percentage of woody structures than seen anywhere else in the river. Rounding the bend 200 m (0.12 mi) downstream from the North River is an unexpectedly deep backwater complex of three pools connected by narrow channels. Judging by the depth (often exceeding 2.5 m (8.2 ft)), these pool areas may be the result of an abandoned channel and therefore provide a slightly different habitat than expected in most other backwaters. Most of the remainder of the site is characterized as a slow run under most flow conditions and travels through mostly undisturbed mixed forests with steep sloping banks. The representative site ends at a small riffle formed on bedrock ledge. The ledge acts as a flow restriction which creates the slow upstream runs. This 15 m (49.2 ft) riffle is the only turbulent flowing habitat until the Rt. 152 Bridge at the end of the Section I.

Section IIa

Section IIa (length 750 m (0.47 mi)) begins at the Rt. 152 Bridge just upstream of Wadleigh Falls. The river splits at a breached dam at Wadleigh Falls, creating a large island that dominates the site and then rejoins approximately 400 m (0.25 mi) further downstream. The section includes dynamic flow conditions, especially in the vicinity of this island, and as a result, it contains a variety of habitat types. Because of its dynamic character and diverse habitat nearly all of the section was mapped. The banks are moderate to steeply-sloped and are largely forested in the upper portion of the section. In the lower portion the banks are still moderately steep, but the floodplain terrace is much closer to the river and the canopy is not as dense. There is some cleared land along the right arm of the split's right bank above the entrenched river channel. Substrates are widely varied throughout this section but are mostly composed of sand to mesolithal sized materials.

Representative Site 2a

This representative site (length 641 m (0.40 mi)) begins about 75m (250 ft) downstream of the Route 152 Bridge just below the breached dam and includes both branches of the split flow. On the right branch the river spills though a narrow gap in the breached dam and collects in a large pool. The pool shallows at its downstream end and the river continues for approximately 150 m (492 ft) as alternating riffle/glide units before converging with the left branch. This area is relatively high gradient for the Lamprey Designated River and typically has embedded mesolithal substrate, moderate canopy cover, and eroded banks. The left branch of the Lamprey around this island receives less than half of the river's flow under most observed conditions. This branch is narrower, has a higher degree of canopy shading and contains two well-established sidearms. The hydromorphological units alternate between riffles and pools, but there are also units of runs, and at higher flows ruffle. Substrates in this branch tend to be of slightly smaller size than the right branch and range between pelal and mesolithal.

Downstream of the confluence of these branches the study site continues for another 400 m (0.25 mi) with generally longer units than were present upstream which alternate between runs, riffles, and glides. The riffles typically have larger substrates comprised of macrolithal and megalithal, while the runs and glides are typically mesolithal and psammal. The site ends downstream of the last riffle in the section (under most flow conditions) which is the last unit of turbulent water until Lee Hook Road 7 km (4.34 mi) downstream.

Section IIb

This section (length 2370 m (1.47 mi)) begins immediately downstream of the riffle that marks the end of Section IIa. The river at this point slows and shallows and continues mostly as runs and glides with occasional deeper areas that could be considered pools. The substrate of this section is dominantly psammal. This section shows the greatest impact of farming in the designated reach. In several locations along this stretch fields extend up to the river banks with only a narrow wooded corridor if any. The areas where this corridor is absent show the greatest impacts of the recent flooding that occurred throughout the study period. The steep silt and clay banks are punctuated with rotational slumps. Large trees have fallen into and across the river, further eroding the adjacent banks and river bed. There is almost no visible housing in this section and those that can be seen through the fields are at a great distance from the river. Canopy cover varies from absent in some of the areas adjacent to fields to abundant where the forest is intact. The section ends at a pool where the river begins to deepen and slow approximately 350 m (0.22 mi) upstream of the representative site for Section 3.

Representative Site 2b

This representative site (length 335 m (0.21 mi)) begins at the beginning of the section and continues 335 m (0.21 mi) downstream ending at the downstream end of a field on the right bank which is approximately 400 m (0.25 mi) upstream of the confluence of Tuttle Swamp Creek. The site is made up of runs and glides and was chosen to represent a section of the Lamprey Designated River that appears to be the most impacted by farming and erosion. Choriotops throughout the site range mostly between psammal and akal. Canopy cover is present in most locations, except where fields periodically intersect the river corridor.

Section III

Section III (length 4700 m (2.92 mi)) is the longest of the study sections on the Lamprey Designated River. The section begins at the first pool associated with the downstream end of Section 2b and meanders its way to the Lee Hook Road Bridge. This section is disproportionately long in comparison to the others because of its' homogeneous nature. The section is dominated by one long slow-moving run with almost no turbulent sections, except for small riffles and upwelling associated with bedrock ledges and an old oxen crossing. There are several small backwaters throughout the section, but very little other variation. The section is almost entirely unpopulated and is largely forested, only clearing briefly in the middle of the section and at Lee Hook Road. At the clearing in the middle of the section there is an increase in bank erosion similar to what has occurred in Section 2b. The section has moderate to high canopy cover, psammal to mesolithal choriotops, and passes over several bedrock ledges. There are two or three large tree snares which completely cross the river in some cases. The section ends in a small riffle at the upstream end of the Lee Hook Road Bridge.

Representative Site 3

The representative site (length 751 m (0.47 mi)) for this section begins 350 m (0.22 mi) downstream of the beginning of Section III and includes an area with a small pool and a long run with varying substrate conditions. Choriotops range from psammal to macrolithal and canopy is present throughout the site. The banks in the site are generally low but nearly vertical in some location with a broad floodplain terrace throughout the study site. The site ends just downstream of a small wetland area on the right bank.

Section IV

Section IV (length 2090 m (1.30 mi)) begins at the Lee Hook Road Bridge and continues downstream to just upstream of Hook Island. Approximately 75 percent of this section is a slow run or pool, naturally impounded by the island at the end of the section. The upper portion of the section however is much more dynamic and includes several different types of habitat units. The section begins at the Lee Hook Road Bridge where there is a small pool with bedrock substrate and riprap from the bridge caisson. Within 40 m (131.2 ft) of the bridge, the pool shallows just upstream of a small island where the flow is briefly split. At most flows, both arms of the river around this island are rapids or ruffles and the gradient is fairly steep over this small area. At extreme low flows there is a sequence of riffles and ruffles here. The split flow merges again at the bottom of the island and narrows briefly before losing velocity in a wide and shallow glide. After approximately 200 meters (0.12 mi) the glide deepens into a slow run/pool which carries throughout the rest of the section. Canopy cover consisting of mixed forests is generally present, but not abundant in this section. Choriotops vary from psammal to gigalithal in the upper portion of the section and gradually transitions to pelal/sapropel further downstream. The river banks are moderately steep here and the river is well below the gently sloping flood plain. There are several houses and two campgrounds (Ferndale and Wellington) on this section. The section ends 20 m (65.6 ft) upstream of Hook Island where the river shallows due to exposed bedrock.

Representative Site 4

This representative site (length 842 m (0.52 mi)) for Section IV begins downstream of the pool below the Lee Hook Road Bridge and just upstream of the island located there. A complicated mosaic of habitat units surrounding the island at low flows quickly transitions from a ruffle to a rapid as flow increases. Downstream of the island the river widens and a long shallow glide is present. This glide gradually becomes a slow, and often deep, run which continues without interruption for the remainder of the site's length. A range of choriotops between pelal and gigalithal are present in the representative site. Canopy cover is present in most habitat units with the exception of the large glide that is largely un-shaded. The site ends at a large beach associated with the Ferndale Acres Campground on the left bank of the river.

Section V

Section V (length 2690 m (1.67 mi)) begins 20 m (65.6 ft) upstream of Hook Island. The combination of the island itself and the exposed bedrock that surrounds it results in a small gradient change in the river here and the section and study site begins as a rapid with split flow around the island. The substrate here is mostly gigalithal and megalithal with smaller, loose fragments occasionally resting on top. The turbulent water throughout this unit is limited to the 75 m (246 ft) adjacent to the island.

Immediately downstream of the island the river more than doubles in width to nearly 90 m (295.3 ft) and the velocity gained in the rapid above is lost in a large pool. The pool is up to 3 m (9.8 ft) deep in places and its substrate ranges from peal and psammal to macrolithal. There is some shading along the right bank, but is otherwise open canopy. This reach hosts an abundant population of mussels.

At the downstream end of the unit the river returns to a narrower width and continues throughout the rest of the section as a slow, impounded run. The substrate is a combination of psammal to mesolithal sized pieces but slowly transitions over the next 1 km (0.62 mi) to a pelal/sapropel substrate. This is likely the result of organic deposition overlying the original riverbed which is now impounded by the Wiswall Dam.

The final 1 km (0.62 mi) of river is a deep slow moving pool often in excess of 4 m (13 ft) deep in the Wiswall Dam impoundment. This reach has many wetland fringe areas of various sizes which continue past the Wiswall Road Bridge ending at the Wiswall Dam. The UNH pumping station is in this reach approximately 830 m (0.52 mi) upstream of the dam.

Representative Site 5

Representative Site 5 (length 1602 m (1.0 mi)) begins at the start of the section and includes the turbulent area around the island. The site continues downstream with the large/deep pool below the island and includes approximately 1450 meters (0.90 mi) of impounded river. Choriotops above and around the island are mostly gigalithal and megalithal with meso- to megalithal fragments resting on top. The choriotops in the pool downstream of the island range from pelal to megalithal. For the remainder of the representative site, choriotops range from pelal to mesolithal with grain size generally decreasing downstream. The site has varying degrees of canopy cover, but it is rarely abundant because of the width of the river in this section. The site ends 50 m (165 ft) upstream of the large backwater wetland associated with the Wiswall Dam impoundment.

Section VI

Section VI (length 1130 m (0.70 mi)) begins at Wiswall Dam and continues downstream to the end of the pool upstream of the Packers Falls Road Bridge. The site begins below the dam as a rapid under most flow conditions which then splits around a small island and narrows from approximately 50 m (164 ft) at the dam's face to less than 10 m (32.8 ft) near its downstream constriction point. The substrate of this unit is mostly made up of macrolithal choriotops. Downstream of the constriction, which is adjacent to the spillway associated with an old mill site, the river opens up again and the velocity slows. The former tailrace acts as a man-made backwater and is heavily shaded. The backwater appears to have some groundwater contribution, possibly from seepage around the dam, and served as a small thermal relief site during the hot, low-flow periods.

Downstream of the rapids tailrace and the entrance to the backwater, the river widens to its typical 30 m (98.4 ft) and levels out briefly forming a run/pool extending to the top of an 80 m (262 ft) narrow island. The majority of flow continues in the main channel and the gradient increases resulting in a riffle, rapid, and run along the left side of the island.

The sidearm on the right side of the island is very narrow (under 4 m (13.1 ft)) and due to several downed trees, is mostly a series of riffles and pools. The river makes a sharp turn where it encounters a steep hillside and after passing a small backwater and narrow ruffle caused by a bedrock ledge and some large boulders, transitions into a slow run. This 200 m (0.12 mi) run is partially shaded because of the steep banks and surrounding hills. The substrate ranges from psammal to megalithal and depths are mostly less than 1.5 m (4.92 ft). The unit ends at a small round island where the gradient changes briefly.

The right arm is the main branch and carries most of the flow as a ruffle or run under the three higher flows mapped and the left sidearm flows over a small rock wall built for access to the island. As a result, this unit acts more like a backwater and under lower flow conditions the rock wall effectively cuts off flow to the left branch entirely. Downstream of the island, the remaining 600 m (0.37 mi) of the section is a slow run or pool ending just upstream of the Packers Falls Bridge. This section has high banks throughout and steep hillsides. There are few homes along this section because of the hills and the ones that are present are generally set back further than in the sections upstream. There is an almost constant human presence at the Wiswall Dam and the area downstream of the dam during the summer months. The parking area gives people access to the section, the old mill site, and various trails that lead to the river where fisherman were often encountered. The USGS gage for the Lamprey River is located near the end of this section just upstream of Packers Falls and the Packers Falls Bridge.

Representative Site 6

Representative Site 6 (length 1130 m (0.70 mi)) occupies the entirety of Section VI. Because of the unique character of this section, it was decided that the whole length of river in this section should be mapped for its habitat conditions. Therefore, the description for Section 6 also applies to Site 6.

Section VII

Section VII (810 m (0.50 mi)) is a dynamic area on the Lamprey beginning just upstream of the Packers Falls Bridge. It is a short section with a large change in gradient across a natural series of rapids separated by deep pools. The three rapids are narrow and have choriotops ranging from macrolithal to gigalithal. They are typically a little more shaded than the wide and exposed pools and contain small amounts of woody structure which were stranded after high flow events.

Packers Falls is at the top of the section and has the greatest natural gradient change observed in the designated reach. The river funnels through a narrow bedrock channel below Packers Falls Bridge and drops several meters over a 120 m (393.6 ft) stretch before entering the first of three large pools. The first pool is the longest and narrowest of the three and is approximately 200 m (0.12 mi) long and 50 m (165 ft) wide. It is in excess of 2 m (6.5 ft) deep for most of its area and depths of greater than 4 m (13 ft) were common. There is a shallow area along the left bank that has a fine organic substrate (Sapropel) and some wetlands plants (Phytal). Otherwise, the pool is deep, exposed to the sun, and has choriotops ranging from psammal to megalithal.

Near the downstream end of the unit, along the left bank, is a small tributary that enters the Lamprey through a culvert. The river downstream of here encounters another change in gradient and abruptly narrows, resulting in a 150 m (490 ft) long rapid. This rapid is not as turbulent as at Packers Falls, has a macrolithal substrate, and a presence of shading. The pool below this rapid is the smallest of the three, but is still very deep and as wide as it is long (70 m (230 ft)).

The final turbulent unit of water on the Lamprey Designated River begins below this pool and is a short rapid with macrolithal substrate and some canopy cover present. The rapid empties into the largest of the three pools. It is 90 m (295 ft) wide and 150 m (492 ft) long and extends to the end of the section, marking the end of the consistently free-flowing portion of the designated reach. The pool is very deep, often in excess of 5 m (16 ft), and is only shaded close to its banks. There are some shallow wetlands at the top of the pool along the right bank and substrates throughout are a mixture of pelal to mesolithal. At the top end of the hydromorphologic unit along the left bank is a large curving backwater which appears to be the submerged former channel of Woodman Brook. Woodman Brook enters through a culvert below Bennett Road. The culvert is perched several feet above the normal water level of the Lamprey River.

Representative Site 7

Representative Site 7 (length 808 m (0.50 mi)) occupies the entirety of Section 7. Because of the unique character of this section, it was decided that the whole length of river in this section should be mapped for habitat conditions. Therefore, the description for Section 7 also applies to Site 7.

Section VIII

The entire length (2580 m (1.60 mi)) of this section is impounded by the Macallen Dam in Newmarket and the section is dominated by slow runs, pools, and large backwaters. Because of the Macallen Dam, there was very little observed change in conditions over the flow range surveyed. This section was included in the modeling to characterize the habitat usage of the large impounded areas on the Lamprey Designated River and to give insight into habitat area lost or gained with any changes to the current dam management.

Section VIII begins at a small island just downstream of the confluence of Woodman Brook with the Lamprey Designated River. The first 640 m (0.40 mi) of this section is a relatively straight, deep, slow run or pool. It flows though nearly uninterrupted forest with moderately steep banks and pelal/psammal substrates. The section continues as a pool along the main channel before ending at the Durham/Newmarket town line. The section includes several backwaters of various sizes, including the very large submerged floodplain of the Piscassic River and the extensive area known as Moat Island. The section ends at the finish of the designated reach (Newmarket/Durham town line), which is approximately 1.15 km (0.71 mi) upstream of the Macallen Dam.

Although Section VIII is impounded and therefore doesn’t fit into the normal hydromorphologic unit survey criteria, the need for a study site in this section was recognized. This decision was made because the large impoundment in this section provides abundant habitat for macrohabitat generalists, which were identified to be included in the MesoHABSIM modeling of the Lamprey Designated River. Additionally, since this section is impounded by the Macallen Dam there once was a pre-existing riverine habitat assemblage inundated by the retained water. Through surveying the impoundment, the previous hydromorphologic unit assemblage was reconstructed to model the likely habitat of an un-impounded Section VIII.

Due to the depth of water, Section VIII was mapped using remote sensing techniques to assess the existing conditions. All of the resources from throughout the study were combined to develop a representative site that accurately describes the habitat characteristics of the section. Using aerial photos taken of the section during the five survey mapping flyovers as well as during a reconnaissance flight, the spatial extent of the hydromorphologic units were mapped at the same flows as for the other representative sites. The aerial photographs also aided in describing attribute information like canopy cover, submerged vegetation, overhanging vegetation, and woody debris.

Data from the 7 November 2006 Acoustic Doppler Current Profiler bathymetry survey (See Appendix 12) was used to select the random depth measurements used for modeling in the annotated hydromorphologic units. A two meter (6.6 ft) reduction in water depths at this study site was implemented based on observations of bedrock and river constriction just upstream of the Macallen Dam.

Additional attribute information was developed based on observations through visiting these areas during the reconnaissance survey and the full day Acoustic Doppler Current Profiler (ADCP) survey. Finally, the velocities to be associated with hydromorphologic units were transferred from those measured in the portions of Wiswall impoundment that were mapped during the five flow conditions.

Representative Site 8

Representative Site 8 (length 1421 m (0.88 mi)) begins at a near 90° bend in the river, or at the downstream end of the Springfield Terminal Railroad Bridge. The first unit of the study site, a 700 m (0.43 mi) slow run/pool, is deep and slow moving. Depths exceed 6 m (19.7 ft) in several locations. The banks are gently to moderately sloping, except along the left bank in the downstream end of the hydromorphologic unit where an extensive floodplain forest exists. The unit ends at the confluence of the Moat Island backwater complex. This is the most extensive backwater and wetland feature in the study reach and includes two small tributaries: La Roche and Ellison Brook. It also appears as though there is a small connection to the Oyster River though Hamel Brook during high water events.

Starting at the confluence of the Lamprey and the Moat Island backwater the mapping site continues as a 700 m (0.43 mi) pool. It is very deep with banks that drop off rapidly from shore. Substrates are all organic silts (sapropel) in this area with abundant submerged vegetation (phytal) along the banks and patches of woody materials. Along this unit there are five additional smaller backwaters with a wide range of depths and cover attributes. The mapping site ends approximately 750 m (0.47 mi) upstream of the end of the designated reach.

3. Habitat Data Collection

Habitat mapping was conducted to define the physical habitat components existing at different flows. The physical habitat components are used in the MesoHABSIM model with fish habitat suitability criteria to identify habitat that is used by individual and groups of fish. Additional details about habitat data collection techniques can be found in Appendix 7.

4. Habitat Mapping Surveys

The five surveys of the representative sites were conducted at target flow conditions representing a range of low through moderate/high summer flows between 0.1 cfsm and the low pulse threshold of 2.0 cfsm. The low pulse threshold has been determined by analysis of hydrologic time series obtained from the Packers Falls gage using the Indicators of Hydrological Alteration (IHA) methodology (Richter et al. 1997). To describe the entire range of the low flow conditions with five surveys, flows corresponding with 0.1, 0.2, 0.5, 1.0, and 1.5-2.0 cfsm were targeted using real time discharge readings at the Packers Falls gage (Table 11). The flows during habitat mapping at each site were not adjusted from the gage reading to compensate for the change in watershed area. This was thought to be unnecessary because the Lamprey Designated River is short (12 miles) and the differences in the watershed areas are less than 10 percent between the representative sites and the Packers Falls gage.

Table 11 presents the timing and flows measured during the habitat mapping surveys. Four of the surveys took place in summer 2006. Initially, the intent was to survey only four flows. However, due to the flooding experienced early in the study season and a generally wet summer, low flow conditions at a significant level below the measured target flow of 0.25 cfsm did not occur. This left an important target flow unmeasured. It was decided that if flow conditions dropped below 0.15 cfsm then an additional survey would be conducted. These flow conditions occurred in August 2007 and the habitat characteristics at the representative sites were mapped at the target flow of 0.10 cfsm at that time.

5. Target Fish Community

The status of the Lamprey Designated River's existing fish community was evaluated using the Target Fish Community (TFC) approach developed by Bain and Meixler (2000). A TFC model represents the expected fish community of a natural, or near natural, un-impacted stream. The TFC was developed using a GIS based method of selecting reference river segments that were physically and zoogeographically similar to the Lamprey Designated River. Fish data from these reference rivers were then used to compute the expected proportions of fish in the Target Fish Communities using the rank-weighted technique developed by Bain and Meixler (2000). The existing fish community of the Lamprey Designated River was then compared to the TFC using the percent model affinity procedure developed by Novak and Bode (1992) to quantify the overall similarity (or dissimilarity) of the two communities. This information, along with similar comparisons at the species- and species-group levels provided the basis for an inference-based ecological integrity evaluation of the Lamprey Designated River macrohabitat conditions. A more detailed description of the TFC development and analysis processes

Table 11 - Lamprey River targeted survey flows for each representative site with flows measured at the USGS Packers Falls gage.

Watershed area = 183 mi2	Lamprey HMU Survey Chart									
	~18 CFS	0.1 cfsm				~37 CFS	0.2 cfsm			
	Date	cfsm	cfs	start	stop	Date	cfsm	cfs	start	stop
Site 1	8/21/2007	0.09	16	16	16	9/19/2006	0.26	47	47	47
Site 2	8/21/2007	0.09	16	16	16	9/19/2006	0.25	47	47	46
Site 3	8/21/2007	0.09	16	16	16	9/19/2006	0.25	45	45	45
Site 4	8/22/2007	0.08	15	15	15	9/19/2006	0.25	45	45	45
Site 5	8/22/2007	0.08	14	14	14	9/28/2006	0.28	52	52	52
Site 6	8/22/2007	0.08	14	14	14	9/28/2006	0.28	52	52	51
Site 7	8/23/2007	0.08	14	14	14	9/28/2006	0.27	50	51	49
	~90 CFS	0.5 cfsm				~183 CFS	1.0 cfsm			
	Date	cfsm	cfs	start	stop	Date	cfsm	cfs	start	stop
Site 1	7/20/2006	0.56	103	104	102	4/28/2006	0.95	173	174	172
Site 2	7/20/2006	0.55	101	102	100	4/27/2006	1.28	235	241	229
Site 3	7/20/2006	0.53	98	98	97	4/27/2006	1.24	227	227	227
Site 4	7/20/2006	0.53	97	97	97	4/27/2006	1.22	223	225	220
Site 5	7/20/2006	0.52	95	95	95	4/27/2006	1.19	217	218	216
Site 6	7/21/2006	0.48	88	89	87	4/28/2006	1.00	183	188	178
Site 7	7/21/2006	0.48	87	87	87	4/28/2006	0.96	176	176	176
	~275 -360	1.5 -2.0 cfsm								
	Date	cfsm	cfs	start	stop					
Site 1	7/25/2006	2.00	366	370	362					
Site 2	7/25/2006	1.89	345	354	336					
Site 3	7/25/2006	1.81	331	333	328					
Site 4	7/26/2006	1.47	269	271	266					
Site 5	7/26/2006	1.42	261	262	259					
Site 6	7/26/2006	1.37	251	257	245					
Site 7	7/26/2006	1.30	239	241	236					

Start/stop refers to the cfs at the Packers Falls gage at the start and finish of each mapping of a representative site. The cfs at the time of mapping was then calculated by taking the average of these two numbers.

was documented during an earlier phase of this project (see DES report R-WD-07-36, DES 2007).

Lamprey Designated River Target Fish Community

The Target Fish Community (TFC) serves as a benchmark for the assessment of the Lamprey River's ecological status and for the selection of the species assemblages that will serve as indicators for the determination of protected instream flows. The Lamprey Designated River TFC was created using fish collection data from six quality reference rivers as described in the Lamprey Target Fish Community Report Appendix (DES 2007, NHDES R-WD-07-36). The reference rivers' fish data used to calculate the ranks and expected proportions of species within the TFC developed for the Lamprey Designated River are presented in Table 12. Species found in the reference rivers, which are not native to the Lamprey River watershed were ranked, but were not given proportions or included in the TFC model.

Table 12 - Reference River fish data and mean rankings. Data shown was used to calculate the expected proportions of fish species in the Lamprey Designated River Target Fish Community.

***Reference Rivers:* Common Name**	**Bio-geographic Status***	**Cocheco River**	**Eightmile River**	**Fort River**	**Isinglass River**	**Nissitissit River**	**Wood River**	**Mean Rank**
Common Shiner	Native	33	130	1	168	85	197	1
Fallfish	Native	4	22	49	94	137	25	2
American Eel	Native	43	62	24	102	8	36	3
Common White Sucker	Native	22	35	33	4	122	13	4
Longnose Dace	Native	53	7	4	67	40	76	5
Redbreast Sunfish	Native		76		58		98	6
Tessellated Darter	Non-native		121				83	7
Pumpkinseed	Native	13	23	1	13	38	2	8
Spottail Shiner	Non-native	17	79					9
Blacknose Dace	Native	2	24			49		10
Largemouth Bass	Non-native	4	42		6	9	1	11
Bluegill	Non-native	1	3		17	5	30	12
Chain Pickerel	Native	2	1		9	31	7	13
Atlantic Salmon	Native		10		18		17	14
Rock Bass	Non-native			9				15
Smallmouth Bass	Non-native		9	5	2	1		16
Yellow Perch	Native	1	30		2	2		17
Brown Bullhead	Native		1		7	5	5	18
Rainbow Trout	Non-native	1		2		2	1	19
Creek Chubsucker	Native				1	6	8	20
Redfin Pickerel	Native	3	6					21
Central Mudminnow	Non-native		14					22
Yellow Bullhead	Non-native	1				7		23
Bridle Shiner	Native				9			24
Brook Trout	Native		2				5	25
Margined Madtom	Non-native				5			26
Brown Trout	Non-native						4	27
Sea Lamprey	Native		3					28
Creek Chub	Native				2			29
Swamp Darter	Native				1			30
Black Crappie	Non-native						1	31
Totals:		200	700	128	585	547	609	

*Native or non-native statuses given here are specific to the Lamprey River watershed.

The Lamprey Designated River's TFC consists of a diverse fish fauna of 18 species dominated by common shiner (31 percent), fallfish (16 percent), American eel (10 percent), common white sucker (8 percent), longnose dace (6 percent), redbreast sunfish (5 percent), pumpkinseed (4 percent), blacknose dace (3 percent), chain pickerel (2 percent), and Atlantic salmon (2 percent). The remaining 12 percent of the community was comprised of eight species (yellow perch, brown bullhead, creek chubsucker, redfin pickerel, bridle shiner, brook trout, creek chub, and swamp darter) having individual proportions ranging between 1 percent and 2 percent (Table 14, Figure 8). Four anadromous species (alewife, American shad, blueback herring, and sea lamprey), listed in Table 13, are also a component of the TFC. While specific proportions could not be calculated for these species they are expected to occur within the Lamprey Designated River. The TFC is composed of 31 percent fluvial specialist, 39 percent fluvial dependent, and 30 percent macrohabitat generalist species (Figure 9).

Table 13 - Definition of the Lamprey Designated River Target Fish Community (TFC). Calculated from the rankings of the reference river fish species native to the Lamprey watershed status as native (N) or introduced (I) fish species.

FAMILY Common name	Genus	Species	Native or Introduced	Habitat use classification	Pollution tolerance	Thermal regime
Petromyzontidae						
Sea lamprey	*Petromyzon*	*marinus*	N	FD	M	Eurythermal
Anguillidae						
American eel	*Anguilla*	*rostrata*	N	MG*	T	Eurythermal
Clupeidae						
Blueback herring	*Alosa*	*aestivalis*	N	FD	M	Warm
Alewife	*Alosa*	*pseudoherangus*	N	FD	M	Eurythermal
American shad	*Alosa*	*sapidissima*	N	FD	M	Warm
Salmonidae						
Rainbow trout	*Oncorhynchus*	*mykiss*	I	FD	I	Cold
Atlantic salmon	*Salmo*	*salar*	N	FS	I	Cold
Brown trout	*Salmo*	*trutta*	I	FD	I	Cold
Brook trout (char)	*Salvelinus*	*fontinalis*	N	FS	I	Cold
Escocidae						
Redfin pickerel	*Esox*	*americanus*	N	MG	M	Warm
Chain pickerel	*Esox*	*niger*	N	MG	M	Warm
Cyprinidae						
Common shiner	*Luxilus*	*cornutus*	N	FD	M	Eurythermal
Golden shiner	*Notemigonus*	*crysoleucas*	N	MG	T	Eurythermal
Bridle shiner	*Notropis*	*bifrenatus*	N	MG	I	Warm
Spottail shiner	*Notropis*	*hudsonius*	I	MG	M	Eurythermal
Blacknose dace	*Rhinichthys*	*atratulus*	N	FS	T	Eurythermal
Longnose dace	*Rhinichthys*	*cataractae*	N	FS	M	Eurythermal
Creek chub	*Semotilus*	*atromaculatus*	N	FS	T	Eurythermal
Fallfish	*Semotilus*	*corporalis*	N	FS	M	Eurythermal
Catostomidae						
Common white sucker	*Catostomus*	*commersoni*	N	FD	T	Eurythermal
Creek chubsucker	*Erimyzon*	*oblongus*	N	FS	I	Eurythermal
Ictaluridae						
Yellow bullhead	*Ameiurus*	*natalis*	I	MG	T	Warm
Brown bullhead	*Ameiurus*	*nebulosus*	N	MG	T	Warm
Cyprinodontidae						
Banded killifish	*Fundulus*	*diaphanus*	N	MG	T	Warm
Moronidae						
White perch	*Morone*	*americana*	N	MG	M	Eurythermal
Striped bass	*Morone*	*saxitilis*	N	FD	M	Warm
Centrarchidae						
Rock bass	*Amblopites*	*rupestris*	I	MG	M	Eurythermal
Banded sunfish	*Enneacanthus*	*obesus*	N	MG	M	Warm
Redbreast sunfish	*Lepomis*	*auritus*	N	MG	M	Warm
Pumpkinseed	*Lepomis*	*gibbosus*	N	MG	M	Warm
Bluegill	*Lepomis*	*macrochirus*	I	MG	T	Warm
Smallmouth bass	*Micropterus*	*dolomieu*	I	MG	M	Eurythermal
Largemouth bass	*Micropterus*	*salmoides*	I	MG	M	Warm
Black crappie	*Pomoxis*	*nigromaculatus*	I	MG	M	Warm
Percidae						
Swamp darter	*Etheostoma*	*fusiforme*	N	MG	M	Warm
Yellow perch	*Perca*	*flavescens*	N	MG	M	Eurythermal

Habitat use classifications as fluvial specialist (FS), fluvial dependent (FD), or macrohabitat generalist (MG). Pollution tolerances as intolerant (I), moderately tolerant (M), or tolerant (T). Thermal regime tolerances as Cold, Eurythermal, or Warm.

*American eel have been classified as *fluvial dependent* in other TFC due to this species dependency upon fluvial conditions for migration to and from the sea to complete their catadromous life-cycle.

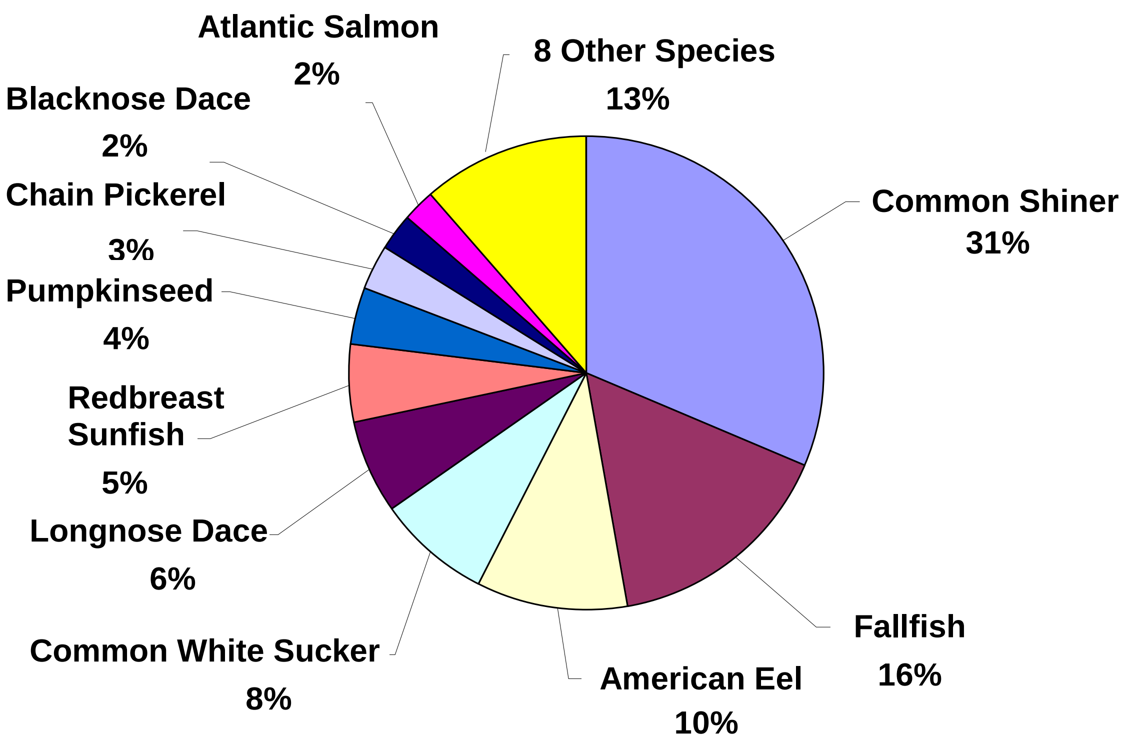

Figure 8 - Lamprey Designated River Target Fish Community (TFC).

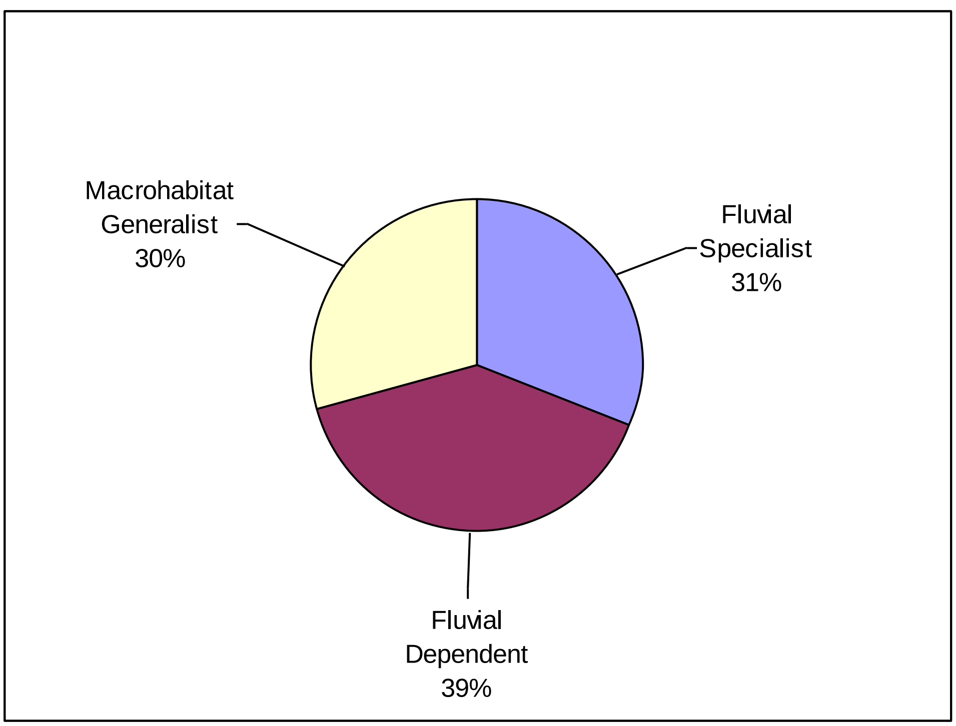

Figure 9 - Lamprey Designated River Target Fish Community (TFC) composition by habitat-use classification guilds.

Comparison of Target Fish Community to the Lamprey Designated River Existing Fish Community

This comparison is performed to investigate how far the current fish fauna deviates from the target community. Determining that some species or order groups are underrepresented or overly abundant in the study area narrows the focus to those species and selects them as indicators for the development of a habitat model. The following paragraphs describe this process.

Percent Model Affinity

The current condition of the existing fish community was evaluated by comparing the Target Fish Community (TFC) and the existing fish community. To make this comparison, the Percent Model Affinity procedure developed by Novak and Bode (1992) was used. This procedure yields values from 0 to 100 to describe the similarity of the existing fish community to the TFC. Higher percent model affinity values indicate higher degrees of similarity between the communities. These values are calculated as:

$$\text{Percentage similarity} = 100 - 0.5 \sum \left| \textit{expected}\ \% - \textit{observed}\ \% \right|$$

Where *expected* % is the percentage of individuals of a particular species in the TFC and *observed* % is the percentage of the same species in the existing fish community. Additional similarity comparisons were made between the two communities based on the expected and existing proportions of habitat use, pollution tolerance, and thermal regime tolerance classification guilds using the percent model affinity approach. The absolute differences between proportions of the habitat-use, pollution tolerance, and thermal regime classification guilds of the communities were summed, multiplied by 0.5, and subtracted from 100 to determine the percentage similarity between the two communities based on these classification guilds.

The overall affinity of the existing fish community to the TFC model was 71 percent (Table 14). This is also illustrated in Figure 10, where the proportion of fish species for the existing fish community (proportion existing) is shown along with the proportion of fish species for the TFC (proportion expected).

The comparison of the existing fish community and TFC based on habitat-use guilds also showed a close match between the two communities (Figure 11). Proportions of fluvial dependent species were the same in both communities (39 percent). Differences between the two communities are apparent in the minor overabundance of macrohabitat generalist species and underabundance of fluvial specialist species within the existing fish community. The percent model affinity calculated based on the two communities' habitat-use classification guilds showed 86 percent similarity.

Figure 12 shows the comparison of the proportions of fish species pollution tolerance classification guilds of the existing fish community (20 percent tolerant, 78 percent moderately tolerant, and 2 percent intolerant species) to those of the TFC (24 percent

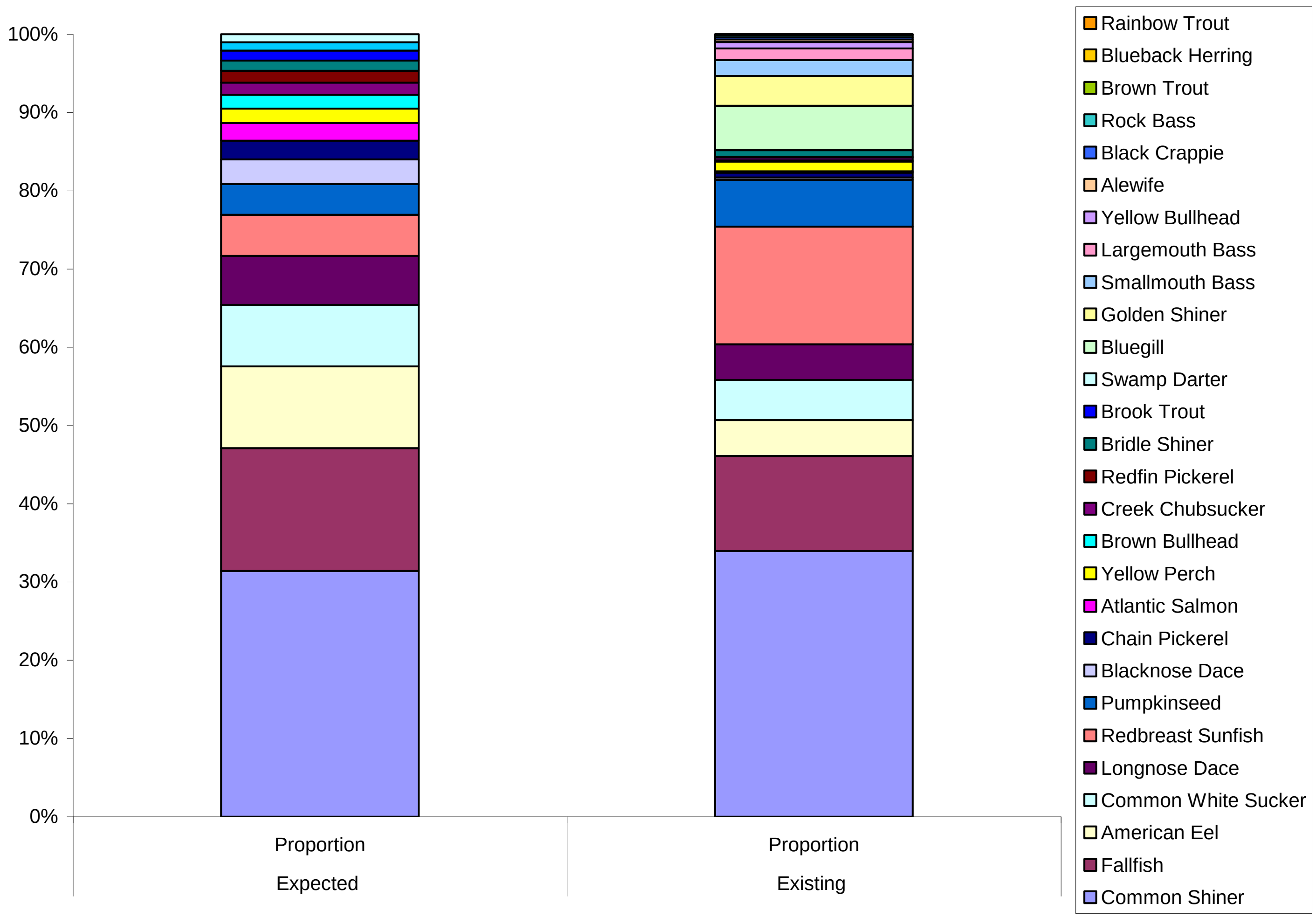

Figure 10 - Target Fish Community (TFC) and existing fish community comparisons showing proportions of individual fish species.

Table 14 - Comparison of proportions of fish species between the TFC and the existing fish community in the Lamprey Designated River.

Species	Proportion of Target Fish Community	Proportion of Existing Fish Community	Percent Deviation	Native or Introduced	Habitat use Classification	Pollution Tolerance	Thermal Regime
Underrepresented fish species							
American Eel[1]	10%	5%	56%	N	MG*	T	Eurythermal
Blacknose Dace	3%	0.3%	90%	N	FS	T	Eurythermal
Chain Pickerel	2%	1%	75%	N	MG	M	Warm
Atlantic Salmon[1]	2%	0.2%	91%	N	FS	I	Cold
Brown Bullhead	2%	0.2%	90%	N	MG	T	Warm
Creek Chubsucker	2%	0.3%	78%	N	FS	I	Eurythermal
Redfin Pickerel	2%	0.1%	94%	N	MG	M	Warm
Fish species recorded as expected							
Common Shiner	31%	34%	9%	N	FD	M	Eurythermal
Fallfish	16%	12%	22%	N	FS	M	Eurythermal
Common White Sucker	8%	5%	34%	N	FD	T	Eurythermal
Longnose Dace	6%	5%	27%	N	FS	M	Eurythermal
Yellow Perch	2%	1%	33%	N	MG	M	Eurythermal
Bridle Shiner	1%	1%	34%	N	MG	I	Warm
Overly abundant fish species							
Redbreast Sunfish	5%	15%	190%	N	MG	M	Warm
Pumpkinseed	4%	6%	54%	N	MG	M	Warm
Missing fish species							
Brook Trout	1%	-	100%	N	FS	I	Cold
Creek Chub	1%	-	100%	N	FS	T	Eurythermal
Swamp Darter	1%	-	100%	N	MG	M	Warm
Introduced species present within the existing fish community (considered overly abundant)							
Bluegill	-	6%	N/A	I	MG	T	Warm
Smallmouth Bass	-	2%	N/A	I	MG	M	Eurythermal
Largemouth Bass	-	2%	N/A	I	MG	M	Warm
Yellow Bullhead	-	1%	N/A	I	MG	T	Warm
Black Crappie	-	0.3%	N/A	I	MG	M	Warm
Rock Bass	-	0.3%	N/A	I	MG	M	Eurythermal
Brown Trout	-	0.05%	N/A	I	FD	I	Cold
Rainbow Trout	-	0.02%	N/A	I	FD	I	Cold
Native fish species currently or historically present within the Lamprey River Designated Reach missing from the Target Fish Community							
Golden Shiner	-	4%	N/A	N	MG	T	Eurythermal
Banded Sunfish	-	Present**	N/A	N	MG	M	Warm
Anadromous species expected to be present within the Lamprey River during seasonal spawning migration and freshwater life-stage bio-periods							
Alewife[1,2]	Expected	Present	N/A	N	FD	M	Eurythermal
Blueback Herring[1,2]	Expected	Present	N/A	N	FD	M	Warm
American Shad[1,2]	Expected	Not Sampled	N/A	N	FD	M	Warm
Sea Lamprey (adult)[1,2]	Expected	Not Sampled	N/A	N	FD	M	Eurythermal
Sea Lamprey (ammocoete)[1]	Expected	Not Sampled	N/A	N	FD	M	Eurythermal

[1] Diadromous species
[2] Anadromous pulse species (non-resident)
*American eel is a fluvial dependent (FD) macrohabitat generalist (MG) as this species is dependent upon fluvial conditions for migratory purposes
**Banded sunfish were not sampled during the Lamprey River Baseline Fish Sampling (NHDES) efforts but have been previously recorded within the Lamprey River

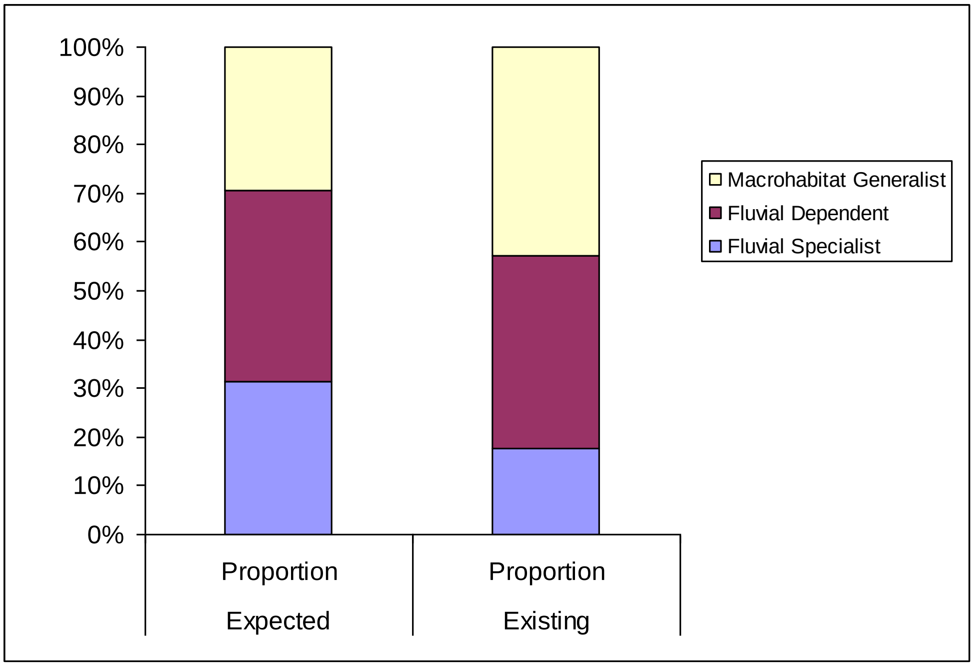

Figure 11 - TFC and existing fish community comparisons showing proportions of habitat-use guilds.

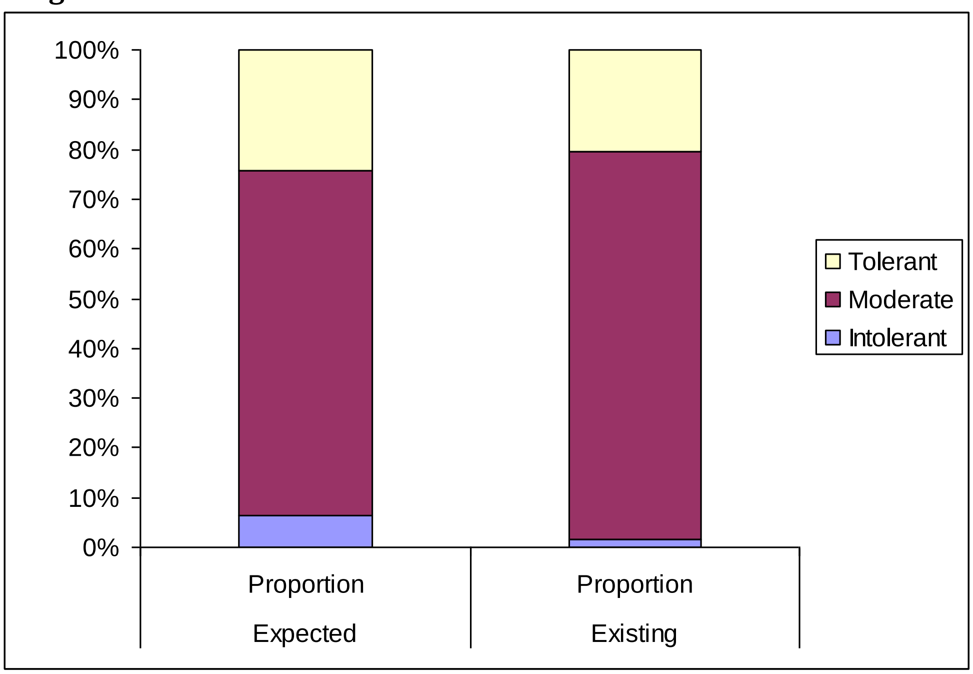

Figure 12 - TFC and existing fish community comparisons showing proportions of pollution tolerance guilds.

tolerant, 69 percent moderately tolerant, and 7 percent intolerant species) showed a considerable under-representation of pollution intolerant species within the existing fish community. Differences between pollution tolerant and moderately tolerant species, however, were minor. Overall, the communities scored a 91 percent model affinity value based on the similarity between the proportions of pollution tolerance classification guilds of the two communities.

When the TFC and existing fish community were compared based on the proportions of thermal regime tolerance guilds of fish species, considerable differences were observed (Figure 13). The existing fish community consisted of 31 percent warm, 69 percent eurythermal (tolerating a wide range of temperatures), and 0.2 percent cold-water fish species (Atlantic salmon [*n*=13], brown trout [*n*=3], and rainbow trout [*n*=1]). Eurythermal fish species existed in a proportion somewhat similar to the expected proportion of the TFC (69 percent *vs.* 79 percent). The proportion of warm-water species was considerably higher than the expected proportion of 17 percent. Conversely, the proportion of cold-water species was much lower than the expected proportion of 4 percent and nearly absent from the existing community. When a percent model affinity similarity measurement was applied to the existing fish community and TFC thermal regime classification guild proportions, a value of 86 percent was calculated despite the substantial underrepresentation of cold-water fish species.

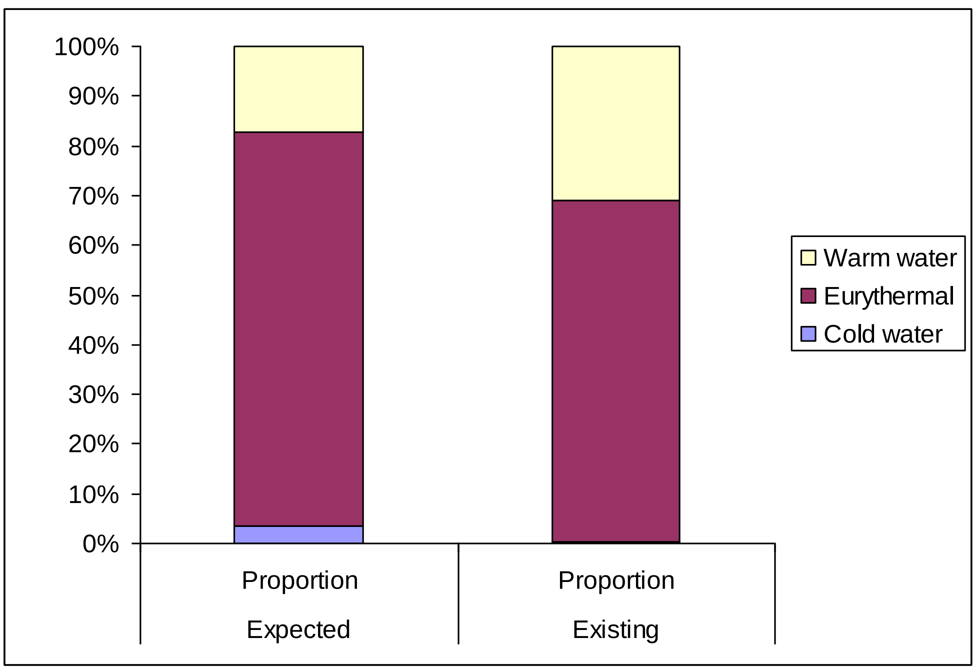

Figure 13 - TFC and existing fish community comparisons showing proportions of thermal regime guilds.

Species Deviations

A percent deviation calculation was then conducted for each individual species and for each individual species-group guild to quantify deviations between expected (TFC) and observed community compositions:

$$\text{Percent deviation} = \left| \textit{expected}\ \% - \textit{observed}\ \% \right| / \textit{expected}\ \%$$

Percent deviation was calculated for each species to document underrepresented species, overrepresented species, and species found in proportions similar to those expected. A degree of deviation of 50 percent or greater was arbitrarily selected to indicate an apparent and substantial departure from expected (TFC) proportions. Species with observed proportions deviating by more than 50 percent, either less or greater than the expected (TFC) proportions, were considered underrepresented or overabundant, respectively. Native species identified within the TFC that were missing from the existing fish community, or *vice versa*, and non-native species occurring within the existing community were also identified. Similarly, a percent deviation analysis was conducted for each of the classes within the species-group guilds to quantify deviations at the species-group level.

Within the Lamprey Designated River, seven native species are considered underrepresented and two are overabundant. Six species are found in proportions similar to those expected by the TFC, while three species are absent. There are eight non-native fish species occurring in the Lamprey Designated River. Non-native species are not a part of the TFC; consequently, these species were considered overabundant within this analysis. One native fish species that was not a member of the TFC, golden shiner, was sampled within the Lamprey Designated River. Two out of the six diadromous species expected to occur within the Lamprey River were sampled within the existing fish community (Table 15).

6. Indicator Fish Species

The Target Fish Community (TFC) model describes the group of native fish species expected to live in the Lamprey Designated River under reference conditions consisting of limited flow disturbance and habitat impairment. Based on their composition within the TFC, American eel, common shiner, common white sucker, fallfish, longnose dace, and redbreast sunfish were selected as indicator species for the MesoHABSIM modeling process. Atlantic salmon was also included as an indicator fish species due to their specific habitat requirements and concerns related to the conservation of this species. The habitat suitability requirements (based on logistic regression coefficients developed from empirical fish capture data) and weighted proportions of these species within the TFC model were used to train the Lamprey River MesoHABSIM model to predict the necessary quantity of instream flow required within the river to provide and maintain sufficient amounts of habitat to support their biological needs during different seasons or bioperiods.

Table 15 - Expected fish species of the Lamprey Designated River.

Note: status as native (N) or introduced (I) fish species. Habitat use classifications as fluvial specialist (FS), fluvial dependent (FD), or macrohabitat generalist (MG). Pollution tolerances as intolerant (I), moderately tolerant (M), or tolerant (T). Thermal regime tolerances as Cold, Eurythermal, or Warm.

FAMILY Common name	Genus	Species	Native or Introduced	Habitat use classification	Pollution tolerance	Thermal regime
Petromyzontidae						
Sea lamprey	*Petromyzon*	*marinus*	N	FD	M	Eurythermal
Anguillidae						
American eel	*Anguilla*	*rostrata*	N	MG*	T	Eurythermal
Clupeidae						
Blueback herring	*Alosa*	*aestivalis*	N	FD	M	Warm
Alewife	*Alosa*	*pseudoherangus*	N	FD	M	Eurythermal
American shad	*Alosa*	*sapidissima*	N	FD	M	Warm
Salmonidae						
Rainbow trout	*Oncorhynchus*	*mykiss*	I	FD	I	Cold
Atlantic salmon	*Salmo*	*salar*	N	FS	I	Cold
Brown trout	*Salmo*	*trutta*	I	FD	I	Cold
Brook trout (char)	*Salvelinus*	*fontinalis*	N	FS	I	Cold
Escocidae						
Redfin pickerel	*Esox*	*americanus*	N	MG	M	Warm
Chain pickerel	*Esox*	*niger*	N	MG	M	Warm
Cyprinidae						
Common shiner	*Luxilus*	*cornutus*	N	FD	M	Eurythermal
Golden shiner	*Notemigonus*	*crysoleucas*	N	MG	T	Eurythermal
Bridle shiner	*Notropis*	*bifrenatus*	N	MG	I	Warm
Spottail shiner	*Notropis*	*hudsonius*	I	MG	M	Eurythermal
Blacknose dace	*Rhinichthys*	*atratulus*	N	FS	T	Eurythermal
Longnose dace	*Rhinichthys*	*cataractae*	N	FS	M	Eurythermal
Creek chub	*Semotilus*	*atromaculatus*	N	FS	T	Eurythermal
Fallfish	*Semotilus*	*corporalis*	N	FS	M	Eurythermal
Catostomidae						
Common white sucker	*Catostomus*	*commersoni*	N	FD	T	Eurythermal
Creek chubsucker	*Erimyzon*	*oblongus*	N	FS	I	Eurythermal
Ictaluridae						
Yellow bullhead	*Ameiurus*	*natalis*	I	MG	T	Warm
Brown bullhead	*Ameiurus*	*nebulosus*	N	MG	T	Warm
Cyprinodontidae						
Banded killifish	*Fundulus*	*diaphanus*	N	MG	T	Warm
Moronidae						
White perch	*Morone*	*americana*	N	MG	M	Eurythermal
Striped bass	*Morone*	*saxitilis*	N	FD	M	Warm
Centrarchidae						
Rock bass	*Amblopites*	*rupestris*	I	MG	M	Eurythermal
Banded sunfish	*Enneacanthus*	*obesus*	N	MG	M	Warm
Redbreast sunfish	*Lepomis*	*auritus*	N	MG	M	Warm
Pumpkinseed	*Lepomis*	*gibbosus*	N	MG	M	Warm
Bluegill	*Lepomis*	*macrochirus*	I	MG	T	Warm
Smallmouth bass	*Micropterus*	*dolomieu*	I	MG	M	Eurythermal
Largemouth bass	*Micropterus*	*salmoides*	I	MG	M	Warm
Black crappie	*Pomoxis*	*nigromaculatus*	I	MG	M	Warm
Percidae						
Swamp darter	*Etheostoma*	*fusiforme*	N	MG	M	Warm
Yellow perch	*Perca*	*flavescens*	N	MG	M	Eurythermal

*American eel have been classified as *fluvial dependent* in other TFC due to this species dependency upon fluvial conditions for migration to and from the sea to complete their catadromous life-cycle.

Upon determination of the primary bioperiods of the Lamprey Designated River, a group of species representing the present aquatic community was selected from the fauna/life stage using the habitat in the bioperiod. For example, the habitat needs for the rearing and growth bioperiod were represented by a select group of species dominating the TFC. These fish species: common shiner, fallfish, white sucker, longnose dace, and redbreast sunfish were analyzed individually as well as a group referred to as generic resident adult fish (GRAF). The new generation of these species was considered as a group called young-of-the-year (YOY) life stage. During the spring spawning season, the habitat needs of the anadromous clupeids (American shad, alewife, and blueback herring) and GRAF were analyzed jointly. In the fall season, the typical habitat requirements of resident fish were assessed in combination to those of the spawning life stage of Atlantic salmon. Habitat models were developed for all of the above groups to determine the flow sensitivity of their habitat. The species (or species groups) with specific flow dependent habitat needs were selected as indicators for each respective season or bioperiod.

7. Bioperiods

Biological processes of fish and other aquatic organisms have evolved with and are dependent upon annual, seasonal and shorter duration variations in river flow (Poff et al. 1997; Bunn and Arthington 2002). The timing, frequency, duration, and magnitude of river flow conditions are temporally variable components of the natural flow regime (Poff et al. 1997). When identifying protected flows in a river, it is necessary to consider these components of flow and the biological requirements of the aquatic species adapted within that river in order to account for their habitat needs. To achieve this, the year was partitioned into biological periods (bioperiods) keyed to when migratory species and certain life stages of resident fauna are particularly dependent upon specific flow conditions. These bioperiods are the critical periods when habitat conditions required by a particular fauna or life stage are dependent upon particular flow conditions.

The timing and duration of these bioperiods were determined using a literature-based analysis of the life histories and biological needs of the resident target species identified in the Target Fish Community (TFC) (see Section IV (D) (5)) and of the fluvial dependent, diadromous pulse species that have the potential to occur within the Lamprey Designated River. The timing of these bioperiods was then compared to the mean of the mean daily flow values (cfs) of the Lamprey River hydrograph recorded at the Packers Falls gage (73 years of record). The specific beginning and ending dates of each bioperiod were then adjusted based on the hydrograph from the general literature-derived dates for the region to dates specific to the Lamprey Designated River (Figure 14).

Six bioperiods and respective indicator species (or species groups) were identified. These were based on Rushing Rivers Institute experience conducting instream flow studies, reviews of scientific literature describing the relationships between fish ecology and hydrologic flow regimes (Poff et al. 1997; Bunn and Arthington 2002), and on biological and life history accounts for the specific fish species (or species groups) selected as indicators for the Lamprey Designated River.

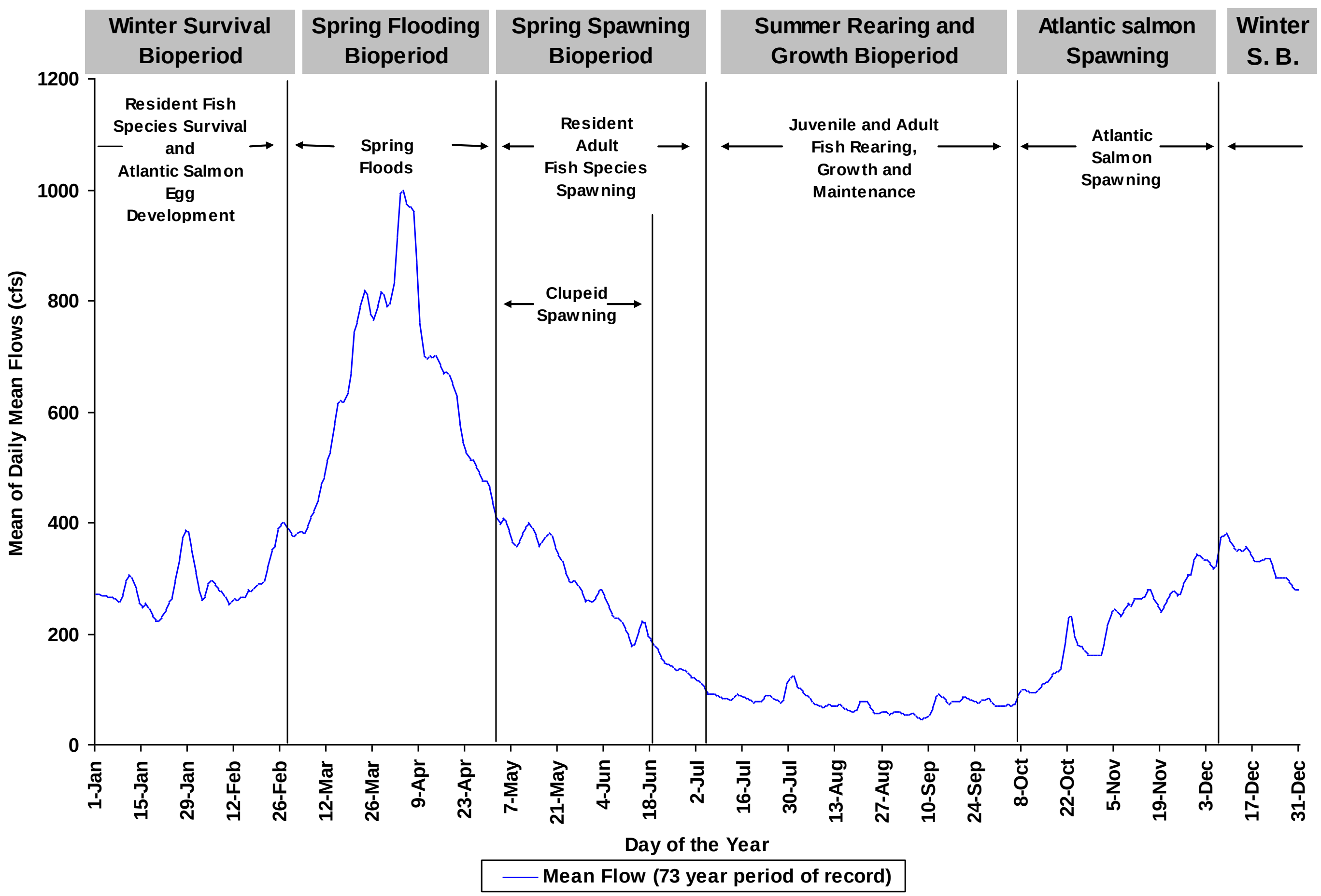

Figure 14 - Bioperiods for indicator fish species of the Lamprey Designated River overlain on the hydrograph of the mean of daily mean flow values for the Lamprey River at Packers Falls gage over a 73-year period of record.

8. Habitat Suitability Criteria

Habitat suitability criteria are filters that evaluate how useful the mosaic of physical parameters such as; velocity, flow, or cover type are represented as habitat. They were defined in one of two ways for each selected species and group of species. For conditions where the collection of empirical data was limited, available literature and professional judgment were used to develop a list of physical criteria associated with suitable habitat for indicator species. For conditions where adequate empirical data from fish collections existed, these data were used to select criteria associated with habitat suitability. Habitat suitability criteria were used to model the habitat suitability of the representative sites of the Lamprey Designated River.

Spawning Habitat Criteria Development

A literature-based spawning habitat model was developed for GRAF and anadromous fish based on four habitat attributes: depth, velocity, choriotop (substrate type), and HMU type. Known ranges for each attribute were determined from literature studies (Appendix 6).

Rearing and Growth Habitat Criteria Development

The empirical set of criteria for the rearing and growth (R&G) season had been developed from habitat use data collected in earlier studies for GRAF and YOY. The Rushing Rivers Institutes' database contains habitat data collected on 17 rivers in the northeastern United States. For each species, data were selected from rivers where this species occurred more than sporadically (more than 5 percent of the total capture). The fish habitat data gathered in the fishing locations was analyzed with the help of a multivariate statistical model (logistic regression) to compute the habitat selection criteria for adult resident fish species (for details on this method please see Appendix 6). The model selects habitat attributes corresponding with presence and abundance of the species that are then used to calculate probability of presence and high abundance in the surveyed mesohabitats. Unsuitable, suitable, and optimal habitats were distinguished corresponding with high probabilities of fish absence, presence, and high abundance, respectively. Separate models were developed for EPT taxa and Odonates. Only presence level models could be developed for macroinvertebrates, no abundance model has been created.

For YOY habitat, which consists only of shallow margins, empirical criteria developed on the Quinebaug River were applied. Observations of aquatic macroinvertebrates taken on the Souhegan and Lamprey Rivers were also used. Separate models were developed for EPT taxa and Odonates. Only presence level models could be developed for macroinvertebrates.

9. Rating Curves under Existing Conditions

The habitat quality in the representative sites was evaluated using the habitat suitability criteria and the measured habitat conditions during the field surveys at each of the target flows (see Table 11). These flows are based on real time discharge values recorded at the USGS Packers Falls gaging station. The habitat suitability for all investigated species was then calculated for each hydromorphologic unit (for details on model development see Appendix 6). Subsequently, the hydromorphologic units were assigned to unsuitable, suitable, or optimal categories. The area of suitable and optimal habitat was determined for each site and flow as a proportion of wetted channel area. The habitat area results across the range target flow surveys were represented as a habitat rating curves for every species and

GRAF. The latter was modeled in two ways: 1) using the Generic Fish model, where the habitat level is expressed as any suitable habitat used by any of the GRAF species regardless of how suitable it is for the other GRAF species and 2) using a Community Habitat model, where the habitat level is expressed as the sum of habitats for GRAF species weighted by their expected proportions in the TFC.

Effective habitat is an agglomerate of suitable and optimal habitat that is needed to support the species under investigation. For species where an optimal habitat model could be established, the habitat area was computed by weighting suitable habitat with 25 percent and optimal with 75 percent and adding them. For other species, only suitable habitat was evaluated. The rating curves for the sites represent habitat conditions for the entire section.

To complement the assessment of the status of the fish fauna, the structure (proportions) of habitat available for GRAF was also computed under the existing conditions. The comparison of the structure of the TFC with the existing fish community allowed for the determination, if habitat was potentially a limiting factor in fish abundance, specifically for species with flow sensitive habitats. The figures presented in the following sections represent the amount of suitable, optimal, and effective habitat for selected species groups in each bioperiod as found under the existing conditions for the Lamprey Designated River.

Rearing and Growth Bioperiod

Common shiner has a steady, but periodically rising suitability habitat with increasing flow rate. Suitability started with 2 percent at 0.2 cfsm, then climbs to approximately 4 percent at 1.4 cfsm, decreasing briefly to 3 percent at 1.2 cfsm (Figure 15). Fallfish suitable habitat area begins a decline from 48 percent at 0.1 cfsm, reaching about 40 percent at 0.5 cfsm where it begins to decline more steeply to about 20 percent at 1.2 cfsm, it then curves upwards slightly to 21 percent at 1.5 cfsm. American eel suitable habitat area curves from 35 percent at 0.5 cfsm up to 44 percent at 0.3 cfsm. It then follows a steady decline throughout 1.2 cfsm to 29 percent, dipping back up to 35 percent at 1.5 cfsm. Longnose dace suitability curve remains linear, wavering between 0-1 percent through 0.1-1.5 cfsm. White sucker suitability curve drops steeply from 33 percent at 0.1 cfsm down to 17 percent at 0.5 cfsm, remaining there through 1.0 cfsm before concluding to curve up to 20 percent by 1.5 cfsm. Redbreast sunfish suitability curve finds 13 percent habitat area at 0.1 cfsm, which declines to 10 percent at 0.3 cfsm, jumping right back up to 14 percent at 0.4 cfsm where it remains until dipping to 10.5 percent at 1 cfsm. It rises to 11 percent cfsm before remaining at 10 percent through 1.4-1.5 cfsm. Atlantic salmon suitable habitat remains under 1 percent throughout the modeled flows (Figure 15).

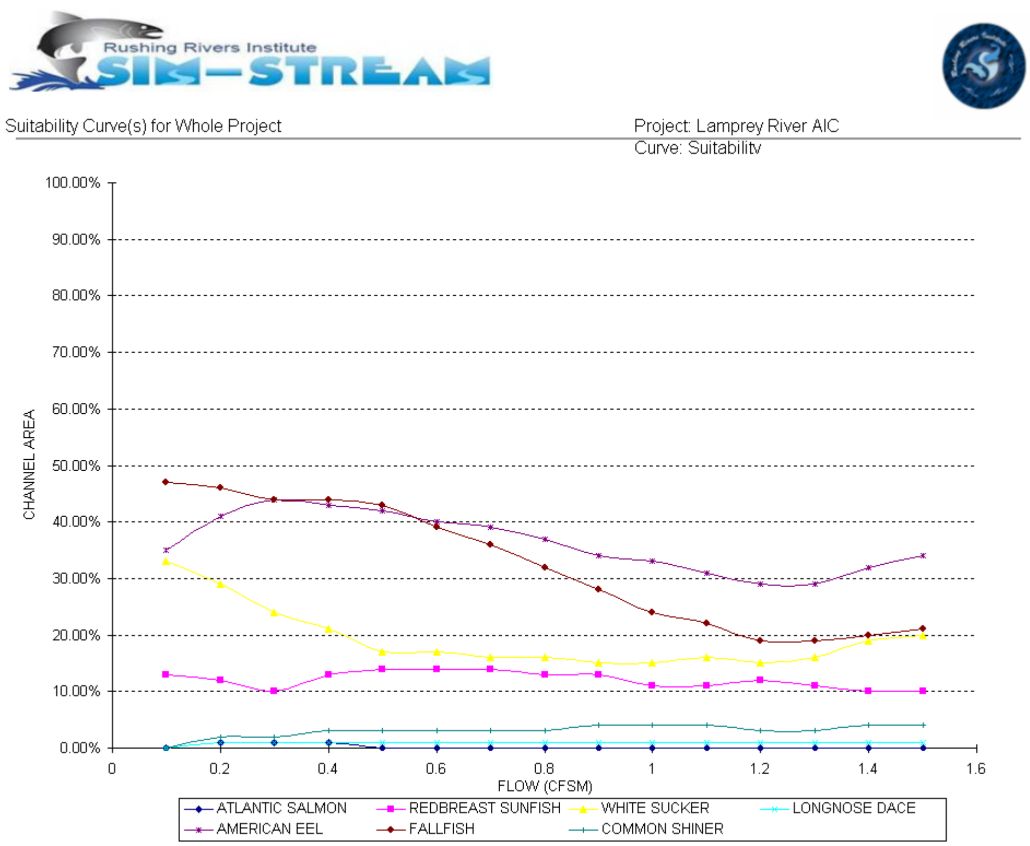

Figure 15 - Suitable habitat rating curves for GRAF species during the rearing and growth bioperiod in the Lamprey Designated River for existing conditions.

Common shiner's optimal habitat rating curve begins with 32 percent at 0.1 cfsm and declines steadily down to about 4 percent at 1.2 cfsm; it rises back to 6 percent at 1.4 cfsm and 7 percent at 1.5 cfsm (Figure 16). Fallfish suitability curves from 32 percent at 0.1 cfsm up to 41 percent at 0.4 cfsm where it then gradually falls back to about 20 percent at 1.2 cfsm, gently rising to 21 percent by 1.5 cfsm. American eel stays at 0 percent throughout 0.1 – 0.8 cfsm. At 0.9 cfsm it increases to 1 percent where it remains until 1.5 cfsm. Longnose dace begins at 0 percent and then wavers between 1-3 percent throughout 0.2-0.8 cfsm, dropping back to 0 percent and remaining there through 0.9-1.5 cfsm. White sucker has a decline from 32 percent at 0.1 cfsm to 1 percent at 1.2 cfsm where it climbs back up to 7 percent at 1.5 cfsm. Redbreast sunfish holds 0 percent through 0.1 to 1.5 cfsm. Atlantic salmon also remains at 0 percent between 0.1-1.5 cfsm (Figure 16).

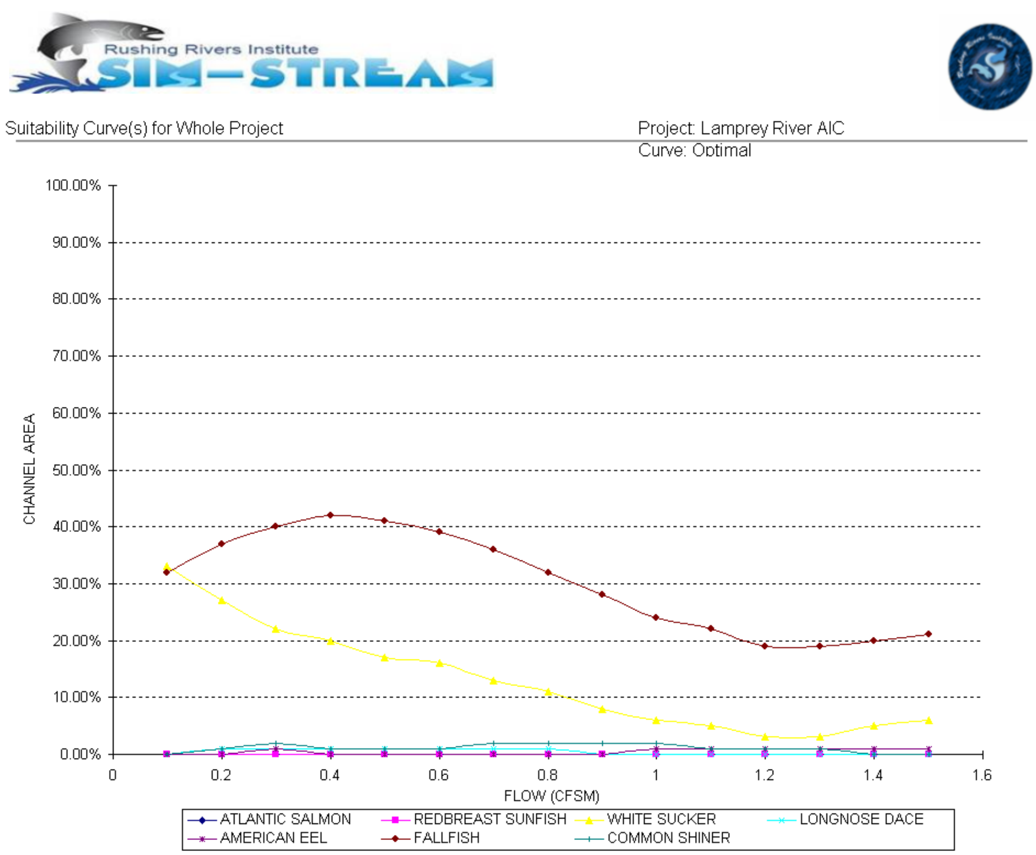

Figure 16 - Optimal habitat rating curves GRAF species during the rearing and growth bioperiod in the Lamprey Designated River for existing conditions.

Starting at 0% at 0.1 cfsm common shiner's effective habitat area reaches approximately 3 percent of channel area (CA) at 0.3 cfsm flows, then remains stable with the flow until 1.3 cfsm, decreasing slightly to 2 percent CA over 1.4 cfsm (Figure 17). Effective habitat for white sucker declines quickly from 36% at 0.1 cfsm until about 22% CA at 0.3 cfsm. It then decreases gradually to 7 percent CA over 1.2 cfsm, gaining effective habitat up to 10 percent CA for higher flows. Fallfish have the highest quantities of effective habitat of approximately 43 percent CA over 0.5 cfsm, which declines steadily to 19 percent CA with flow at 1.2 cfsm, then lightly rises to 21 percent CA. American eel, has stable habitat conditions remaining close to 10 percent CA with all the range of flows, peaking over 0.4 cfsm (close to 12 percent CA) and with lowest levels (approximately 8 percent CA) over 1.2 cfsm. Effective habitat for redbreast sunfish remains also very stable but with lower amounts of habitat, reaching the highest quantities, 5 percent CA, with flows between 0.5 and 0.7 cfsm, and the lowest peaks with 0.3 and 1.4 cfsm flows, with 3 percent CA in each one. Very small quantities of effective habitat and no effective habitat are available for longnose dace and Atlantic salmon respectively (Figure 17).

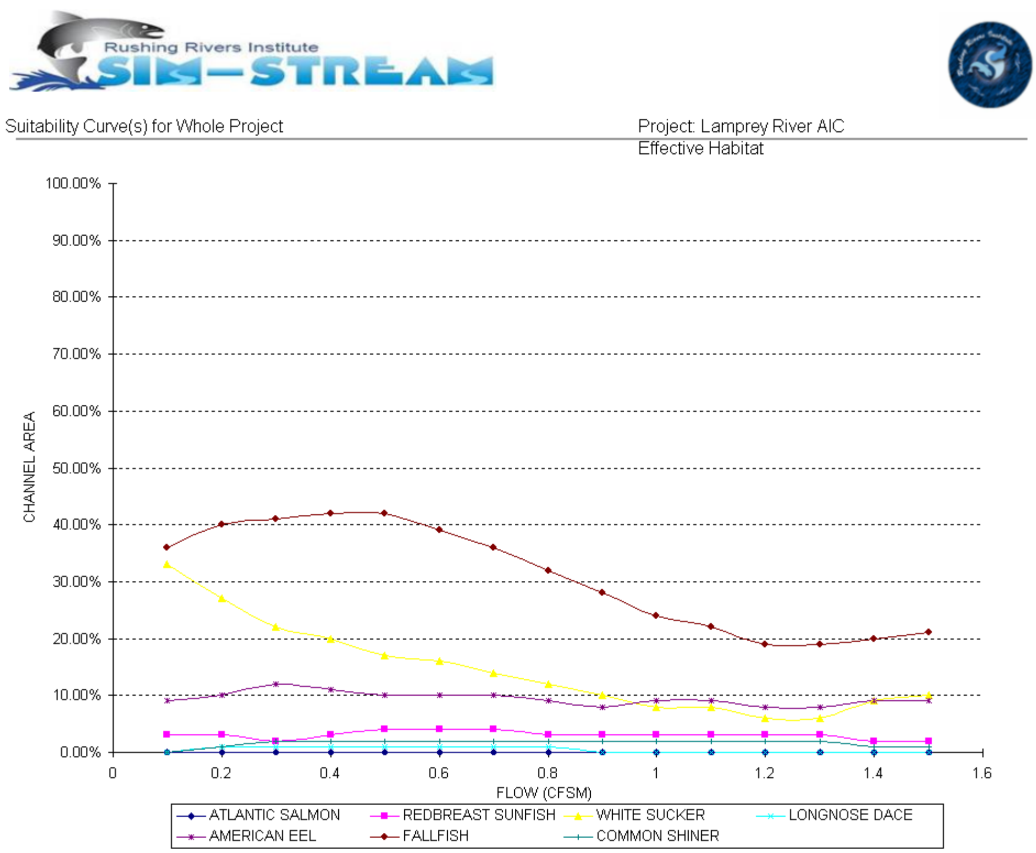

Figure 17 - Effective habitat rating curves for GRAF species during the rearing and growth bioperiod in the Lamprey Designated River for existing conditions.

When the habitats for GRAF species are analyzed under the Generic Fish model, it indicates an overall decline in the quantity of effective habitat beginning with flows above 0.2 cfsm (Figure 18). When analyzed under the Community Habitat model the conditions are relatively stable, but decline with increasing flows. The closing of the gap between the two curves indicates that although less habitat is available, it better corresponds with the target fish community structure (Figure 18). This is because Community Habitat reflects also the fish community structure; therefore the habitat area is weighted by expected species proportions in the community. Should the habitat be distributed accordingly to the community structure (more common fish has more habitat), then both models would provide identical results.

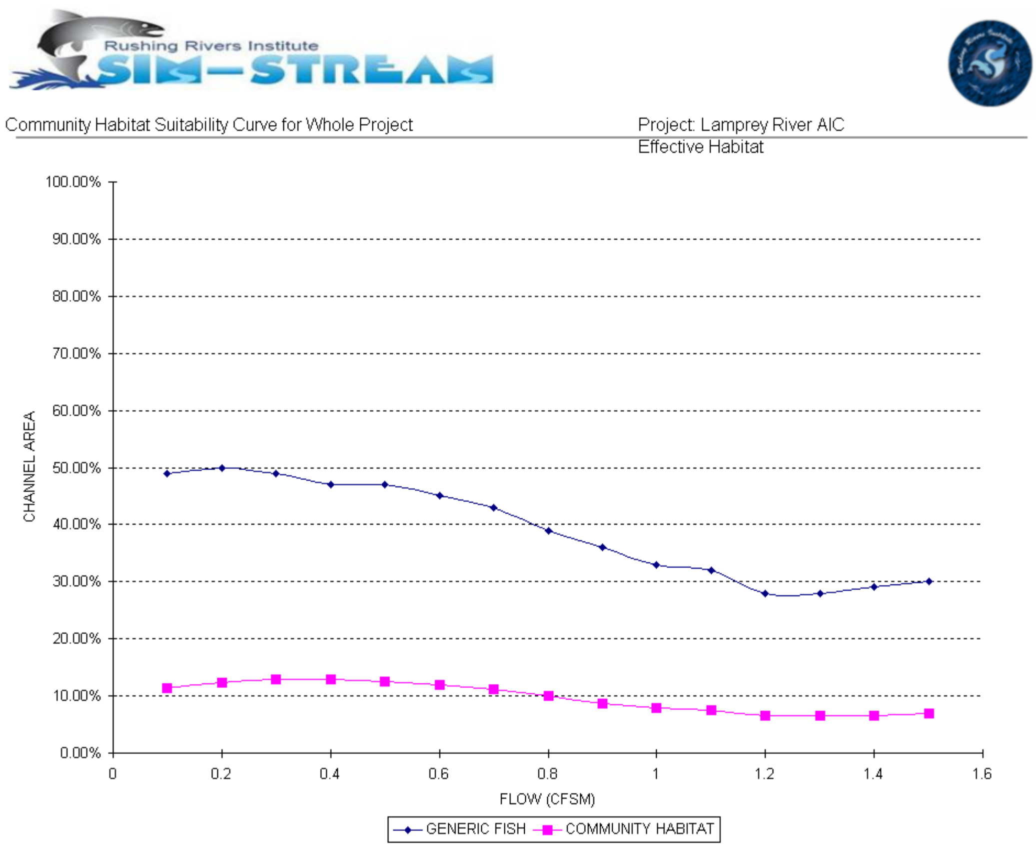

Figure 18 - Habitat rating curves for Generic Fish and Community Habitat during the rearing and growth bioperiod in the Lamprey Designated River for existing conditions.

Hydromorphological units that provide shallow margins suitable for YOY fish constitute 80 percent of the channel area under flow condition up to 1.2 cfsm before declining with increasing flows (Figure 19). It is important to note here that this value does not represent the area of suitable habitat as with the suitability curves presented for individual fish species, rather it represents the area proportion of hydromorphologic units where such habitats occur, e.g. where only a portion of HMU is suitable (Figure 19).

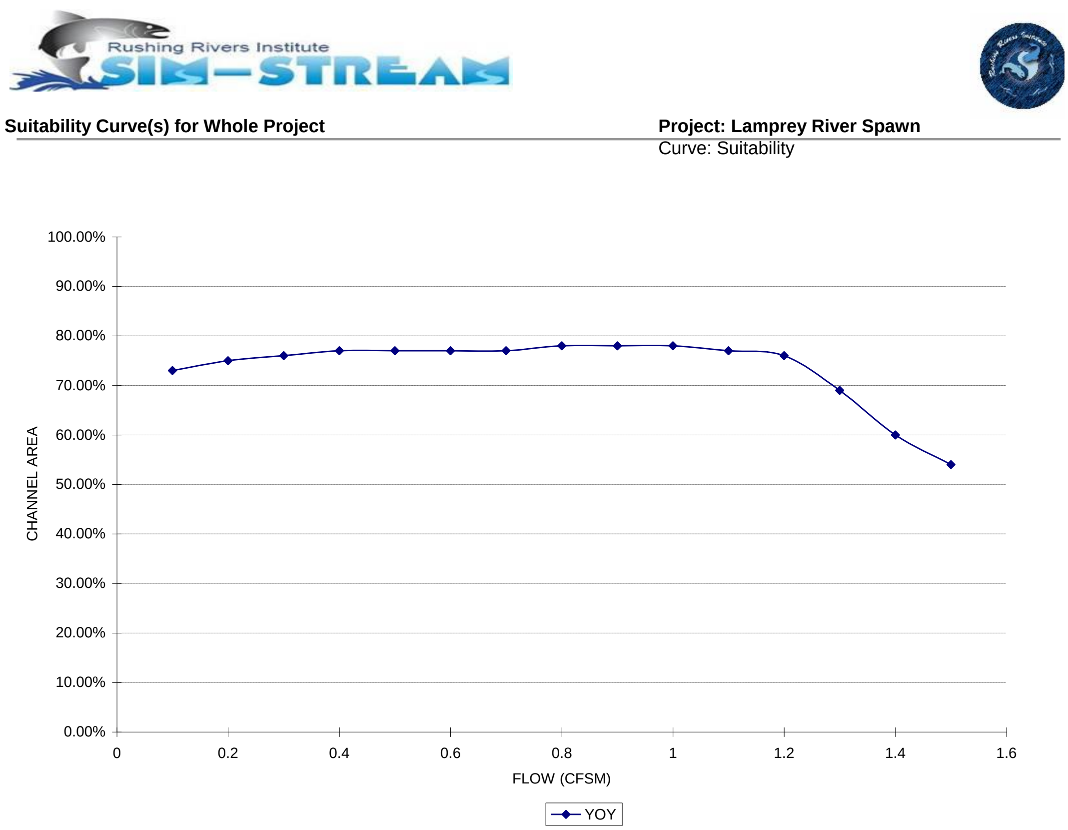

Figure 19 - Suitable habitat rating curves for young of year (YOY) during the rearing and growth bioperiod in the Lamprey Designated River for existing conditions.

The effective habitat for ephemeroptera, plecoptera, and odonates increases with flow. Plecoptera effective habitat follows the same trend but undergoes a decline above 1.2 cfsm (Figure 20). Effective habitat for trichoptera increases at flows lower than 0.3 cfsm and then decreases up to flows of 0.5 cfsm, only to rise slightly again until 1.2 cfsm before dropping sharply The latter group has less habitat than the other taxa and is relatively stable across the range of flows (between 10 and 20 percent CA). Overall, the habitat for invertebrates increases to 50 percent CA at 0.3 cfsm, levels out, and increases again at flows above 0.5 cfsm to 75 percent CA (Figure 20).

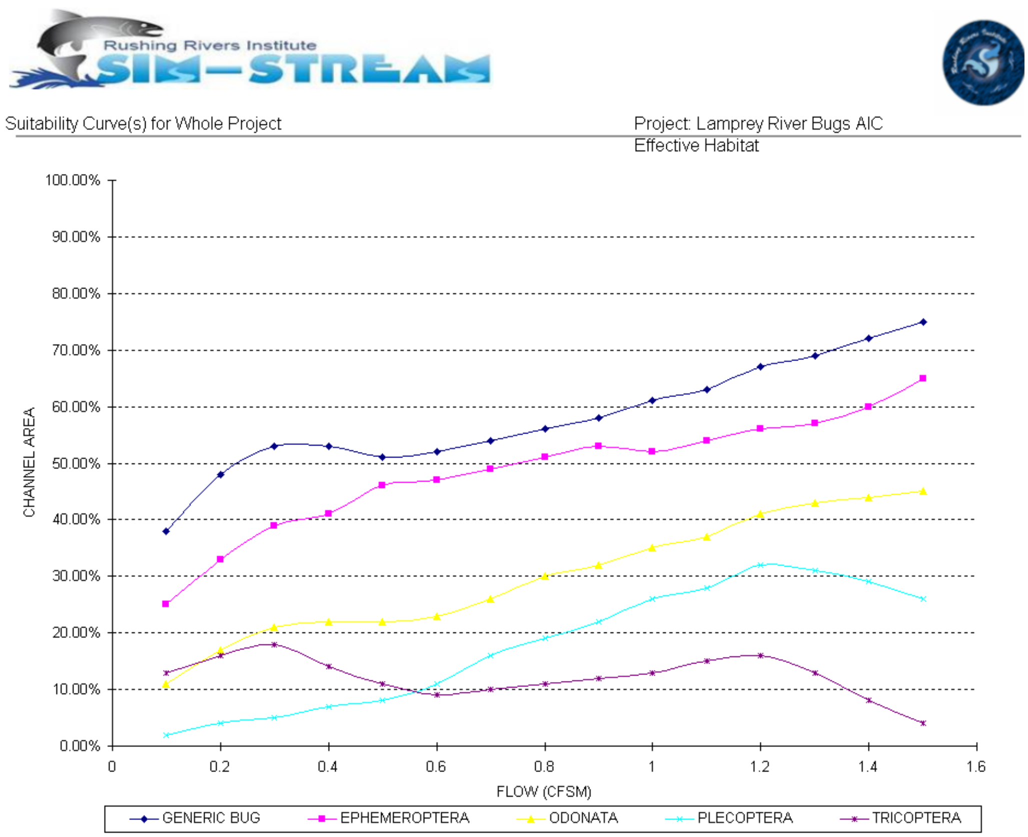

Figure 20 - Effective habitat rating curves for macroinvertebrates during the rearing and growth bioperiod in the Lamprey Designated River for existing conditions.

Spawning

The habitat suitable for spawning of redbreast sunfish is high and remains relatively stable across the investigated flow range (between 40 and 52 percent CA) (Figure 21). The habitat for fallfish first declines from 40 percent CA at 0.1 cfsm to 5 percent at 1.5 cfsm. The curve fluctuates sharply between 0.1 cfsm and 0.5 cfsm making this flow range unsuitable for spawning. Spawning habitat for white sucker increases from 5 percent CA to 20 percent CA between 0.1 and 0.5 cfsm. With increasing flows, habitat falls to nearly zero at 1.5 cfsm. In the Lamprey Designated River, the spawning habitat for common shiner and longnose dace is minimal and available only at flows less than 1.0 cfsm (Figure 21).

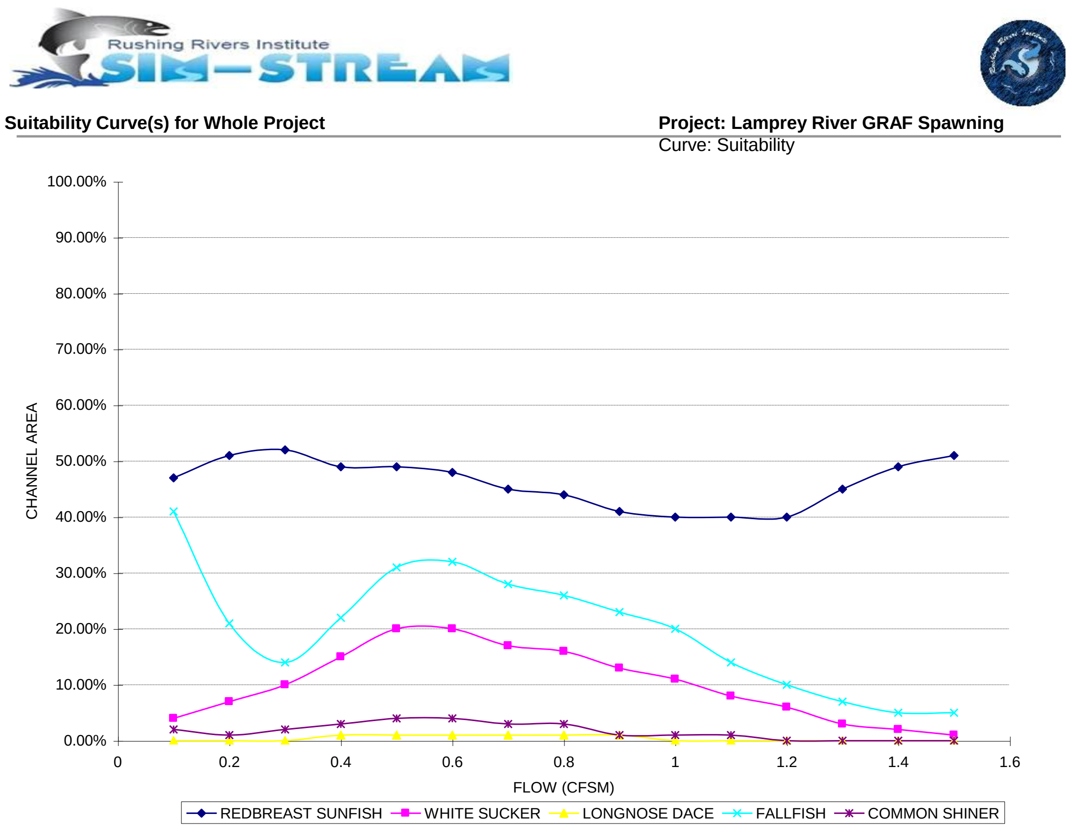

Figure 21 - Suitable habitat rating curves for GRAF species during the spawning bioperiod in the Lamprey Designated River for existing conditions.

The habitat optimal for redbreast sunfish spawning is high and remains relatively stable across the investigated flow range (between 38 and 50 percent CA) (Figure 22). The habitat for fallfish declines from 40 percent CA to 12 percent CA at 0.3 cfsm, before rebounding to over 30 percent CA at 0.5 cfsm. At flows higher than 0.6 cfsm, habitat declines steadily to 5 percent at 1.5 cfsm. The sharply fluctuating curve between 0.1 cfsm and 0.5 cfsm makes this flow range unsuitable for spawning. In the Lamprey Designated River, the optimal spawning habitat for white sucker, common shiner and longnose dace is low and available only at flows less than 1 cfsm (Figure 22).

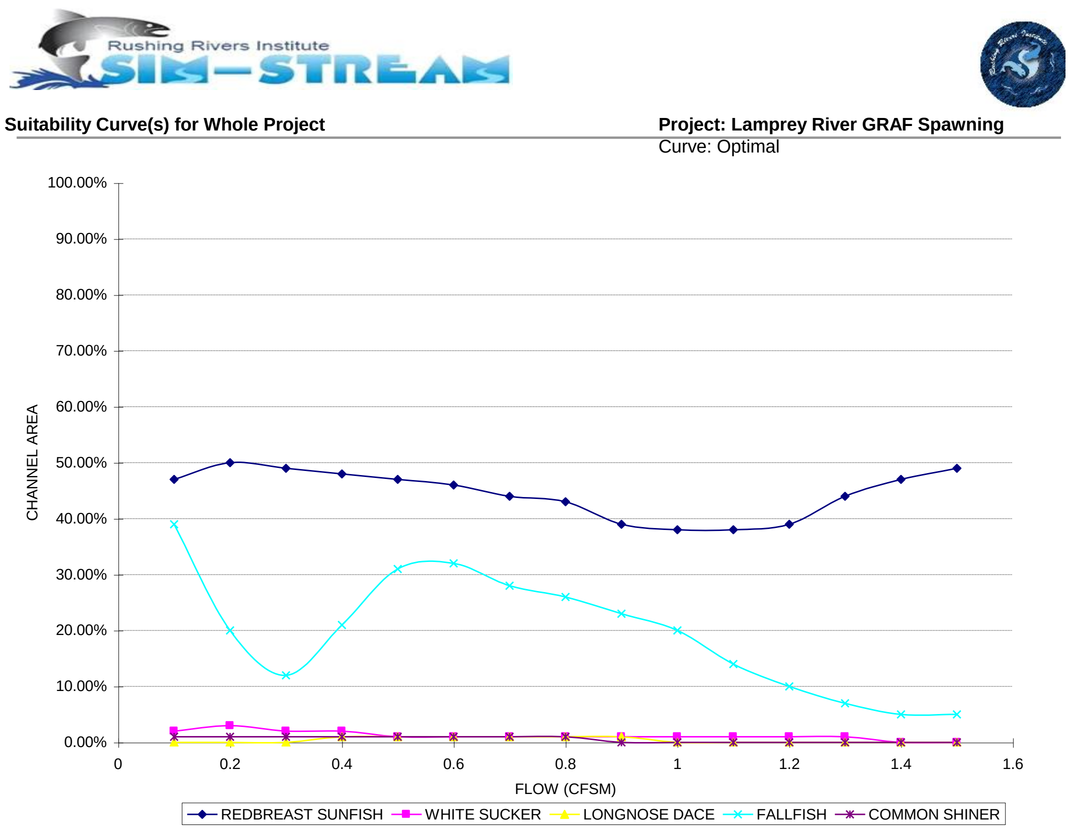

Figure 22 - Optimal habitat rating curves for GRAF species during the spawning bioperiod in the Lamprey Designated River for existing conditions.

The effective habitat for spawning of redbreast sunfish is high and remains relatively stable across the investigated flow range (between 38 and 50 percent CA) (Figure 23). The habitat for fallfish first declines from 40 percent CA at 0.1 cfsm to 5 percent at 1.5 cfsm. The curve fluctuates sharply between 0.1 cfsm and 0.5 cfsm making this flow range unsuitable for spawning. Effective spawning habitat for white sucker stays below 5 percent CA, then declines to almost zero at 1.5 cfsm. In the Lamprey Designated River, the spawning habitat for common shiner and longnose dace is low and available only at flows less than 1 cfsm (Figure 23).

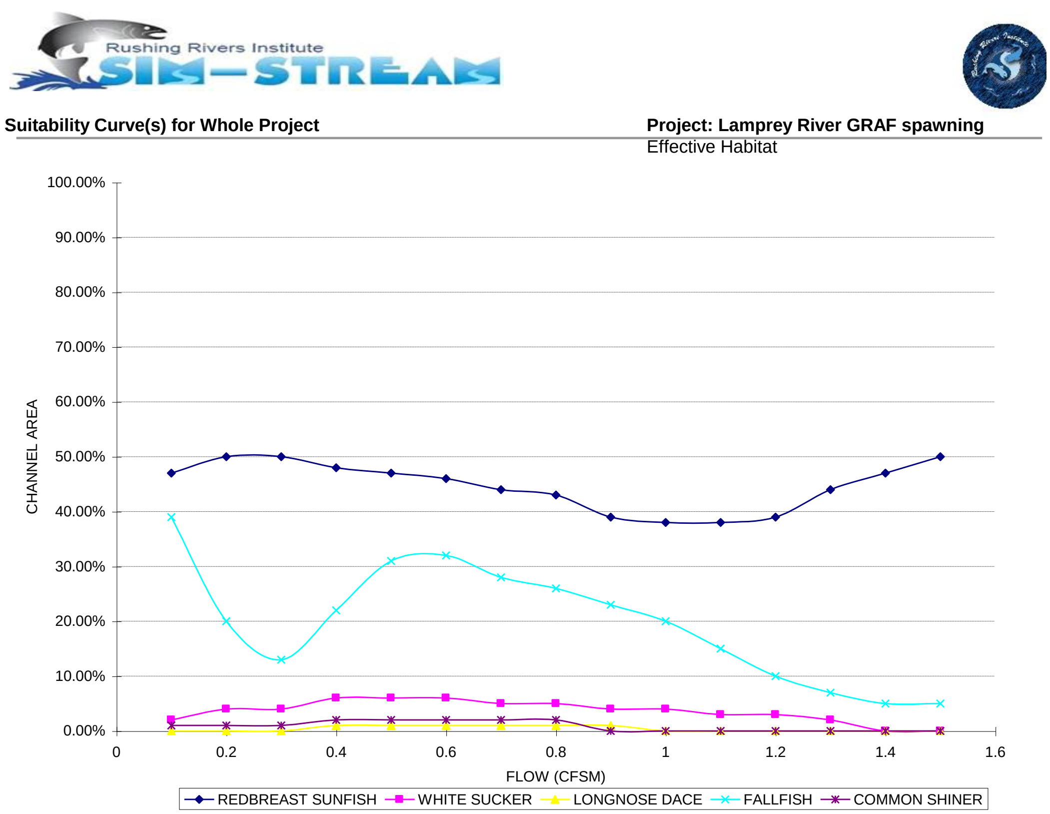

Figure 23 - Effective habitat rating curves for GRAF species during the spawning bioperiod in the Lamprey Designated River existing conditions.

When habitat suitabilities for GRAF species are aggregated into a Generic Fish model, it indicates that stable habitat conditions exist across the range of investigated flows. When expressed as Community Habitat, the conditions are also relatively stable, but decline slightly with increasing flow (Figure 24).

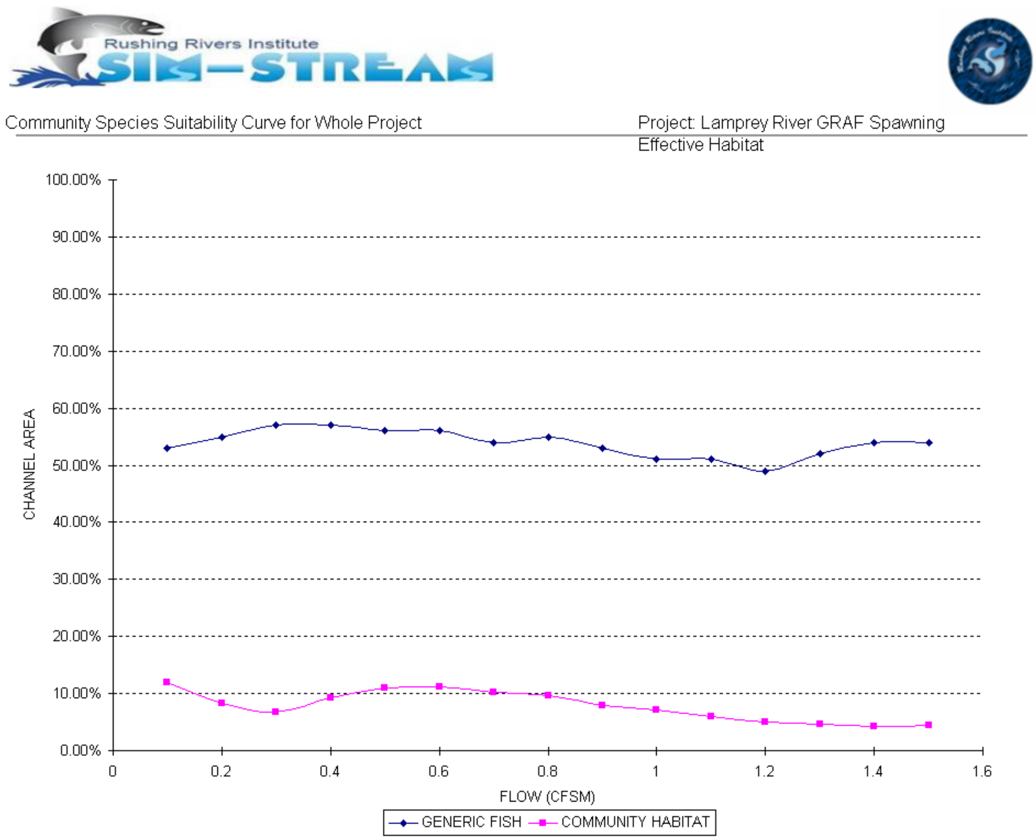

Figure 24 - Suitable community habitat rating curves for GRAF species during the spawning bioperiod in the Lamprey Designated River for existing conditions.

Anadromous Spawning

Suitable habitat for blueback herring and American shad both increase with the flow most rapidly at flows from 0.1 to 0.4 cfsm, at which point the increase is slower and habitat for blueback herring declines at flows higher than 1 cfsm (Figure 25). Alewife habitat is constant below 20 percent CA. American shad gained the most habitat area, increasing from 0 percent at 0.2 cfsm to 48 percent at 1.5 cfsm. Atlantic salmon habitat is available in low quantities with a maximum at flows of 0.5 cfsm (Figure 25).

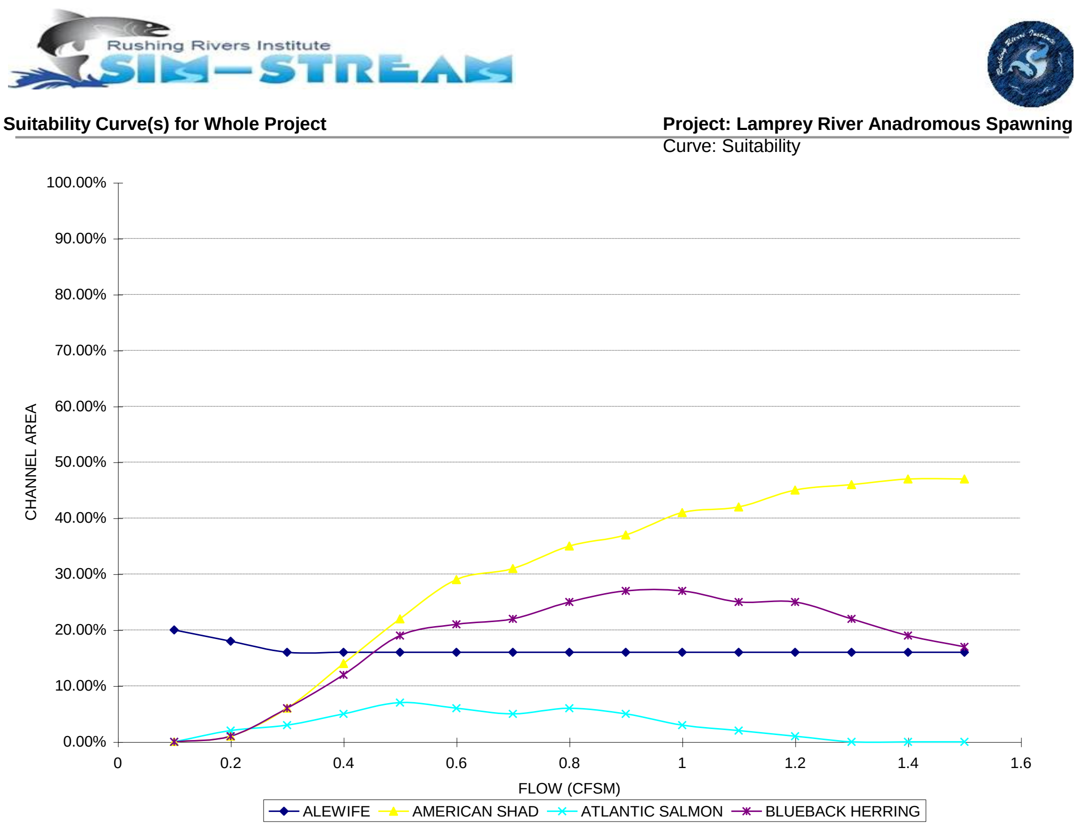

Figure 25 - Suitable habitat rating curves for anadromous species during the spawning bioperiod in the Lamprey Designated River for existing conditions.

Optimal habitat for blueback herring and American shad both increase with flow and most rapidly at flows from 0.1 to 0.4 cfsm, at which point the increase is slower and habitat for blueback herring declines at flows higher than 1 cfsm (Figure 26). Alewife habitat is constant below 20 percent CA. American shad gained the most habitat area, increasing from 0 percent at 0.2 cfsm to 42 percent at 1.2 cfsm. Atlantic salmon habitat is available in very low quantities (Figure 26).

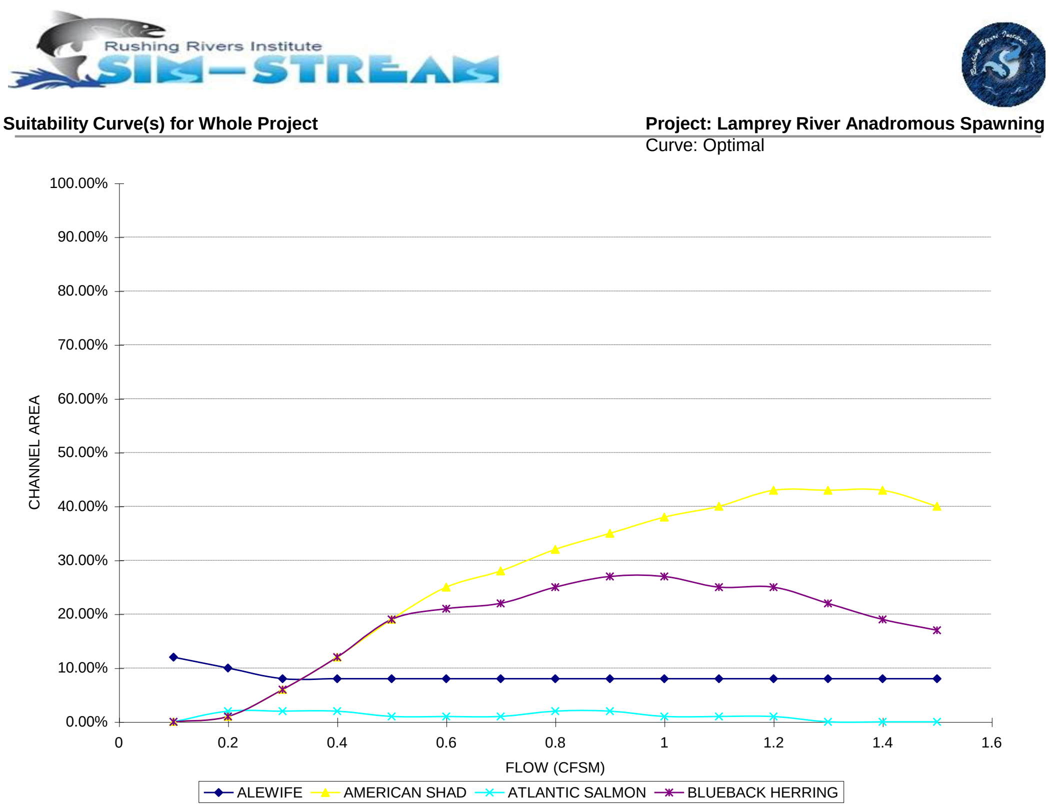

Figure 26 - Optimal habitat rating curves for anadromous species during the spawning bioperiod in the Lamprey Designated River for existing conditions.

Optimal habitat for blueback herring and American shad both increase with flow and most rapidly at flows from 0.1 to 0.4 cfsm, at which point the increase is slower and habitat for blueback herring declines at flows higher than 1 cfsm (Figure 27). Alewife habitat is constant below 20 percent CA. American shad gained the most habitat area, increasing from 0 percent at 0.2 cfsm to 45 percent at 1.3 cfsm. Atlantic salmon habitat is available in low quantities with a maximum at flows of 0.8 cfsm (Figure 27).

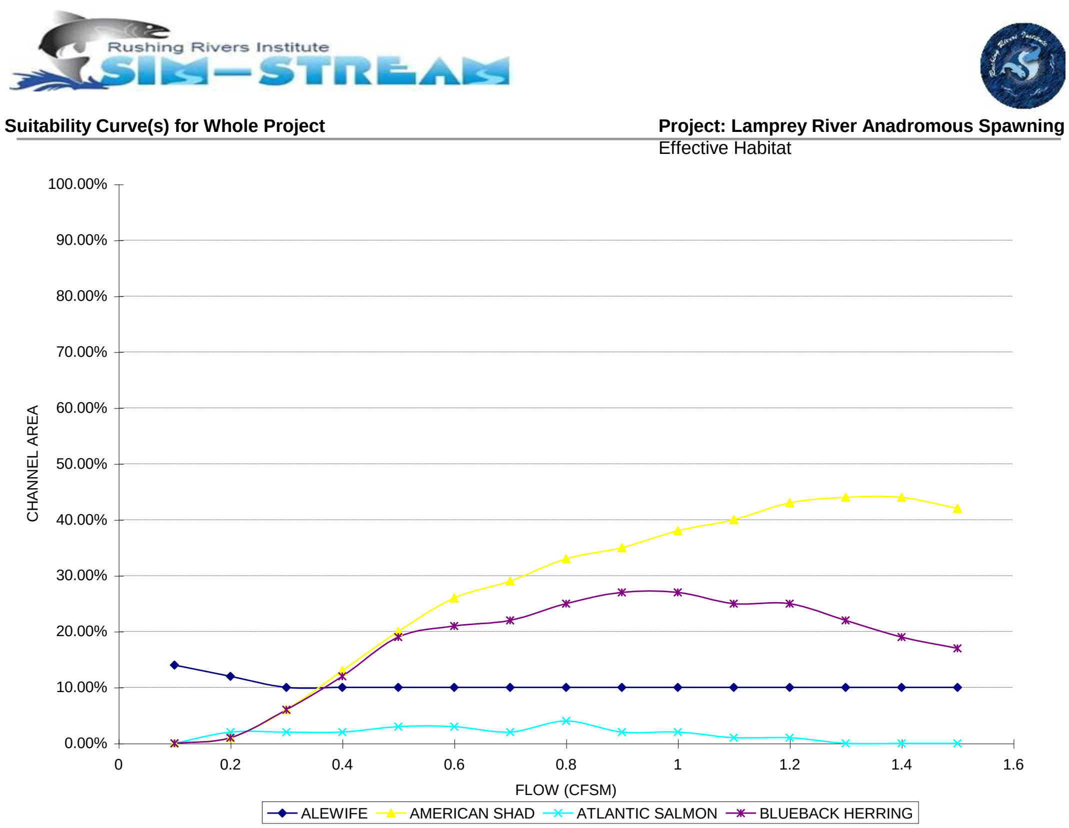

Figure 27 - Effective habitat rating curves for anadromous species during the spawning bioperiod in the Lamprey Designated River for existing conditions.

10. Comparison of Lamprey River Suitable Habitat Availability for TFC and Existing Community Species

Habitat suitability criteria were used to determine the relative proportions of suitable habitat available for the Lamprey Designated River indicator fish species. These habitat proportions were then compared to the relative proportions of expected (TFC) and existing indicator fish species to identify instances where habitat may possibly be a limiting factor in the existing proportions of fish species (Figure 28).

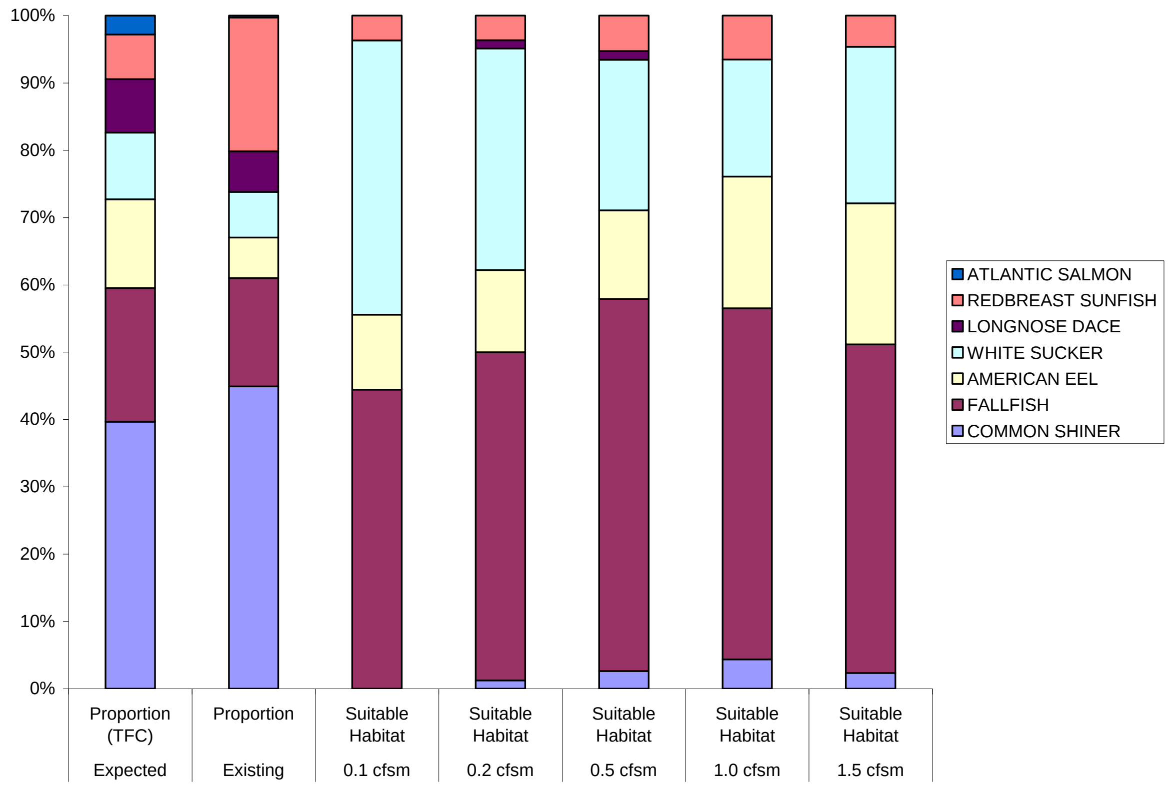

Figure 28 - Comparison of the relative proportions of existing and expected indicator fish species and the suitable habitat availability across the range of the target survey flows (in cfsm).

11. Discussion of Existing Conditions Simulation

In the rearing and growth bioperiod, there is a high amount of suitable habitat for fallfish and white sucker. Fallfish have the highest quantities of optimal habitat of all the species. However, in contrast to fallfish, the majority of habitat is not optimal, but suitable for white sucker. For both species the total amount of suitable habitat declines with flow, but at the highest flows, the proportion of suitable and optimal habitat for both increases, and this increase is sharper for white sucker. American eel has an abundance of suitable habitat, which is not optimal, but the habitat quantity is not changing dramatically with flow increase. Common shiner has a relatively low amount of suitable habitat, but the majority of it is optimal where high abundances of this species are expected. These habitats are very localized and limited to the pockets in the free-flowing sections of the river. This fish is very gregarious and is usually found in high densities in the suitable habitat areas. Very little habitat was found suitable for Atlantic salmon and longnose dace. Both species are not represented very strongly in the target fish community and are not expected to have a lot of habitat. Furthermore, longnose dace is a small gregarious species usually found in large quantities in suitable habitats, and therefore, the habitat may not be limited. Abundant suitable habitat is available for redbreast sunfish and although it is not optimal, it is not very sensitive to flow and roughly remains stable. In terms of effective habitat, the most noticeable sensitivity to flow is for white sucker and fallfish. The amount of habitat decreases with flow for both of these species

The total amount of effective habitat for adult fish (shown on Figure 13 as generic fish habitat) declines with flow and the structure of this habitat doesn’t correspond well with the target fish community structure. This is because the magnitude of Community Habitat is so much lower. Therefore, the decline in generic fish habitat area is caused by the loss of habitat for fallfish and white sucker. Due to the low expected proportions of this species however, their habitat loss has little effect on the Community Habitat curve.

The low quantity of community habitat is caused by limited quantity of habitat for the top fish (common shiner), and higher level of habitat for secondary fish such as redbreast sunfish and white sucker. However, for the reasons mentioned above (relation between suitable and optimal habitat and fish densities in units area), this picture may be a little misleading, and should not be directly contrasted with relatively high proportions of common shiner found in the river. Since this fish should be the most common in the Lamprey River, (it usually occurs in high abundances and available habitat is often optimal), the high proportions of this fish are to be expected. The high levels of stable and largely suitable habitat for redbreast sunfish correspond well with high numbers of this fish captured during the fish surveys. The area within the hydromorphologic units with YOY habitat is very high and it declines at flows higher than 1.2 cfsm, documenting that there is sufficient area offering nurseries for young fish.

The overall increase of habitat with flow for a majority of the invertebrates is interesting because it is almost the opposite of the fish habitat. It is conceivable that this trend is related to the predation on these animals by fish. The data for development of the habitat suitability model were collected in the streams where fish are also present. It is conceivable that the area with a low abundance of macroinvertebrates were those with a high abundance of fish and vice versa.

Many curves show three distinct zones of habitat suitability as flow conditions change. A relatively rapid change of gradient and variability in rating curves occurs where flows are less than 0.3 cfsm; gradually changes and relatively stable habitat suitabilities occur at flows between 0.3 to 1.2 cfsm and at flows higher than 1.2 cfsm, frequent gradient changes occur.

During the spawning season for resident fish, the habitat for sunfish is abundant, often optimal, and relatively stable. There is plenty of habitat for fallfish, although it is flow sensitive and there is only suitable, not optimal habitat for white sucker and common shiner. The best habitat conditions occur between 0.4 and 1.2 cfsm, although overabundance of redbreast sunfish habitat makes this trend less obvious. The habitat for spawning of American shad and blueback herring increases with flows and offers larger quantities at flows higher than 0.5 cfsm, with some decline at flows higher than 1.2 cfsm. Because alewife naturally spawn in lakes, the low habitat levels in the Lamprey Designated River are not limiting. For Atlantic salmon, which spawn in the fall, there is a small amount of suitable habitat with maximum at flows of 0.5 cfsm. This habitat is not optimal and declines at higher flows to zero.

12. Defining Baseline Stream Morphological Conditions

Fish habitat is a function of both flow and stream morphology. If the habitat structure is altered, flow management may not be enough to maintain habitat. To define appropriate flows in the case of the Lamprey Designated River, where segments are altered by dams, requires defining the baseline stream morphology. Once the baseline morphology is established, the flows required to meet the habitat needs can be determined.

Changes in morphology can cause non-linear effects in the flow needed to maintain habitat levels. Defining protected flows for the fish species that should occur in the Lamprey Designated River TFC requires determination of conditions to which the fauna are adapted. The interplay of flow and natural morphological structure define the available habitat within which natural selection favors the species utilizing that habitat. If morphological structure is modified, even the most natural flows may be unable to create the patterns of depth and velocity that the native fauna is looking for. If both flow pattern and habitat structure are modified, finding suitable habitat conditions is even less likely.

This study aims to reconstruct the natural flow patterns to meet the habitat needs of native fauna. Since the occurrence of habitat is a both a function of flow and morphological structure, these two variables must be considered in the evaluation of instream habitat. To identify the native flow needs to maintain a supportive level of habitat, the baseline morphological conditions need to be established first. These are defined by the attributes observed in the river that are associated with fish presence (e.g. woody debris).

The first step is to identify the limitations of the current stream morphology and to substitute improvements. The habitat needs of the target aquatic species for hydromorphologic setting, and historical information, or known obvious impairments, such as dams, guide the computer simulation of habitat improvements by simulating dam removals, the introduction of woody debris, or connecting side arms. The effect of these measures is evaluated by an observation of changes gained in fish habitat. This process is repeated until the best available habitat conditions have been created. Best is determined here as the greatest quantity as well as the quality (e.g. habitat structure) that can be achieved under current landscape limitations. Once the baseline morphology has been created, the temporary habitat patterns that should occur naturally and the flows supporting them need to be determined.

In the Lamprey Designated River, a dramatic shift in fish populations between the upstream sections (1-4) and downstream sections (5-8) was noted. The most noticeable habitat difference between these two areas, and the most significant historical change in habitat, is the increase in impounded area due to the Wiswall and Macallen Dams. It follows that the proportion of free-flowing river could be increased for the model, thereby replacing habitat that was once available to fluvial species to define the baseline conditions. So it was decided to model the potential habitat improvements through the removal of Wiswall Dam and reducing the height of the Macallen Dam by two meters (6.6 ft). The complete removal of Macallen Dam was not included, because it seems to be constructed on a bedrock controlled waterfall, with an apparent high point and constriction of the valley under the Rte 108 Bridge. The estimate of a two meter (6.6 ft) drop was therefore considered a reasonable estimate of the changes associated with removal of the dam.

A detailed bathymetry survey of the two large impoundments was conducted using an Acoustic Doppler Current Profiler (ADCP), accompanied by a scuba survey of the Macallen impoundment. Additional onsite observations of the Wiswall impoundment were made during the draw-down for its' structural inspection. Using this information, the channel morphology of these impounded areas was interpreted and the hydromorphologic units were assigned to the affected areas of Sites 5 and 8. Physical attribute information was based on field observations and reference to hydromorphologic units in what were perceived to be similar physical situations. Velocity data were derived from data gathered in similar hydromorphologic units located upstream.

Secondly, field observations and later analysis led to the decision to develop Section 2b to describe a stretch of habitat that was not observed in quantity anywhere else in the Lamprey Designated River. The close proximity of farmland and pasture to the river in this section has led to areas of increased bank instability, a decrease in attributes like canopy shading and undercut banks, and the addition of large amounts of fine sediment due to slumping and erosion. This led to a section that is shallower than may occur naturally and is practically smothered by large amounts of sand. As a result, it was concluded that it was necessary to include improvement of this section in the baseline conditions simulation. To account for the changes to this site in terms of baseline conditions, it was decided to remove the representative site and extend the lengths of Sites 2a and 3 to account proportionally for the changes in habitat that they would represent under restored conditions.

The model modifications also include a maturing of the river corridor. Woody debris presence was added to nearly all hydromorphologic units to account for the addition and distribution of fallen trees in a mature system. It is acknowledged that the addition of woody debris could have an effect on the distribution and size of hydromorphologic units and other intrinsic attributes, but the prediction of these changes is limited. The model rating curves are therefore a prediction at the instantaneous available habitat changes. Additionally, the presence of undercut banks was added to most of the runs and pools throughout the project where they were previously absent and were considered abundant at the higher mapped flows. Finally, the presence of overhanging vegetation was added to most hydromorphologic units except for those where it was not expected to occur naturally, for example the long glide in Site 4 and the large pools of Site 8.

For the evaluation of the habitat rating curves for the baseline conditions the target survey flows (Table 11) were used. These target survey flows are based on the discharge of the Lamprey River as recorded at the USGS Packers Falls gaging station during the field work. These flows are not adjusted for any water withdrawals, dam storage or dam releases. These target flows were used for the rating curves in the habitat modeling of the existing and baseline conditions to show the change in habitat that would occur in response to the changes in stream morphology.

13. Results of the Modeling of Baseline Conditions

The following are graphs and descriptions of observed changes in suitable habitat areas between the original MesoHABSIM model and the simulation of river baseline improvements.

Rearing and Growth Bioperiod

The majority of suitable habitat is available for American eel and fallfish with values close to 50 percent CA (Figure 29). The curve for American eel declines slightly and gradually at flows below 1.0 cfsm then remains stable until 1.2 to increase again reaching approximately 55 percent CA. For fallfish the decrease is sharper until 18 percent CA, then starts to rise again over 1.2 cfsm, reaching 22 percent CA for 1.5 cfsm. White sucker habitat declines sharply from 40 to 20 percent at flows of 0.5 cfsm and remains at this level at higher flows. Common shiner has stable habitat levels of 10 percent CA below 0.5 cfsm then the curve inclines to 14 percent CA at flow 1.1 cfsm and then decreases gradually to 11 percent CA over 1.5 cfsm. Habitat suitable for sunfish decreases with flows below 0.3 cfsm until 10 percent CA and then remains stable. Longnose dace remains stable with 6 percent CA between 0.2 and 1.2 cfsm, and decreases slightly and gradually for further flows until 2 percent CA over 1.5 cfsm The quantities of suitable habitat that are available for Atlantic salmon increases with flows between 0.1 and 0.3 cfsm reaching 7 percent CA and then decreasing to 3 percent CA over 0.6 cfsm, remaining relatively stable with a slight decline and then gradually gain habitat for flows higher than 1.2 cfsm recovering 7 percent CA over 1.5 cfsm (Figure 29).

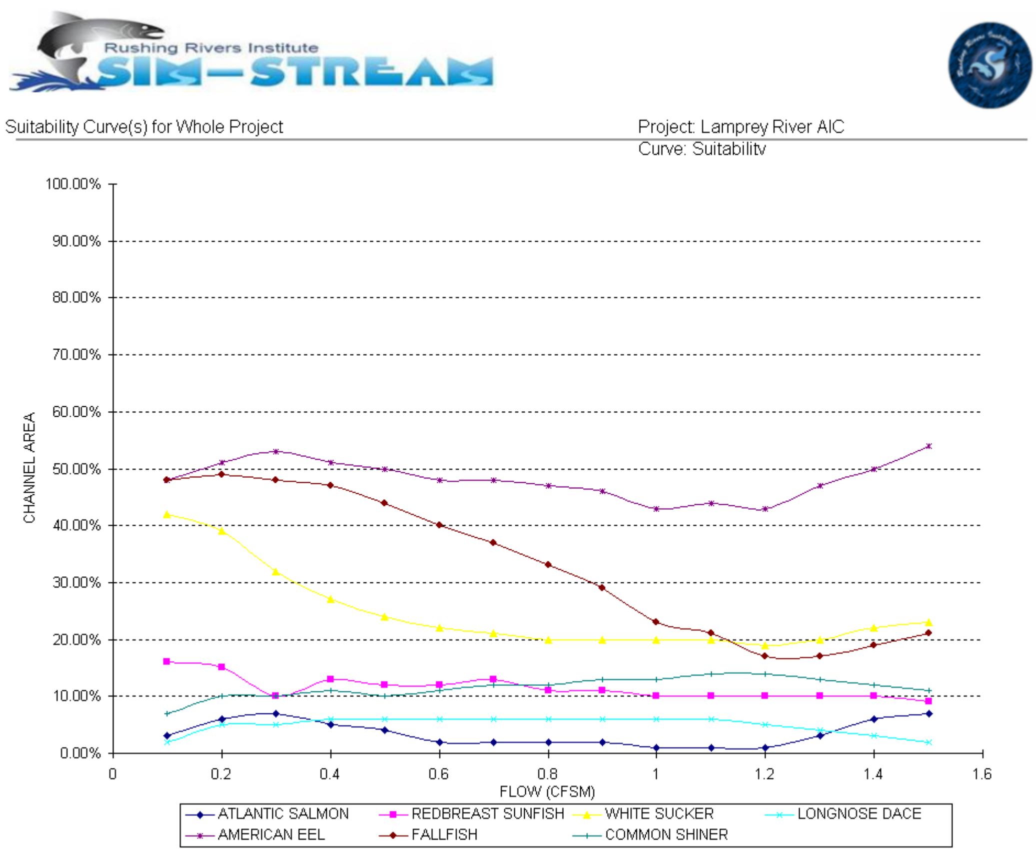

Figure 29 - Suitable habitat rating curves for GRAF species during the rearing and growth bioperiod in the Lamprey Designated River for baseline conditions.

The majority of optimal habitat for any species is available for fallfish, with values close to 45 percent CA peaking at 0.4 cfsm, then decreasing until 16 percent CA at 1.2 cfsm and finally increasing slightly at higher flows (Figure 30). Optimal habitat of white sucker drops with flow, with highest quantities (40 percent CA) for flows close to 0.1 cfsm and the lowest values (4 percent) over 1.2 cfsm. Optimal habitat for American eel is relatively stable remaining close to 5 percent CA. Common shiner has also stable habitat levels below 10 percent CA between 0.2 and 0.9 cfsm, reaching 10 percent over 0.9 to 1.1 cfsm and then gradually dropping to 5 percent CA over 1.5 cfsm. Optimal habitat for sunfish and longnose dace is limited and nonexistent for the majority of the range of flows. The quantities of optimal habitat that are available for Atlantic salmon are around 5 percent at flows between 0.2 cfsm and 0.4 cfsm, and then decreases until 0 percent habitat at flows higher than 1 cfsm (Figure 30).

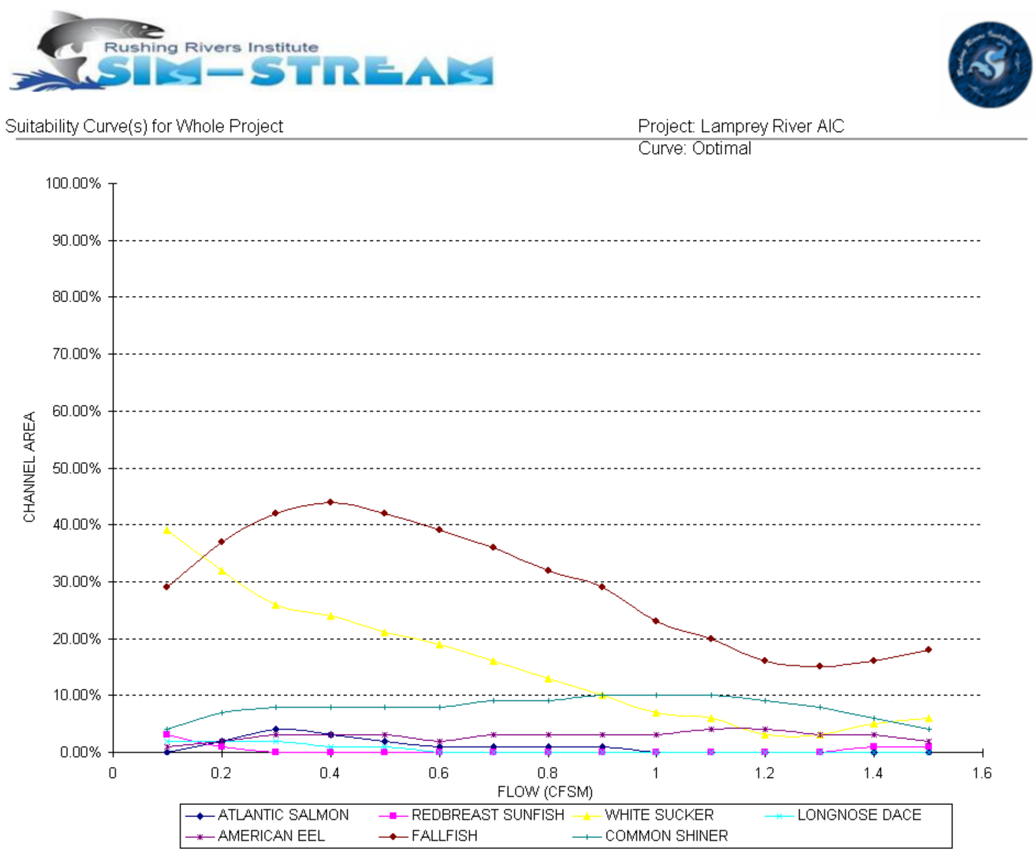

Figure 30 - Optimal habitat rating curves for GRAF species during the rearing and growth bioperiod in the Lamprey Designated River for baseline conditions.

Common shiner has increasing effective habitat area with flow until approximately 1.1 cfsm where it reaches 12 percent of channel area and then declines to 6 percent CA (Figure 31). Effective habitat for white sucker declines gradually with flows, at flows between 1 and 1.1 cfsm remains stable with 10 percent CA then decreases slightly to reach 10 percent CA again over 1.4 cfsm. Fallfish have the highest quantities of optimal habitat (close to 45 percent CA), which however declines to 16 percent CA with flows over 1.2 cfsm until it levels out above 1.2 cfsm, reaching about 18 percent CA over 1.5 cfsm. Effective habitat for American eel remains stable close to 15 percent CA. Very small quantities of optimal habitat are available for Atlantic salmon and longnose dace. Effective habitat for redbreast sunfish also stays relatively stable between 7 percent and 3 percent CA (Figure 31).

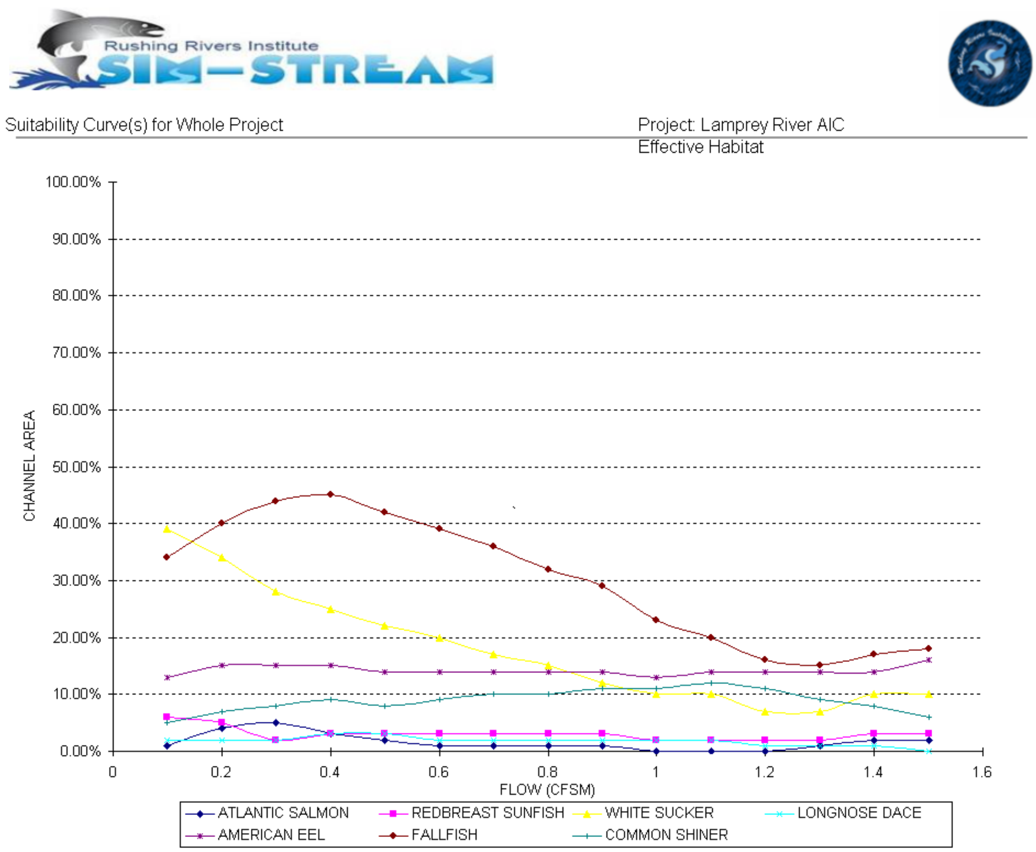

Figure 31 - Effective habitat rating curves for GRAF species during the rearing and growth bioperiod in the Lamprey Designated River for baseline conditions.

When habitat for GRAF species is aggregated to the generic fish model it indicates a decrease of effective habitat as flow increases, starting with 58 percent of CA and gradually dropping to about 35 percent CA over 1.5 cfsm. When expressed as community habitat the conditions are relatively stable, but also showing a slight decrease with flow and finally maintaining 10 percent CA at flows higher than 1.2 cfsm (Figure 32).

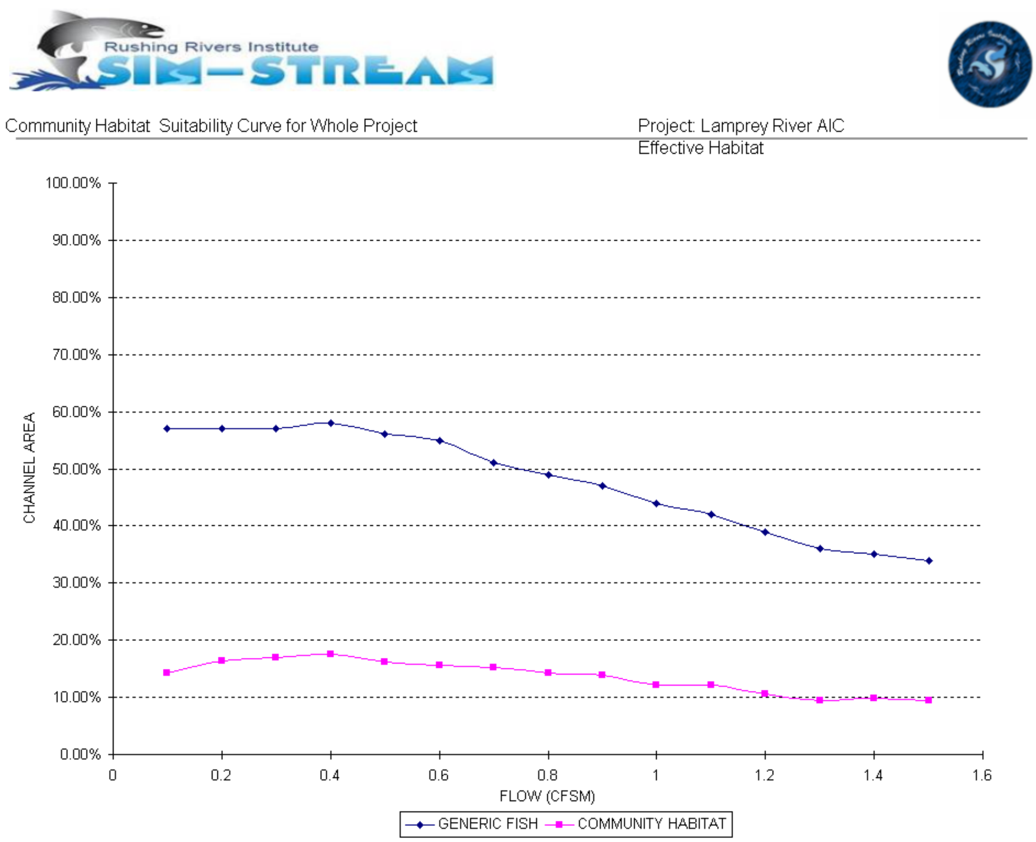

Figure 32 - Habitat rating curves for generic fish and community habitat during the rearing and growth bioperiod in the Lamprey Designated River for baseline conditions.

Units that offer shallow margins suitable for YOY fish make up to 80 percent of the channel area which declines drastically at flows higher than 1.2 cfsm. Please note that this value does not represent the area of suitable habitat for fish, but the hydromorphologic units where such habitats occur (Figure 33).

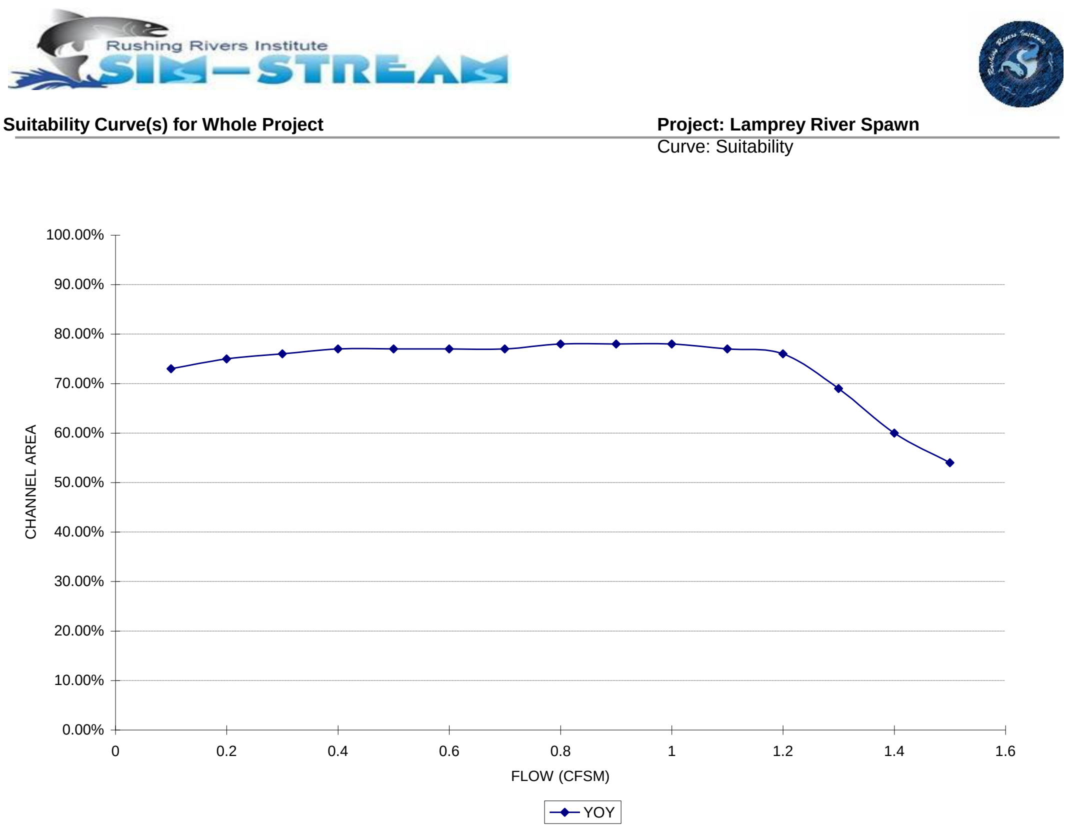

Figure 33 - Suitable habitat rating curves for young of year (YOY) during the rearing and growth bioperiod in the Lamprey Designated River for baseline conditions.

The effective habitat for the families ephemeroptera and plecoptera increases with increasing flow (Figure 34). There is a decline above 1.2 cfsm for plecoptera and trichoptera. The latter group has habitat that is lower than the other taxa and relatively stable across the range of flows (between 14 and 24 percent CA). The habitat suitable for odonates increases only between 0.1 and 0.4 cfs and then remains stable around 50 percent CA. Overall, the habitat for invertebrates increases to 70 percent CA at 0.7 cfsm and levels out at higher flows (Figure 34).

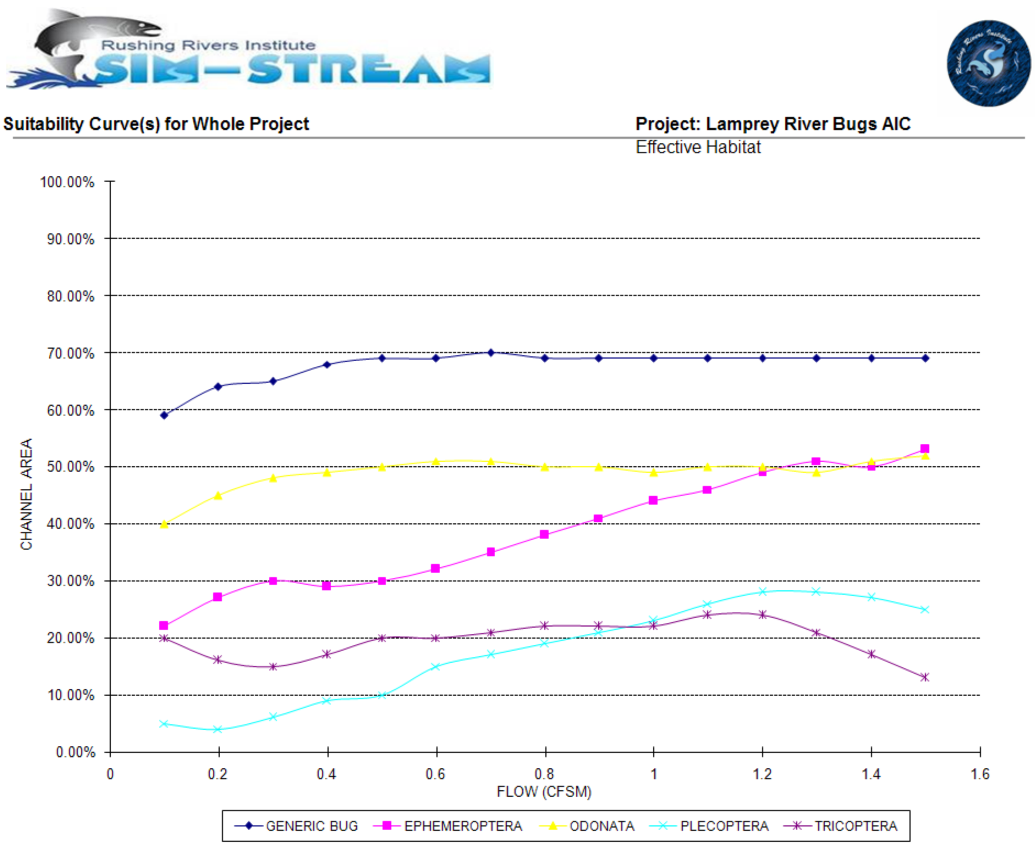

Figure 34 - Effective habitat rating curves for macroinvertebrates during the rearing and growth bioperiod in the Lamprey Designated River for baseline conditions.

Spawning

The habitat suitable for spawning of redbreast sunfish is high and remains relatively stable across the investigated flow range, however suitabilities are optimum at 0.3 cfsm and lowest at values between 0.7 cfsm and 1.2 cfsm (Figure 35). The habitat for fallfish first declines from 40 percent CA at 0.1 cfsm to 5 percent at 1.5 cfsm. The curve fluctuates sharply between 0.1 cfsm and 0.5 cfsm making this flow range unsuitable for spawning. Spawning habitat for white sucker increases from 10 percent CA to 15 percent CA between 0.1 and 0.5 cfsm then remains at 12 percent CA and declines to 5 percent above 1.2 cfsm. The habitat suitable for spawning of common shiner remains at about 5 percent until the flows increase above 1.0 cfsm and for longnose dace the habitat reaches 5 percent CA at flows of 0.5 cfsm (Figure 35).

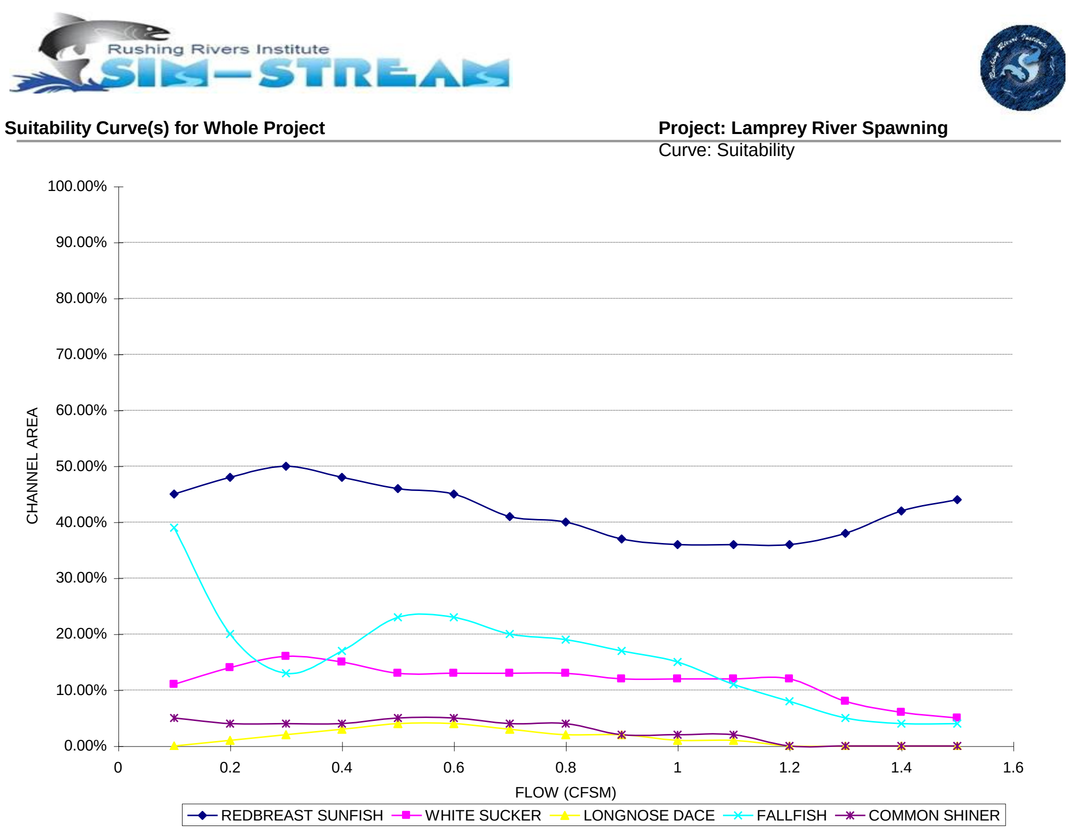

Figure 35 - Suitable habitat rating curves for GRAF species during the spawning bioperiod in the Lamprey Designated River for baseline conditions.

The optimal habitat for redbreast sunfish spawning is high and remains relatively stable across the investigated flow range (between 32 and 48 percent CA) (Figure 36). The habitat for fallfish first declines from 40 percent CA at 0.1 cfsm to 5 percent at 1.5 cfsm. The curve fluctuates sharply between 0.1 cfsm and 0.5 cfsm making this flow range unsuitable for spawning. In the designated river the optimal spawning habitat for common shiner and longnose dace is low and available only at flows less than 1 cfsm. For white sucker the habitat is a little higher (5 percent CA) and available over the entire range of flows (Figure 36).

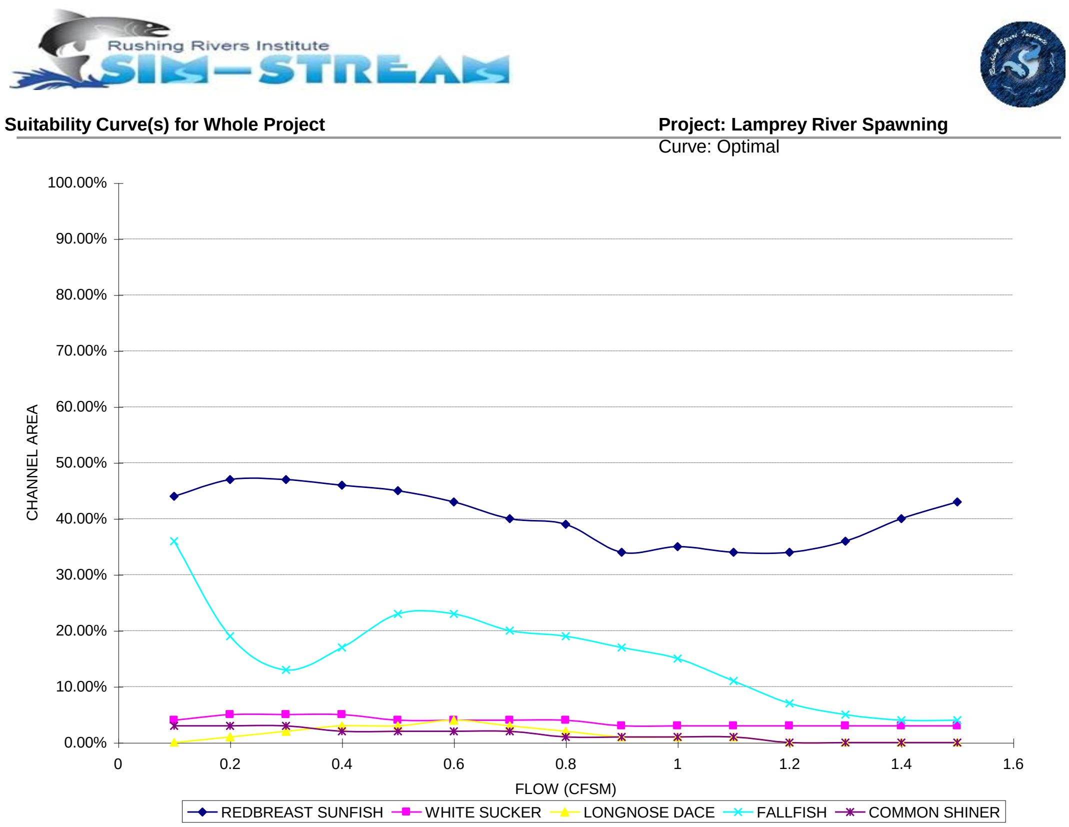

Figure 36 - Optimal habitat rating curves for GRAF species during the spawning bioperiod in the Lamprey Designated River for baseline conditions.

The effective habitat for redbreast sunfish spawning is high and remains relatively stable across the investigated flow range (between 33 and 48 percent CA) (Figure 37). The habitat for fallfish first declines from 40 percent CA at 0.1 cfsm to 5 percent at 1.5 cfsm. The curve fluctuates sharply between 0.1 cfsm and 0.5 cfsm making this flow range unsuitable for spawning. Effective spawning habitat for white sucker stays below 10 percent CA and is stable across the entire flow range. In the Lamprey Designated River, the spawning habitat for common shiner and longnose dace is low and available only at flows less than 1.2 cfsm (Figure 37).

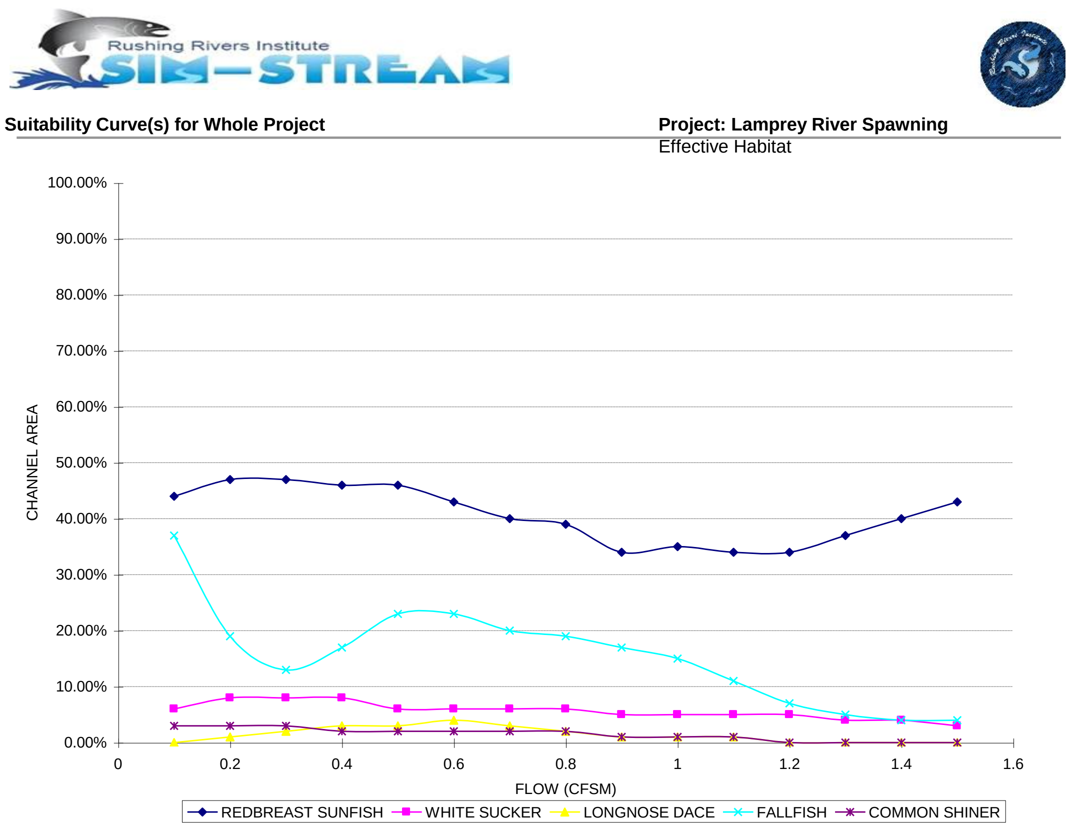

Figure 37 - Effective habitat rating curves for GRAF species during the spawning bioperiod in the Lamprey Designated River for baseline conditions.

When habitat for GRAF species is aggregated to a generic fish model it indicates stable habitat conditions across the range of investigated flows. When expressed as community habitat the conditions are also relatively stable but decline slightly with increasing flows (Figure 38).

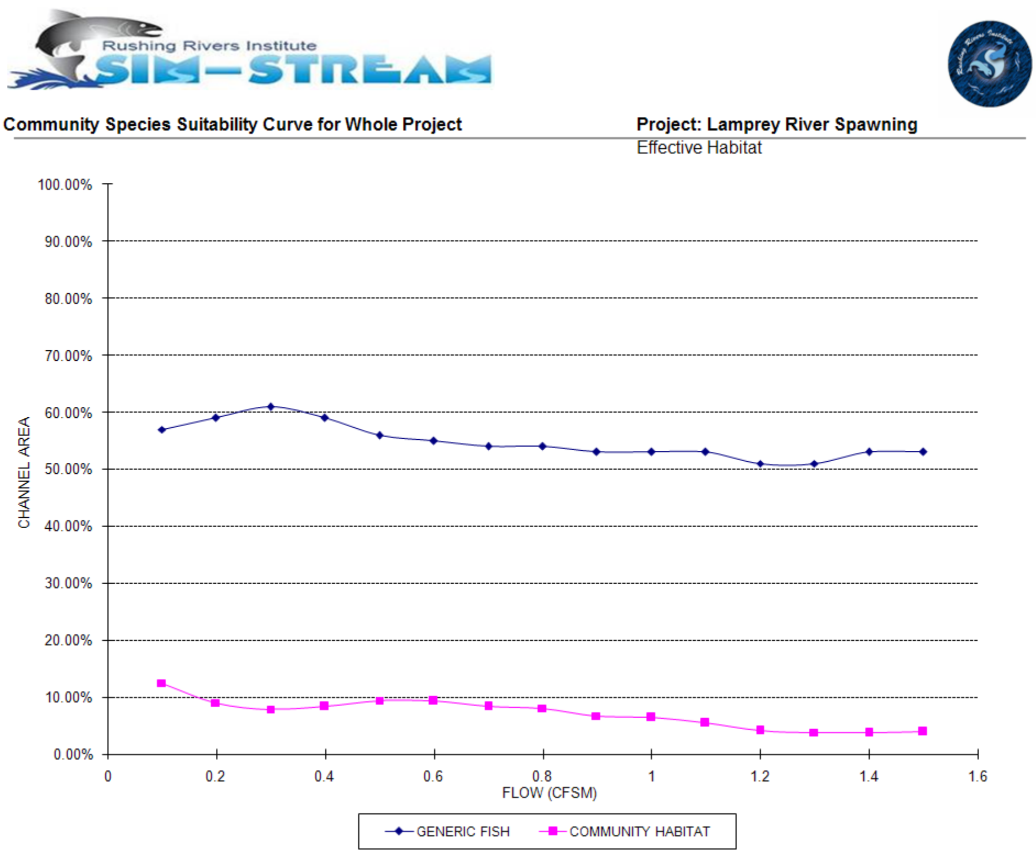

Figure 38 - Suitable community habitat rating curves for GRAF species during the spawning bioperiod in the Lamprey Designated River for baseline conditions.

Anadromous Spawning

Suitable habitat for American shad increases with flow rapidly until 1.2 cfsm, at which point it levels out at 50 percent CA. Suitable spawning habitat for blueback herring also increases until about 1.0 cfsm when it reaches 25 percent CA. Alewife habitat is constant at 10 percent CA. Atlantic salmon habitat is available in low quantities with a maximum at flows of 0.3 cfsm (Figure 39).

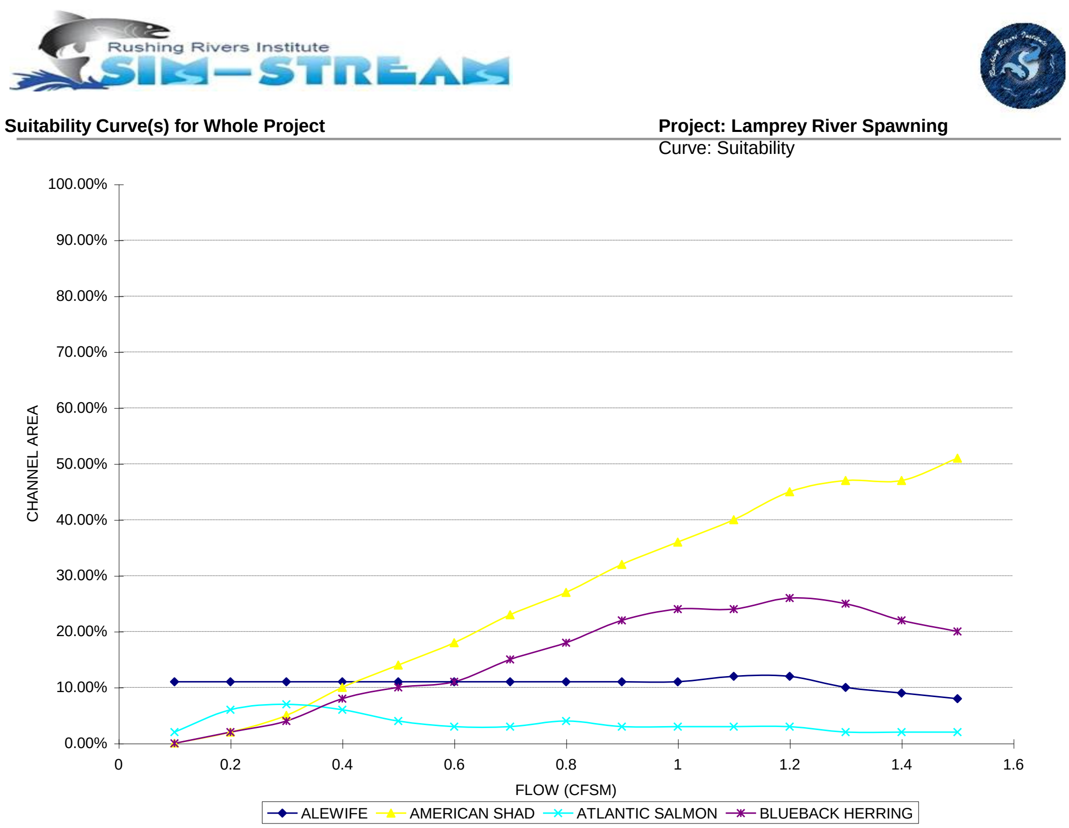

Figure 39 - Suitable habitat rating curves for anadromous species during the spawning bioperiod in the Lamprey Designated River for baseline conditions.

Optimal habitat for blueback herring and American shad both increase with flow until 1.1 cfsm where the habitat then remains stable at 42 percent CA (Figure 40). Habitat for blueback herring declines at flows higher than 1.2 cfsm. Alewife habitat is constantly below 3 percent CA over the range of flows. American shad gained the most habitat area, increasing from 0 percent at 0.1 cfsm to 42 percent at 1.2 cfsm. Atlantic salmon habitat is available at 7 percent CA for flows of 0.2 - 0.4 cfsm and then declines and levels out at 4 percent CA (Figure 40).

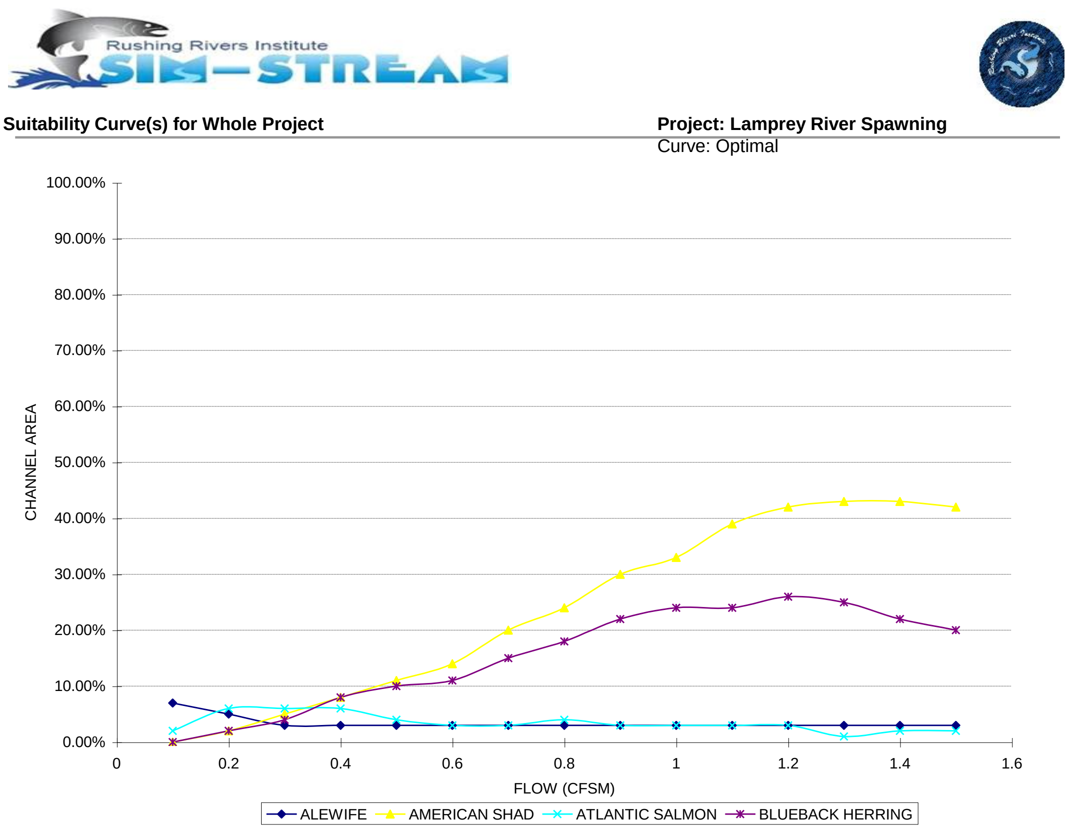

Figure 40 - Optimal habitat rating curves for anadromous species during spawning in the Lamprey Designated River for baseline conditions.

Effective habitat for blueback herring and American shad both increase with the flow until about 1.1 cfsm, at which point the increase is less steep (Figure 41). Habitat for blueback herring declines at flows higher than 1.2 cfsm. Alewife habitat is consistently below 5 percent channel area. American shad gained the most habitat area, increasing from 0 to 42 percent with flow increases from 0.1 cfsm to 1.2 cfsm. Atlantic salmon habitat is 7 percent available in the CA level for flows of 0.2 -0.4 cfsm and then levels out at 4 percent CA (Figure 41).

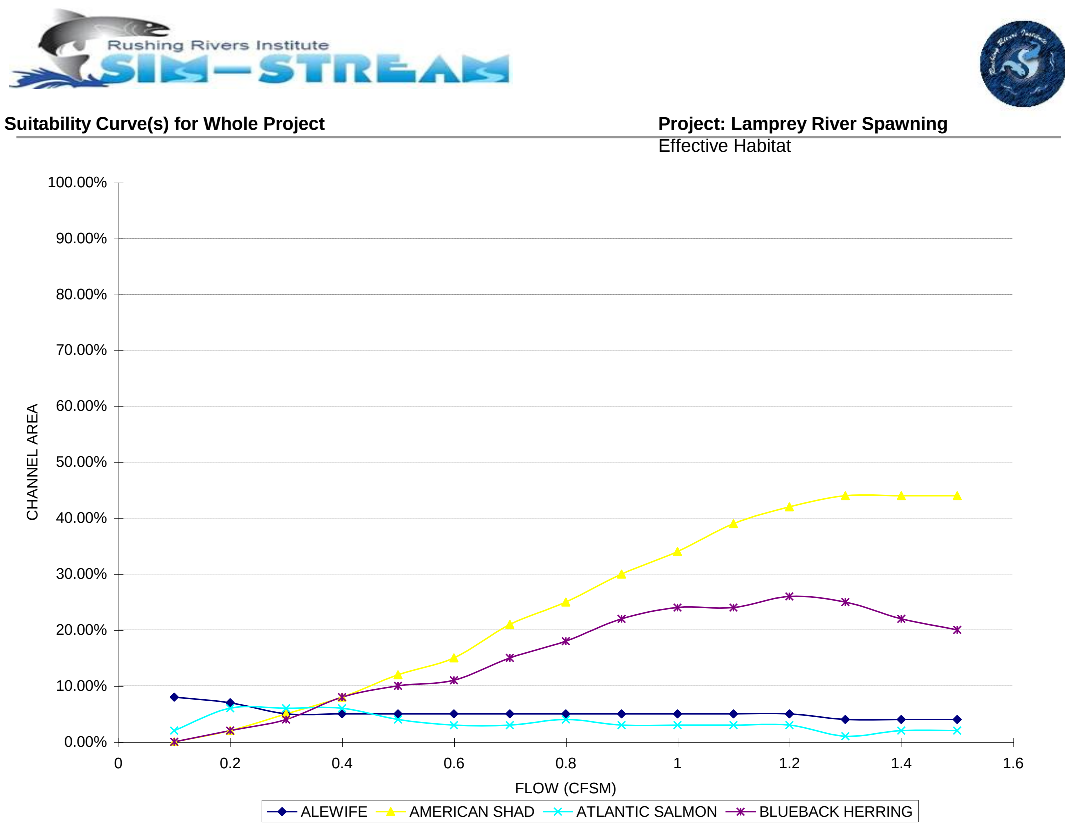

Figure 41 - Effective habitat rating curves for anadromous species during the spawning bioperiod in the Lamprey Designated River for baseline conditions.

14. Discussion of Baseline Conditions Simulation

Overall, the adjustment of the habitat template to better represent baseline conditions stabilized the habitat conditions in the rearing and growth bioperiod causing an increase of suitable habitat for the white sucker and American eel, particularly for the American eel. Suitable habitat for fallfish remains the same, with a slight decrease of the amount of suitable habitat at flows higher than 1.1 cfsm. The majority of fallfish habitat is also optimal, which is also the case for white sucker and American eel. The optimal habitat for American eel substantially rises under baseline conditions. Hence, both would gain habitat and its quality would stay the same or increase.

Common shiner gains the most with these baseline conditions, as its habitat would increase at both levels and specifically at the very low flows between 0.1 cfsm and 0.4 cfsm. It is more stable, but still retains an optimum condition at 1.1 cfsm. Other species showing positive gains in their habitat are Atlantic salmon and longnose dace, for which suitable habitat more than doubles and is available over a wider range of flows. The optimal habitat for Atlantic salmon also increases noticeably under these conditions, while for longnose dace it remains the same. Redbreast sunfish is not notably affected, for which the suitable as well as the optimal habitat area is very slightly reduced. The overall habitat structure (community habitat) has been increased and it is even more constant across the flows.

The habitat for EPT taxa and odonates increased between 0.1 cfsm and 0.8 cfsm (for odonates at 0.4 cfsm) and dramatically stabilized. The habitat for plecoptera and trichoptera increased, however it declined for the ephemeroptera. The greatest increase is in the habitat for odonates.

During the spawning season for resident fish, the greatest change caused by habitat adjustments is the reduction of the suitable habitat for fallfish and white sucker. However, for white sucker more habitat is available at the low flows and over a wider range of flows. The habitat for common shiner and longnose dace also increased. Also, the portion of optimal habitat increased for white sucker, common shiner, and longnose dace. Hence, although the effective habitat for redbreast sunfish declined, it increased and became more stable for the other three species. Overall, the effective spawning habitat for GRAF increased and became much more stable.

The habitat for spawning of American shad and blueback herring increases more rapidly after the habitat adjustments, offering less habitat between 0.4 cfsm and 0.8 cfsm, but more habitat at higher flows. This change corresponds well with higher flows in spring and early summer. Alewife habitat declined and became less abundant, but since Alewife naturally spawn in lakes, the low habitat levels in the river are not limiting. Spawning habitat for Atlantic salmon increased substantially in quantity and quality.

15. Habitat Time Series Analysis

The purpose of the Instream Flow Program is to develop flow protection criteria to avoid or mitigate both pulse and press disturbances as described by Niemi et al. (1990). A pulse stressor is an instantaneous alteration in fish densities; a press disturbance causes sustained alteration of species composition. The key to describing these criteria is the determination of habitat stressor thresholds (HST) from their frequency of occurrence. Intra-annual rules should specify the magnitude of extreme habitat that should always be exceeded, as well as the magnitude and the duration of low-habitat events that are common in an average year. Inter-annual rules should define how frequently uncommonly low and long events could occur. For the rare events two duration types were defined: persistent lows that can happen two or three years in a row (equivalent to a press disturbance); and catastrophic events that occur on the decadal scale (pulse stressors). All of these rules are organized by annual bioperiods. These rules are developed from empirical observations of frequency and duration of thresholds occurring in numerous time series.

To identify the HST, habitat time series were developed and the habitat duration curves analyzed. Next, uniform continuous under-threshold habitat-duration curves (UCUT-curves – Parasiewicz 2007) were created. The curves evaluate durations and the frequency of continuous events with habitat lower than a specified threshold. This is as a proportion of the entire study period, which is a sum of all days within one bioperiod in the hydrological record. As documented by Capra et al. (1995), the curves are good predictors of biological conditions.

Approximations of the threshold within the habitat template of the Lamprey Designated River were developed from the naturalized hydrograph and the habitat rating functions. To create the UCUT curves, the naturalized hydrological time series was used. The naturalized hydrological time series is based on the 30 year (October 1975 to October 2005) mean daily flow record of the Lamprey River as recorded at the USGS Packers Falls gaging station. The recorded mean daily flows were corrected for water use in the watershed and dam storage and releases from Pawtuckaway Lake. The corrections were made to create a hydrograph more representative of a baseline condition; free of alteration by water use and management. The development of the naturalized hydrograph is discussed in more detail in Appendix 13.

These naturalized flows were first "translated" into a habitat time series (habitograph). Each incremental flow value was converted into a habitat value using a flow-habitat rating curve (representing habitat as a function of flow) for a bioperiod under the present habitat conditions.

A habitat event is defined as a continuous period in which the quantity of habitat (WUA, wetted usable area) stays under a predefined threshold. In our adaptation, the UCUT curves describe the duration and frequency of events for a given bioperiod. Therefore, the first step is to extract bioperiod data for each year from the habitographs (Figure 42).

In the second step, the sum of all the events of the same duration within each bioperiod is computed as a ratio of the total duration of all bioperiods in the record (on the x-axis of the graph). The proportions are plotted as a cumulative frequency, i.e., the proportion of shorter periods is added to the proportions of all longer periods (Figure 43).

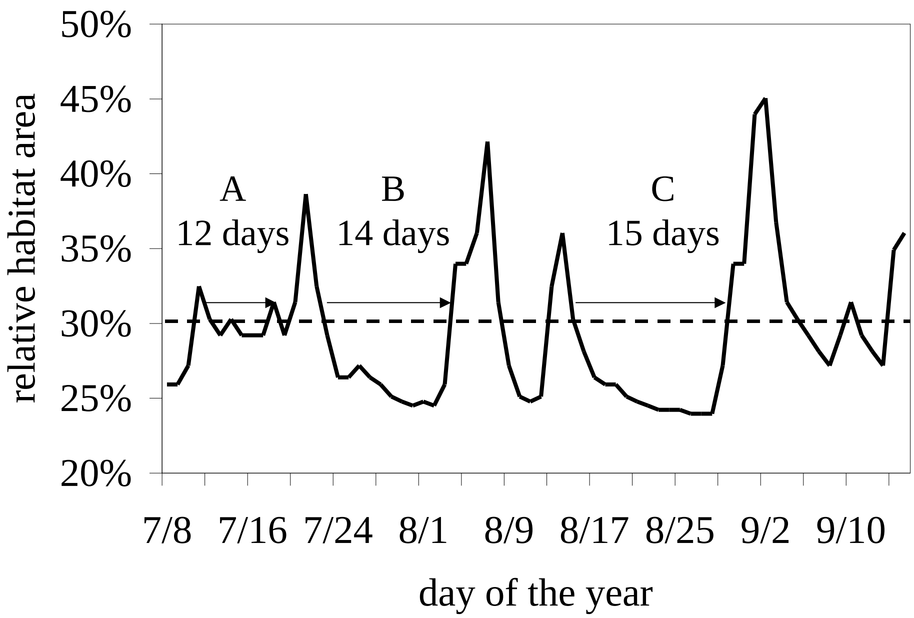

Figure 42 - Schematic of UCUT curve computation for hypothetical suitable habitat time series.

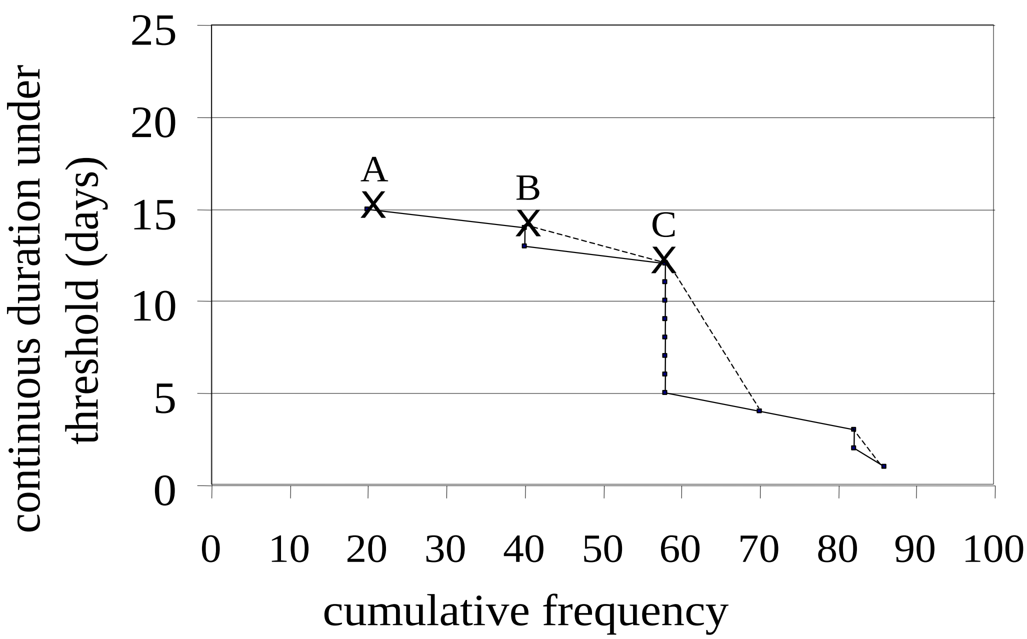

Figure 43 - Differences between the CUT curves defined by Capra et al. 1995 (dashed line) and UCUTs (solid line).

For easier interpretation and calculation, Capra's technique was modified by including in the plot the cumulative frequency for all continuous durations in days. This results in points for durations with 0 percent of cumulative increase (e.g., events that did not occur in the time series). For example, if the time series data included events for durations of 14 and 12 days, but not events of 13 days, the CUT curve method would only plot the two points at 14 and 12 days duration (note the dashed line in Figure 43). For the UCUT curves, the points for a cumulative duration of 13 days (equal in cumulative frequency to the cumulative frequency of 14 days) were also plotted, dropping the line first vertically (from 14 to 13 days) before joining it with the point for 12 days (note the solid line in Figure 43). To distinguish between the two approaches, this adaptation is called the 'uniform continuous under-threshold' or UCUT for short.

For each bioperiod, all habitat events occurring in the bioperiod over the period of the study record and at multiple incremental habitat thresholds were analyzed. A habitat event is defined as a continuous period in which the quantity of habitat (% Channel Area or CA)) stays under any predefined threshold. The UCUT curves diagram captures the duration and frequency of events for a given bioperiod (Figure 44). The y-axis represents event durations in days. The x-axis represents the cumulative percent duration of events within a bioperiod aggregated by increasing duration. The sum-length of all the events of the same duration within a bioperiod is computed as a ratio of the total duration of all years of the bioperiod in the record.

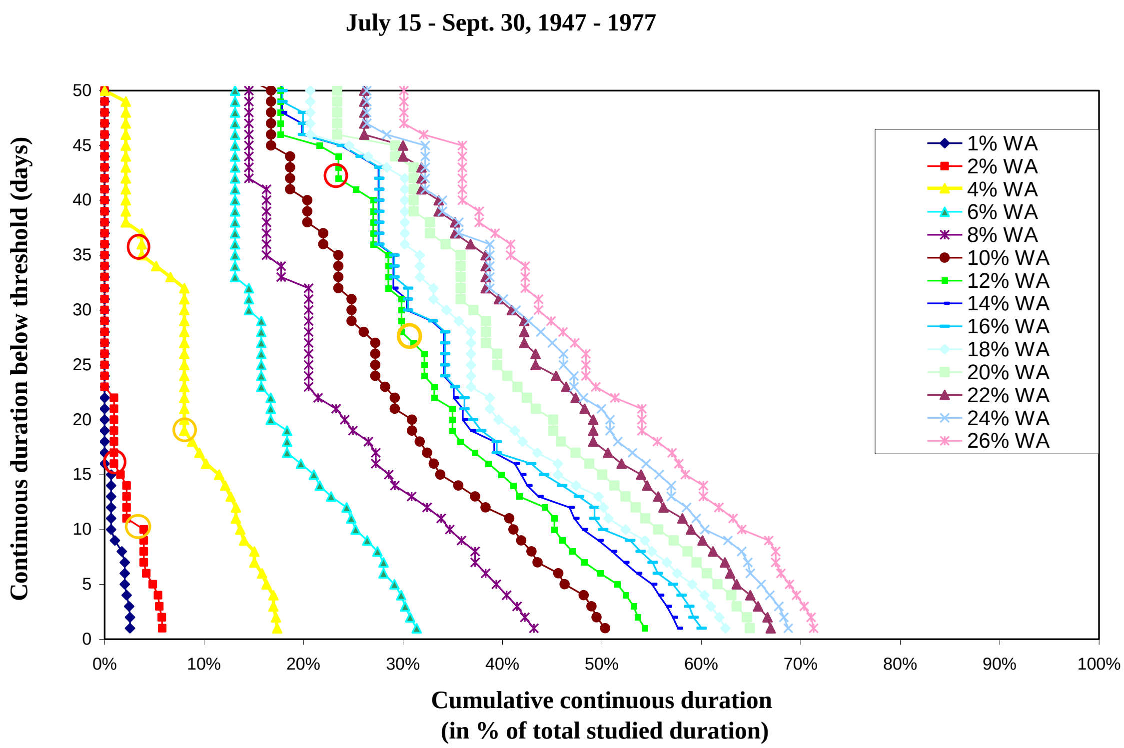

Figure 44 - An example of UCUT curves developed for the Souhegan River, NH.

The curves above indicate selected habitat thresholds in increments of 0.2 percent of wetted area (% WA). Based on the density of curves, three have been selected as significant thresholds for; rare (red), critical (yellow), and common (green) events. The circles at the inflection points demarcate persistent (yellow) and catastrophic (red) durations.

This procedure is repeated for the entire set of thresholds with constant increments. The magnitude of the habitat increments between the thresholds is selected on an iterative basis, e.g., changing the increments until a clear pattern can be recognized. The focus here is to look for specific regions with a higher or lower concentration of the curves on the plot that would correspond with *rare, critical, and common* events. When many curves are plotted, these three regions are easily identifiable.

Common and less common habitat events can be identified based on the cumulative durations, the shape, and distances between the curves. The procedure has two steps; the determination of habitat threshold levels by selecting curves on the graphs, which is followed by the identification of critical durations by locating inflection points. Interpretation of these patterns is based on the following observations:

- The curves in the lower left portion of the graph depict rare events (i.e., with low cumulative durations).
- The horizontal distance between curves indicate the change in frequency of events associated with a habitat increase to the next level (i.e., the larger the distance between two curves at the same continuous duration, the larger the change in the frequency of the events).
- Steep curves represent little change in event frequency.
- Inflection points reflect a rapid change in frequency of continuous durations.

The relative position of a curve defines the magnitude of habitat and the ecologically relevant threshold demarcating pulse stressors. Specifically, the focus is looking for the extreme, rare, critical, and common habitat stressor thresholds (HST) for the low-flow conditions. Rare habitat events happen infrequently and only for a short period of time. The critical level defines a more frequent event than rare, below which the habitat circumstances rapidly decrease to the rare level. Common habitat levels are the highest defined and should demarcate the beginning of normal circumstances from the less common events.

Typically, the UCUTs for rarely low habitat availability are located in the left corner, and are steep and very close to each other. Apparently, in this range, small increases in habitat level have barely any effect on cumulative duration. As the habitat level increases, this pattern rapidly changes. The highest value in this lower-habitat group (before the rapid change of cumulative duration) of curves was selected as a *rare* habitat level threshold. The *rare* habitat level threshold should be exceeded most of the time because of the potential ecological impacts that would result otherwise. The next highest UCUT line (the first that stands out) was identified as a *critical* level. The distance between the lines after exceeding the *critical* level are usually greater than in the previous group, but still close to each other. The next outstanding curve demarcating rapid changes in the frequency of events is assumed to mark the stage at which more *common* habitat levels begin.

Once the three threshold levels were identified, the shortest persistent durations were searched for and were indicated by the lowest, convex inflection points on the UCUT curves.

Above these points the curves are steep, which shows a low frequency of long events. The shortest of the long durations, appearing only on the decadal scale, are defined as catastrophic durations along with their frequency of occurrence. In this way, the three categories of habitat event durations: typical, persistent and catastrophic (Figure 45) were identified.

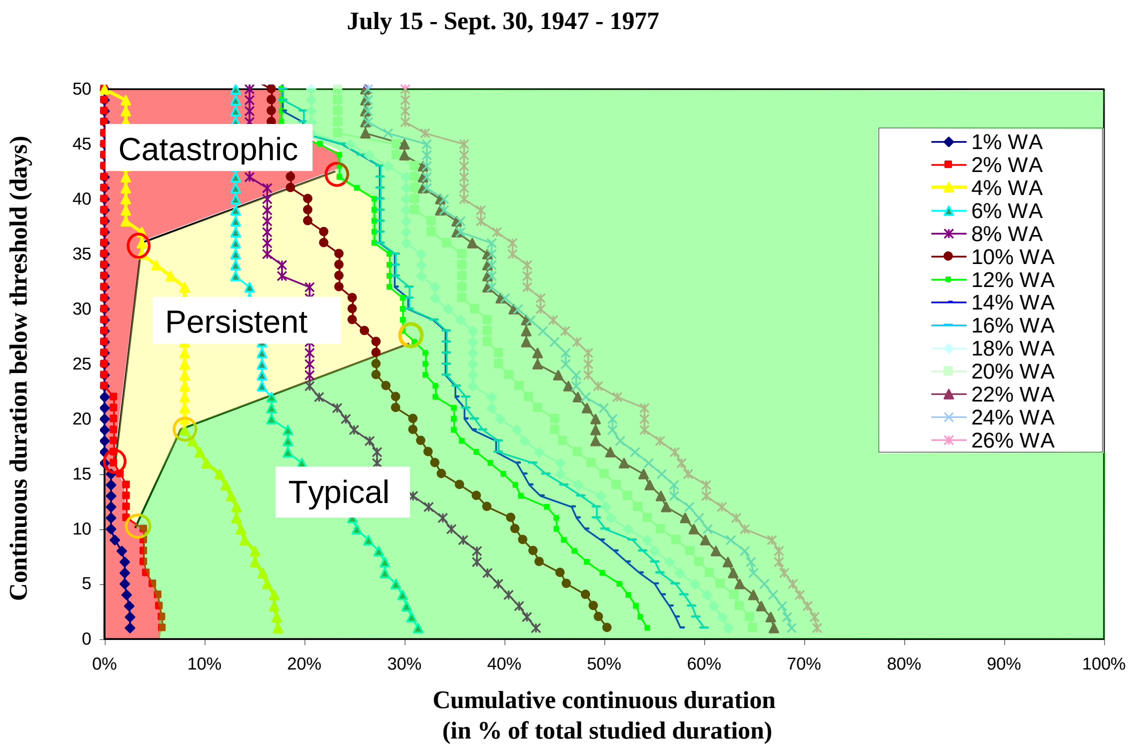

Figure 45 - Schematic of frequency and duration zones on UCUT curves.

As shown on the above diagram, most of the UCUTs display the rapid change in gradient demarcating the beginning of persistent or catastrophic conditions. The border line between zones can be drawn by connecting the inflection points. From an active management perspective this would not be feasible, and therefore, the prescription was simplified by identifying only the most outstanding curves in the diagram. This allows for some flexibility in the above definitions.

To develop the habitat time series, the habitat rating curves described above are applied to naturalized flow time series as developed for specific reaches. During the resident-species spawning seasons the preference was to choose the generic resident adult fish (GRAF) as the indicator. In other bioperiods, individual indicator species such as common shiner, Atlantic salmon, and blueback herring were used. The UCUT curves were computed for selected indicator species in every reach using a time series from associated flow gages.

Habitat UCUTs were not developed for the seasons in which habitat information was sparse or nonexistent for the fauna of interest (e.g., over-winter). Instead, for the over-winter bioperiod we evaluated negative run length (i.e., flow-based UCUTs) and derived criteria solely on this data, presuming again that the fauna have adjusted to the most common natural flow conditions.

16. Time Series Analysis Results

In this step, the above procedures are applied to the habitat time series developed for the Lamprey Designated River for each bioperiod. The UCUT curves are interpreted to determine the magnitude of rare, critical and common thresholds. Subsequently the common and allowable duration is determined for each of the thresholds.

Rearing and Growth Bioperiod (July 5th – October 6th)

Figure 46 presents UCUT curves for the common shiner in the Lamprey Designated River. The value of 3 percent CA of habitat is selected as a *rare* threshold. The UCUT curves show a strong increase of frequency when the threshold moves to 4 percent CA for *critical*. The *common* threshold is identified with 8 percent CA.

For the determination of the longest common duration for *rare* habitat events, the lowest of the two inflection points, corresponding with 5 days, was selected. The catastrophic duration begins where the curve moves very close to the x-axis and was selected as 15 days. The UCUT for the *critical* event has an inflection point at 15 days and a catastrophic duration of 32 days. For the *common* level the inflection points were estimated with 46 days for common durations and 82 days for a catastrophic duration.

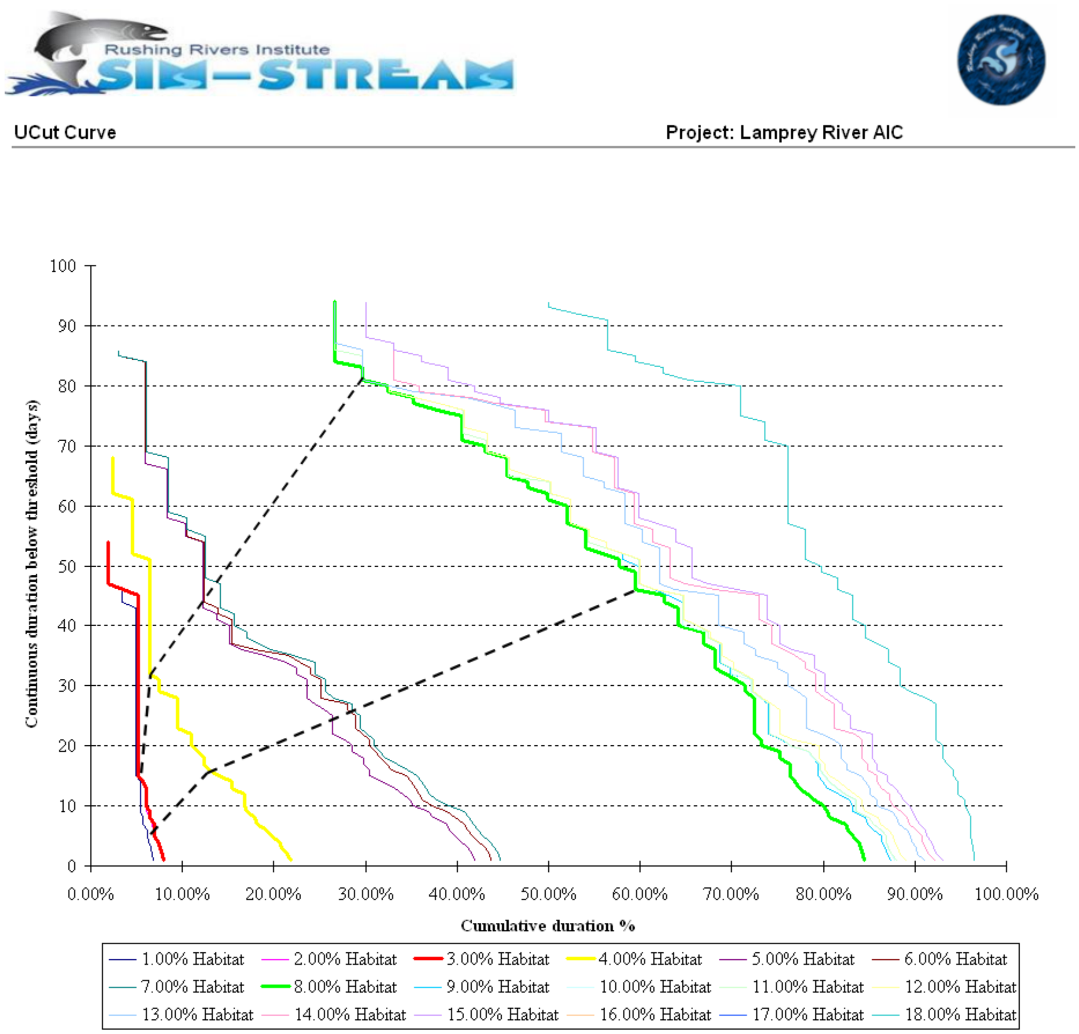

Figure 46 - UCUT curves for the common shiner rearing and growth bioperiod for the Lamprey Designated River.

Atlantic Salmon Spawning (Oct. 7th - Dec. 8th)

Figure 47 presents UCUT curves for Atlantic salmon spawning habitat in the Lamprey Designated River. The determination of the thresholds was difficult because of the small amount of habitat available for salmon spawning. A value of 2 percent CA of habitat is selected as a *rare* threshold. The UCUT curves show dramatic increase of frequency when the threshold moves to 4 percent CA. The *common* threshold is identified with 5 percent CA.

For the determination of the longest common duration for *rare* habitat events, the lowest of the two inflection points corresponding with six days was selected. The catastrophic duration begins where the curve moves very close to the x-axis and was selected with 11 days. The UCUT for the *critical* event has an inflection point at 11 days and a catastrophic duration of 33 days. For the *common* level the inflection points were estimated with 17 days for common durations and 55 days for a catastrophic duration.

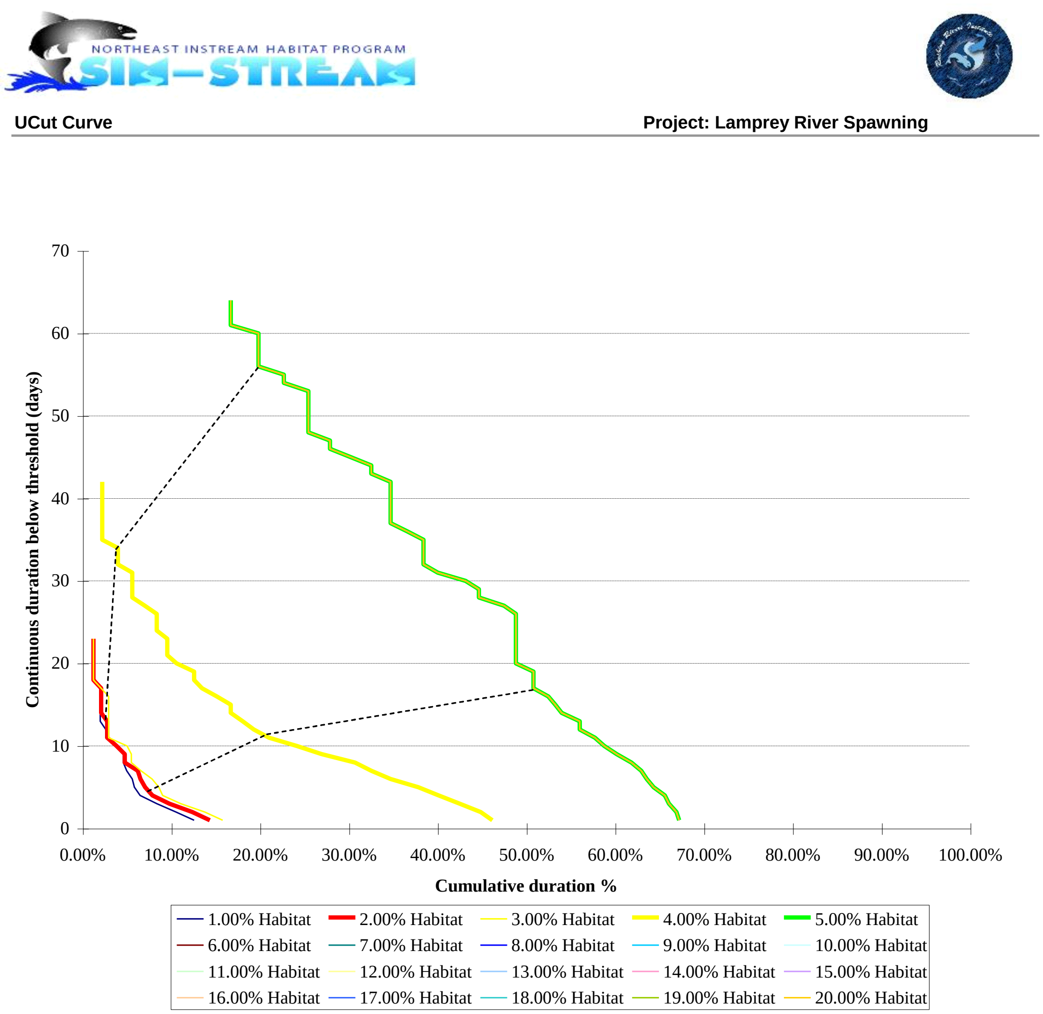

Figure 47 - UCUT curves for the Atlantic salmon spawning bioperiod on the Lamprey Designated River.

Overwintering (Dec 9th – Feb. 28th)

Figure 48 presents flow based UCUT curves for the USGS Lamprey River Packers Falls gage near Newmarket in the overwintering season. Events of flows lower than 0.4 cfsm occurred for 10 percent of the time. The *critical* level was chosen with 0.6 cfsm and *common* levels with 1.3 cfsm. The allowable and catastrophic durations were approximated at 7 and 30 days for the *rare* threshold, 10 and 37 days for the *critical* threshold, and 20 days and 57 days for the *common* threshold.

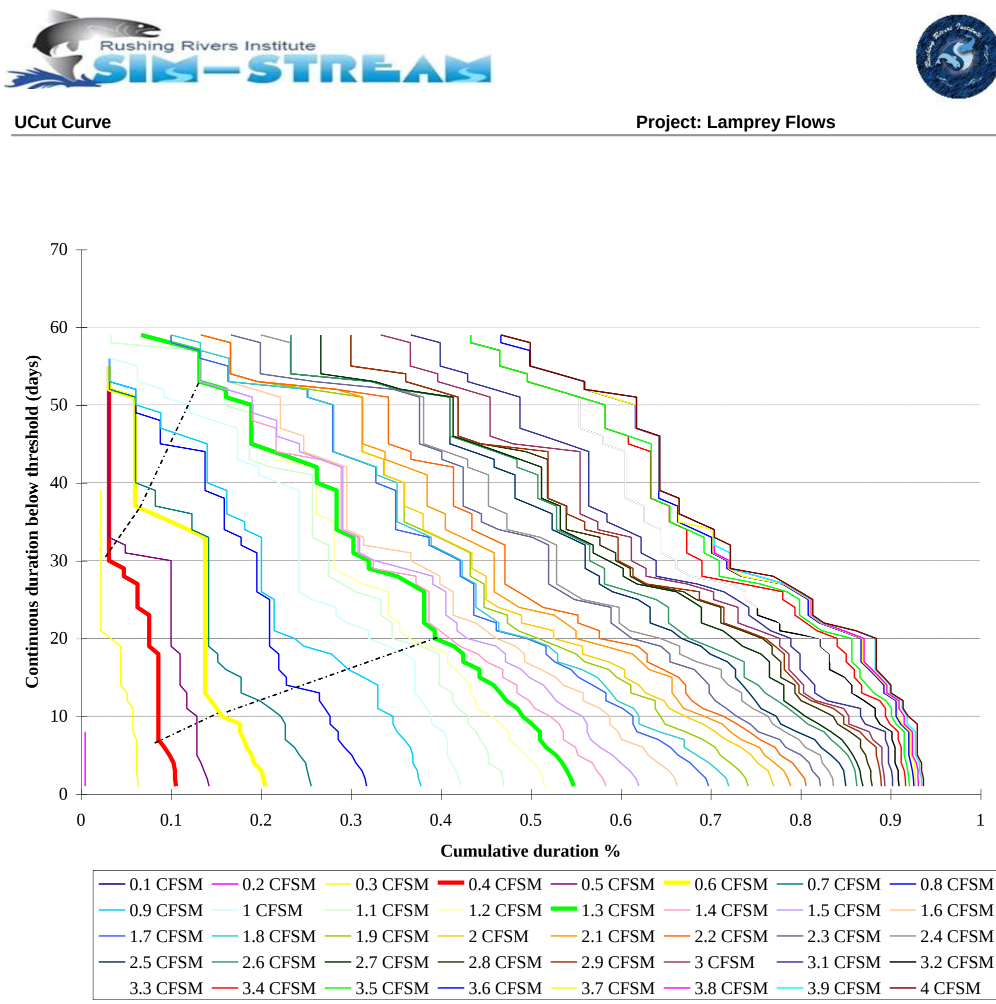

Figure 48 - Flow UCUT curves for the overwintering bioperiod on the Lamprey Designated River.

Flooding ***(March 1st – May 4th)***

Figure 49 presents flow based UCUT curves for the USGS Lamprey River Packers Falls gage near Newmarket in the flooding season. Events of flows lower than 0.8 cfsm occurred for 3 percent of the time. The *critical* level was chosen with 1.3 cfsm and *common* levels with 3.4 cfsm. The allowable and catastrophic durations were approximated at 3 and 9 days for the *rare* threshold, 10 and 19 days for the *critical* threshold, and 15 days and 42 days for the *common* threshold.

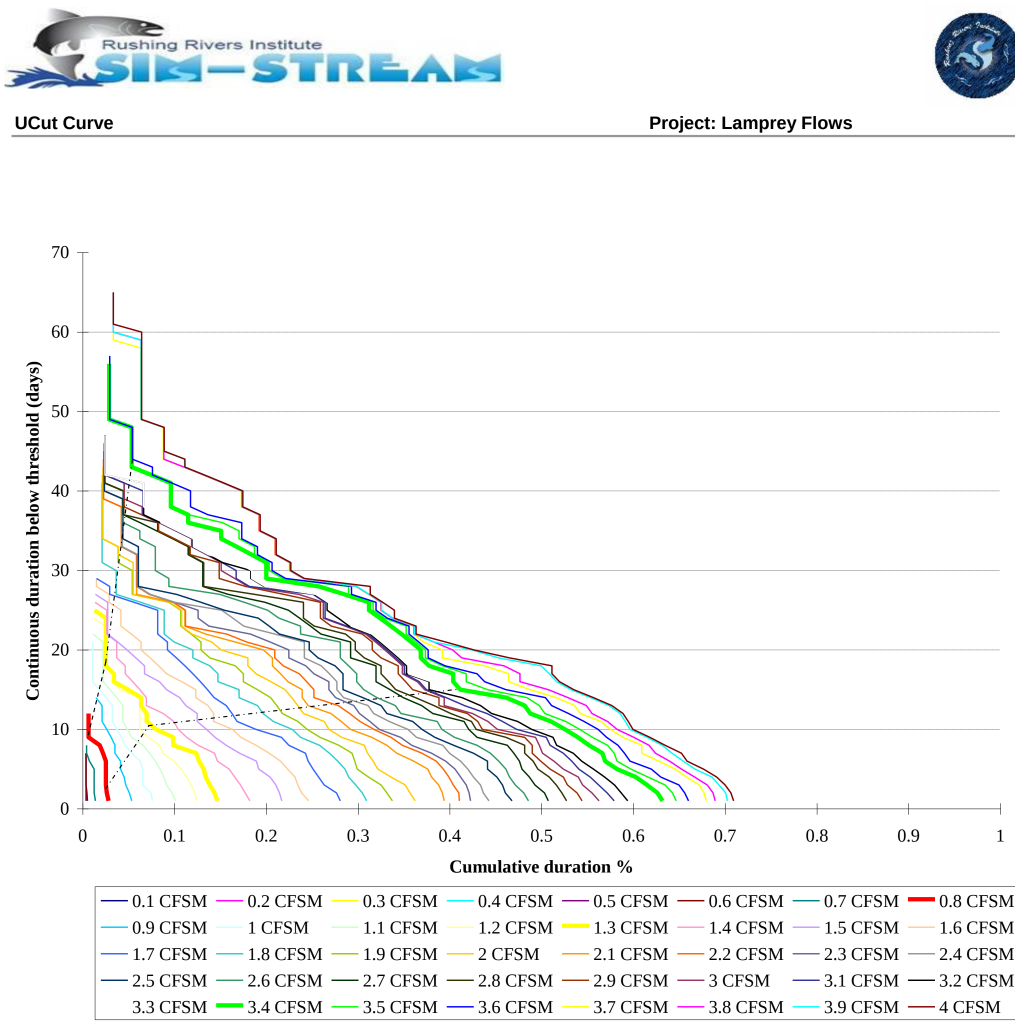

Figure 49 - Flow UCUT curves for the flooding bioperiod on the Lamprey Designated River.

Clupeid Spawning *(May 5th – June 19th)*

Blueback herring habitat has been chosen as an indicator for this season. Figure 50 presents UCUT curves for blueback herring spawning habitat. 4 percent CA of habitat is selected as a *rare* threshold. The UCUT curves show a dramatic increase of frequency when the threshold moves to 5 percent CA. The *common* threshold is identified with 17 percent CA.

For the determination of the longest common duration for *rare* habitat events, the lowest of the two inflection points corresponding with four days was selected. The catastrophic duration begins where the curve moves very close to the x-axis and was selected with 10 days. The UCUT for the *critical* event has an inflection point at five days and a catastrophic duration of 13 days. For the *common* level the inflection points were estimated with 13 days for common durations and 27 days for a catastrophic duration.

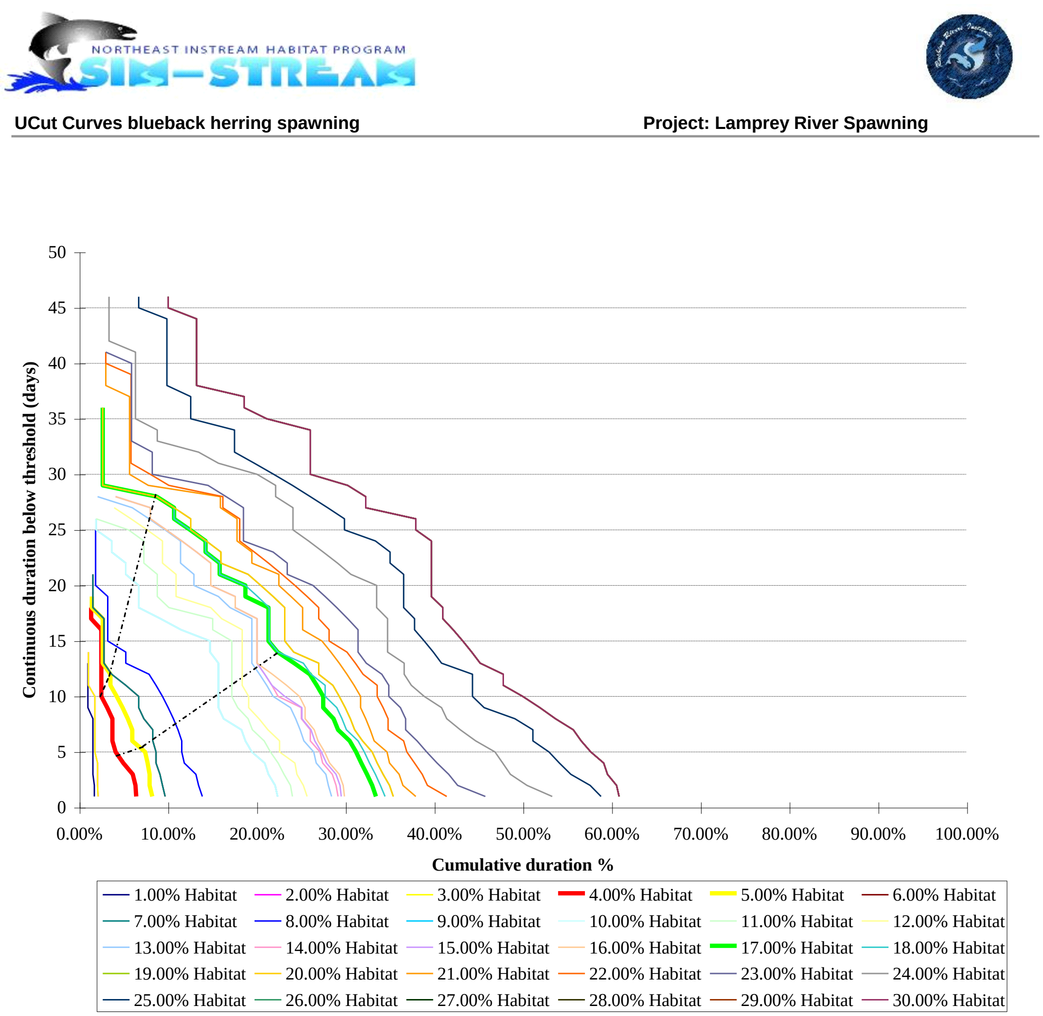

Figure 50 - UCUT curves for the American shad spawning bioperiod on the Lamprey Desginated River.

Resident Adult Spawning (May 5th – July 4th)

The resident adult spawning bioperiod overlaps with the spawning of clupeids and it is therefore calculated for the entire length of the season. Figure 51 presents UCUT curves for resident fish spawning habitat in the Lamprey Designated River. A value of 51 percent CA of habitat is selected as a *rare* threshold. The UCUT curves show a dramatic increase of frequency when the threshold moves to 54 percent CA. The *common* threshold is identified with 56 percent CA.

For the determination of the longest common duration for *rare* habitat events, the lowest of the two inflection points corresponding with two days was selected. The catastrophic duration begins where the curve moves very close to the x-axis and was selected with three days. The UCUT for the *critical* event has an inflection point at 10 days and catastrophic duration of 13 days. For the *common* level the inflection points were estimated with 22 days for common durations and 31 days for a catastrophic duration.

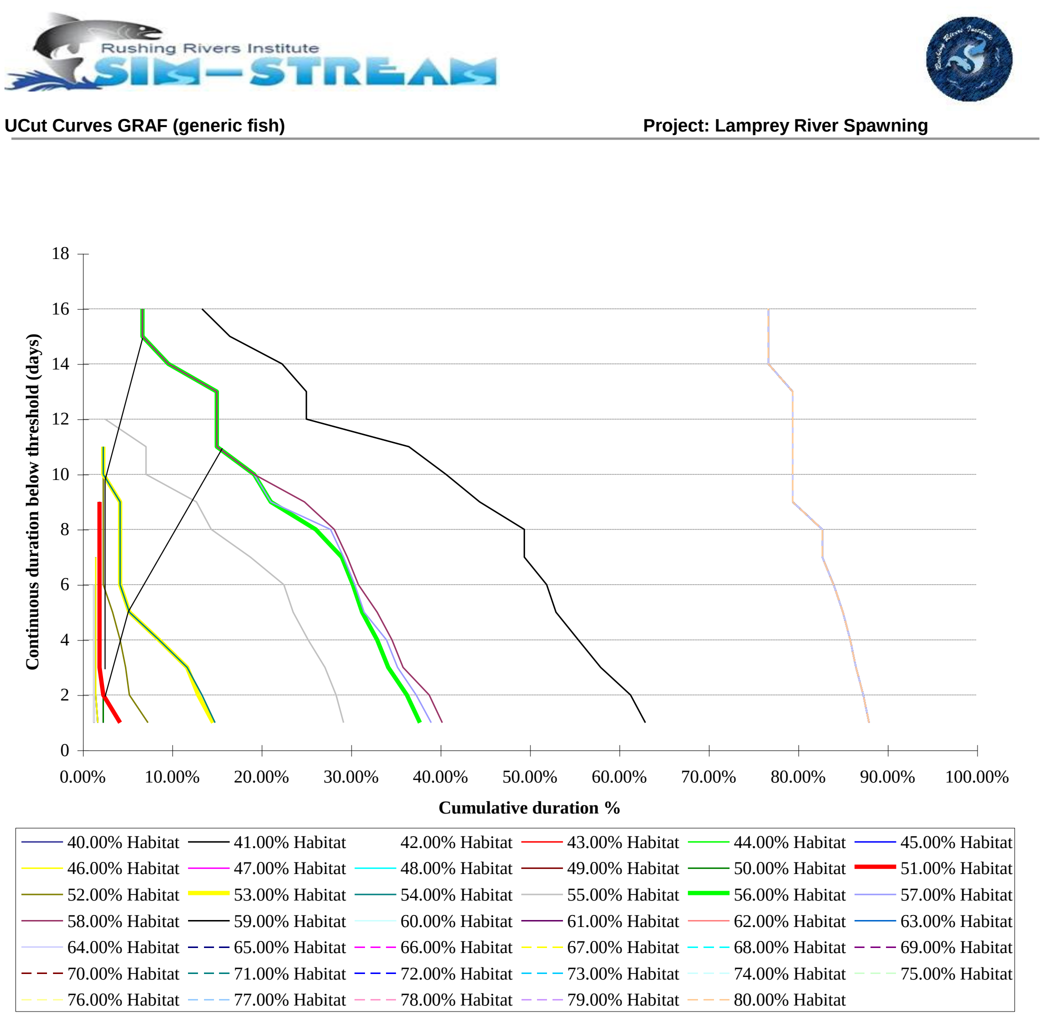

Figure 51 - UCUT curves for the resident adult spawning bioperiod for the Lamprey Designated River.

17. Protected Habitat Flow Levels and Durations

For the three bioperiod-specific habitat magnitudes obtained from the UCUTs analysis, the instream flows that would be necessary, under baseline conditions, to provide specified habitats were then identified. How much habitat would be available under existing (present) conditions with these flows was also specified. This specifies the habitat cost of human induced alterations of riverbed or potential for habitat improvement accomplishable with their reduction. The allowable and catastrophic durations (days) for each of these flow magnitudes were also defined. These durations represent significant changes in frequency of the occurrence of these flow magnitudes. Allowable durations occur in an average year. Flow below protected flow levels may often continue for this duration. Catastrophic durations can occur not more frequently than once in ten years. Otherwise, flows below protected levels for catastrophic durations initiate management activities pursuant to a Water Management Plan.

Rearing and Growth Bioperiod (July 5th – October 6th)

During the rearing and growth bioperiod, common shiner habitat stays under 8 percent CA for no longer than 46 days, and 82 days represents a catastrophic duration (Table 16). The flow corresponding with 8 percent CA under baseline conditions is **0.57 cfsm (104 cfs)**. This flow currently offers 2 percent of habitat for the common shiner. At present conditions, the existing common habitat for common shiner is much lower and never reaches this level. So, there is no point in acknowledging further flows for existing conditions.

Critical events begin if the habitat is lower than 4 percent CA for 15 days and it becomes catastrophically long at 32 days. The flow corresponding with 4 percent CA under baseline conditions is **0.1 cfsm (18 cfs)**. This flow currently offers 1 percent of habitat for common shiner. At present conditions, the existing common habitat for the common shiner is lower than 4 and never reaches this level. So, there is no point in acknowledging further flows for existing conditions.

Rare habitat events occur when GRAF habitat is lower than 3 percent CA for longer than 5 days. The rare event flow will be catastrophic if it lasts for more than 15 days. The flow corresponding with 3 percent under baseline conditions is **0.09 cfsm (16 cfs)**. A flow of 0.09 cfsm does not currently offer suitable habitat for the common shiner.

Table 16 - Protected flows for the rearing and growth bioperiod on the Lamprey Designated River.

Rearing & Growth July 5 – Oct. 6	Common shiner
Watershed area (mi^2)	183
Location	Lamprey Gage
Common habitat (% Channel Area)	**8**
Persistent duration	46
Catastrophic duration (days)	82
Corresponding flow baseline (cfsm)	0.57
Current habitat with baseline flow (% CA)	2
Corresponding flow present (cfsm)	NA
Critical habitat (% Channel Area)	**4**
Persistent duration	15
Catastrophic duration (days)	32
Corresponding flow baseline (cfsm)	0.1
Current habitat with baseline flow (% CA)	1
Corresponding flow present (cfsm)	NA
Rare habitat (% Channel)	**3**
Persistent duration	5
Catastrophic duration (days)	15
Corresponding flow baseline (cfsm)	0.09
Current habitat with baseline flow (% CA)	0
Corresponding flow present (cfsm)	NA

Atlantic Salmon Spawning Bioperiod (October 7th – December 8th)

Historically this species occurred in the watershed and their habitat needs during the spawning bioperiod indicate conditions that should be present in the river. Commonly, habitat does not stay under 5 percent CA for longer than 17 days and after 55 days it is catastrophic. Presently, this corresponds with a flow of **0.82 cfsm (150 cfs)**. The flow corresponding with 5 percent under baseline conditions is **0.49 cfsm (90 cfs)**. A flow of 0.49 cfsm currently offers 3 percent habitat for Atlantic salmon spawning (Table 17).

The critical levels begin below 4 percent CA (**0.78 cfsm – 142 cfs**), which should not last longer than 11 days. Habitat under this level for 33 days is already catastrophic. The flow corresponding with 4 percent under baseline conditions is **0.22 cfsm (40 cfs)**. A flow of 0.22 cfsm currently offers 2 percent habitat for Atlantic salmon spawning.

The rare events occur when habitat drops under 2 percent CA (**0.18 cfsm – 33 cfs**). Those may last up to six days and are catastrophic when duration exceeds 11 days. The flow corresponding with 2 percent under baseline conditions is **0.11 cfsm (20 cfs)**. A flow of 0.11 cfsm currently offers less than 1 percent habitat for common shiner.

Table 17 - Protected flows for the Atlantic salmon spawning bioperiod on the Lamprey Designated River.

Spawning (Atlantic salmon) Oct. 7 – Dec. 8	Atlantic salmon
Watershed area (mi^2)	183
Location	Lamprey Gage
Common habitat (% Channel Area)	**5**
Persistent duration	17
Catastrophic duration (days)	55
Corresponding flow baseline (cfsm)	0.49
Current habitat with baseline flow (% CA)	3
Corresponding flow present (cfsm)	0.82
Critical habitat (% Channel Area)	**4**
Persistent duration	11
Catastrophic duration (days)	33
Corresponding flow baseline (cfsm)	0.22
Current habitat with baseline flow (% CA)	2
Corresponding flow present (cfsm)	0.78
Rare habitat (% Channel)	**2**
Persistent duration	6
Catastrophic duration (days)	11
Corresponding flow baseline (cfsm)	0.11
Current habitat with baseline flow (% CA)	1
Corresponding flow present (cfsm)	0.18

Overwintering Bioperiod (December 9th – February 28th)

During this season no habitat data was available and flow recommendations were based on UCUT analysis of naturalized flows derived from the flow records at the USGS Lamprey River Packers Falls gage near Newmarket (Table 18). It is recommended that flows not fall below **1.3 cfsm (238 cfs)**, **0.60 cfsm (110 cfs)**, and **0.40 cfsm (73 cfs)** for longer than 20, 10, and seven days, respectively. Catastrophic durations are 57, 37, and 30 days for these levels.

Table 18 - Protected flows for the overwintering bioperiod on the Lamprey Designated River.

Winter Dec. 9 – Feb. 28	Flow
Watershed area (mi^2)	183
Location	Lamprey Gage
Common habitat (% Channel Area)	—
Persistent duration (days)	20
Catastrophic duration (days)	57
Corresponding flow (csfm)	1.3
Corresponding flow (cfs)	238
Critical habitat (% Channel Area)	—
Persistent duration (days)	10
Catastrophic duration (days)	37
Corresponding flow (csfm)	0.6
Corresponding flow (cfs)	110
Rare habitat (% Channel)	—
Persistent duration (days)	7
Catastrophic duration (days)	30
Corresponding flow (csfm)	0.4
Corresponding flow (cfs)	73

Spring Flood Bioperiod (March 1st through May 4th)

During this season no habitat data was available and flow recommendations were based on UCUT analysis of naturalized flows derived from the flow records at the USGS Lamprey River Packers Falls gage near Newmarket. It is recommended that flows not fall below **3.4 cfsm (622 cfs)**, **1.3 cfsm (238 cfs)**, and **0.8 cfsm (146 cfs)** for longer than 14, 10, and three days, respectively. Catastrophic durations are 42, 19, and nine days for these levels (Table 19).

Table 19 - Protected flows for the spring flood bioperiod on the Lamprey Designated River.

Flooding March 1 – May 4	Flow
Watershed area (mi^2)	183
Location	Lamprey Gage
Common habitat (% Channel Area)	—
Persistent duration (days)	14
Catastrophic duration (days)	42
Corresponding flow (csfm)	3.4
Corresponding flow (cfs)	622
Critical habitat (% Channel Area)	—
Persistent duration (days)	10
Catastrophic duration (days)	19
Corresponding flow (csfm)	1.3
Corresponding flow (cfs)	238
Rare habitat (% Channel)	—
Persistent duration (days)	3
Catastrophic duration (days)	9
Corresponding flow (csfm)	0.8
Corresponding flow (cfs)	146

Clupeid Spawning Bioperiod (May 5th through June 19th)

The spawning of American shad occurs during the same period as blueback herring and alewife. Blueback herring was chosen as an indicator species since it appears to be most flow sensitive; allowing for more precise analysis. Commonly, the habitat suitable for blueback herring spawning does not stay under 17 percent CA for longer than 13 days and a duration of 28 days is considered catastrophic. Under present conditions this corresponds to a flow of **0.47 cfsm (86 cfs)**. The flow corresponding with habitat of 17 percent CA under baseline conditions is **0.78 cfsm (143 cfs)**. A flow of 0.78 cfsm offers 20 percent habitat for blueback herring spawning (Table 20).

The critical habitat level begins below 5 percent CA **(0.29 cfsm – 53 cfs)**, which should not last longer than five days. Habitat under this level for 13 days is already catastrophic. The flow corresponding with habitat of 5 percent CA under baseline conditions is **0.34 cfsm (62 cfs)**. A flow of 0.34 cfsm currently offers 9 percent habitat for blueback herring spawning.

The rare habitat events are when habitat drops under 4 percent CA **(0.27 cfsm – 49 cfs)**. Those may last up to four days and are catastrophic with duration over 10 days. The flow corresponding with habitat of 4 percent CA under baseline conditions is **0.31 cfsm (57 cfs)**. A flow of 0.31 cfsm currently offers 7 percent habitat for Atlantic salmon spawning (Table 20).

Table 20 - Protected flows for the Clupeid spawning bioperiod on the Lamprey Designated River.

Spawning Clupeid May 5 – June 19	Blueback Herring
Watershed area (mi^2)	183
Location	Lamprey Gage
Common habitat (% Channel Area)	**17**
Persistent duration	13
Catastrophic duration (days)	28
Corresponding flow baseline (cfsm)	0.78
Current habitat with baseline flow (% CA)	20
Corresponding flow present (cfsm)	0.47
Critical habitat (% Channel Area)	**5**
Persistent duration	5
Catastrophic duration (days)	13
Corresponding flow baseline (cfsm)	0.34
Current habitat with baseline flow (% CA)	9
Corresponding flow present (cfsm)	0.29
Rare habitat (% Channel)	**4**
Persistent duration	4
Catastrophic duration (days)	10
Corresponding flow baseline (cfsm)	0.31
Current habitat with baseline flow (% CA)	7
Corresponding flow present (cfsm)	0.27

Generic Resident Adult Fish Spawning Bioperiod (May 5th through July 4th)

Common habitat does not stay under 56 percent CA for longer than 11 days and a duration of 15 days is catastrophic. Presently, this corresponds with a flow of **0.62 cfsm (113 cfs)**. The flow corresponding with habitat of 56 percent CA under baseline conditions is **0.55 cfsm (101 cfs)**. A flow of 0.55 cfsm currently offers 55 percent habitat for GRAF spawning (Table 21).

The critical level begins below 54 percent CA (**0.87 cfsm – 159 cfs**), which should last no longer than five days. Habitat under this level for 10 days is already catastrophic. The flow corresponding with habitat of 54 percent CA under baseline conditions is **0.85 cfsm (156 cfs)**. A flow of 0.85 cfsm currently offers 55 percent habitat for GRAF spawning.

The rare events are when habitat drops under 51 percent CA (**1.24 cfsm – 226 cfs**). Those may last up to two days and are catastrophic with durations over three days. The flow corresponding with habitat of 51 percent CA under baseline conditions is **1.32 cfsm (242 cfs)**. A flow of 1.32 cfsm currently offers 56 percent habitat for GRAF spawning.

Table 21 - Protected flows for the GRAF spawning bioperiod on the Lamprey Designated River.

Spawning GRAF May 5 – July 4	GRAF
Watershed area (mi^2)	183
Location	Lamprey Gage
Common habitat (% Channel Area)	**56**
Persistent duration	11
Catastrophic duration (days)	15
Corresponding flow baseline (cfsm)	0.55
Current habitat with baseline flow (% CA)	55
Corresponding flow present (cfsm)	0.62
Critical habitat (% Channel Area)	**54**
Persistent duration	5
Catastrophic duration (days)	10
Corresponding flow baseline (cfsm)	0.85
Current habitat with baseline flow (% CA)	55
Corresponding flow present (cfsm)	0.87
Rare habitat (% Channel)	**51**
Persistent duration	2
Catastrophic duration (days)	3
Corresponding flow baseline (cfsm)	1.32
Current habitat with baseline flow (% CA)	56
Corresponding flow present (cfsm)	1.24

18. Protected Instream Flow Recommendations for Aquatic Life and Fish

Selected flows represent the amount of water that would occur under baseline conditions to provide protected habitat levels. Protected instream flow values, described as magnitudes and durations, are defined for each of the six bioperiods during the year. Selection of these magnitudes and durations is based on changes in frequency. The three flow magnitudes of protected instream flows are named: common, critical, and rare.

- The **common flow** is the flow corresponding to the highest habitat magnitude above which the frequency of occurrence begins to decline significantly with incremental increases in habitat magnitude. Common flow magnitudes represent near-optimal habitat availability conditions that are exceeded for approximately 45 percent of the bioperiod.
- The **critical flow** is the flow corresponding to the second lowest habitat magnitude for which the frequency of occurrence increases significantly with an incremental increase in habitat magnitude. Critical flow magnitude describes less habitat availability than that provided by the common flow, but this habitat magnitude is not unusual. Critical flows represent habitat availability conditions that are exceeded during approximately 65 to 85 percent of the bioperiod.
- The **rare flow** is the flow corresponding to the lowest of habitat magnitudes for which the frequency of occurrence increases significantly with an incremental increase in habitat magnitude. Rare flow habitat availability is severely reduced and very uncommon. Rare flow represents habitat availability that is exceeded for more than 90 percent of the bioperiod.

Each flow magnitude is further characterized by two durations: allowable and catastrophic. The durations define limits on the consecutive days when flow is below a protected flow magnitude. These flow/habitat magnitudes and their associated durations are the protected instream flows for fish. Table 22 summarizes the flows and durations selected for all of the bioperiods and are described as follows:

- For the rearing and growth bioperiod (July 5 to October 6) flows should not be under **0.57 cfsm (104 cfs)** for longer than 46 days, under **0.10 cfsm (18 cfs)** for 15 days, or under **0.09 cfsm (16 cfs)** for five days. Catastrophic durations for these flow levels (common, critical and rare) are 82, 32, and 15 days, respectively.

- During the Atlantic salmon spawning bioperiod (October 7 to December 8) the flows should not be under **0.49 cfsm (90 cfs)** for longer than 17 days, under **0.22 cfsm (40 cfs)** for 11 days, or under **0.11 cfsm (20 cfs)** for six days. Catastrophic durations for these flow levels are 55, 33, and 11 days, respectively.
- During the overwintering bioperiod (December 9 to February 28) flows should not be under **1.3 cfsm (238 cfs)** for longer than 20 days, under **0.6 cfsm (110 cfs)** for longer than 10 days, or under **0.4 cfsm (73 cfs)** for longer than seven days. Catastrophic durations for these flow levels are 57, 37, and 30 days, respectively.

Table 22 - Recommended flow criteria for fish.

Bioperiod Approximate dates	**Rearing & Growth** July 5 - Oct. 6	**Salmon Spawning** Oct. 7 - Dec. 8	**Overwintering** Dec 9 - Feb. 28	**Spring Flood** March 1 - May 4
Indicator	Common shiner	Atlantic salmon	Flow	Flow
Watershed area (mi^2)	183	183	183	183
Common flow (cfs)	104	90	238	622
Common flow (cfsm)	0.57	0.49	1.3	3.4
Allowable duration under (days)	46	17	20	14
Catastrophic duration (days)	82	55	57	42
Critical flow (cfs)	18	40	110	238
Critical flow (cfsm)	0.10	0.22	0.60	1.3
Allowable duration under (days)	15	11	10	10
Catastrophic duration (days)	32	33	37	19
Rare flow (cfs)	16	20	73	146
Rare flow (cfsm)	0.09	0.11	0.40	0.80
Allowable duration under (days)	5	6	7	3
Catastrophic duration (days)	15	11	30	9
Bioperiod Approximate dates	**Clupeid Spawning** May 5 - June 19		**GRAF Spawning** June 20 - July 4	
Indicator	Min	Max	Min	Max
Watershed area (mi^2)	183	183	183	183
Common flow (cfs)	143		101	
Common flow (cfsm)	0.78		0.55	
Allowable duration under (days)	13		11	
Catastrophic duration (days)	28		15	
Critical flow (cfs)	62	156	18	156
Critical flow (cfsm)	0.34	0.85	0.10	0.85
Allowable duration under (days)	5		5	
Catastrophic duration (days)	13		10	
Rare flow (cfs)	57	242	16	242
Rare flow (cfsm)	0.31	1.32	0.09	1.32
Allowable duration under (days)	4		2	
Catastrophic duration (days)	10		3	
		GRAF Spawning	Common shiner R&G	

- During the spring flood bioperiod (March 1 to May 4) flows should not be under **3.4 cfsm (622 cfs)** for longer than 14 days, under **1.3 cfsm (238 cfs)** for longer than 10 days, or under **0.8 cfsm (146 cfs)** for longer than three days. Catastrophic durations for these flow levels are 42, 19, and nine days, respectively.
- During the American shad spawning bioperiod two events take place, the spawning of Clupeids and GRAF species. Therefore, the flow criteria for both of these events need to be fulfilled. For Clupeid spawning (May 5 to June 19) the flows should not be lower than **0.78 cfsm (143 cfs)** for longer than 13 days, nor less than **0.34 cfsm (62 cfs)** or higher than **0.85 cfsm (156 cfs)** for five days, or less than **0.31 cfsm (57 cfs)** or higher than **1.32 cfsm (242 cfs)** for four days. Catastrophic durations for these flow levels are 28, 13, and 10 days, respectively.
- During early summer the spawning habitat for GRAF species mostly declines as flow increases. Therefore, the flow recommendations for this bioperiod are different than for the others. Target flow levels and durations are recommended rather than a downward limitation of flows. The duration counting begins with the shad spawning bioperiod start (May 5), but the criteria only apply during this bioperiod. For the GRAF spawning bioperiod (June 20 to July 4) flows should stay under **0.55 cfsm (101 cfs)** for at least 11 days, but no longer than 15 days in the catastrophic case. Flow should not be above **0.85 cfsm (156 cfs)**, but no less than **0.10 cfsm (18 cfs)** for longer than five days, but no longer than 10 days in the catastrophic case. The flows should not be higher than **1.32 cfsm (242 cfs)**, but not lower than **0.09 cfsm (16 cfs)** for longer than two days, but no longer than three days in the catastrophic case. For high flows, in order to support spawning, long durations of high flow events should not be caused by management activities under the Water Management Plan. For low flows, rare flows cannot be lower than those recommended for the preceding rearing and growth bioperiod, because the adult fish still need to survive.

These protected flow and duration prescriptions are intended to be used as thresholds to determine when management actions are necessary to maintain fish and aquatic life in the Lamprey Designated River. The specific management actions to taken will be evaluated during the development of the Water Management Plan for the Lamprey Designated River.

V. Protected Instream Flows for the Lamprey Designated River

From a comprehensive analysis of protected instream flow needs for the investigated protected entities, it was concluded that the flows necessary to support instream fauna also fulfill the criteria for all non-opportunistic water users (Table 23). This determination comes from comparing the timing and magnitude of the flow needs for fish, riparian vegetation and wildlife and human uses. The emphasis of this comparison was to determine the highest flow need of all entities in order to define the controlling flow. By satisfying the highest flow, all other flow needs are then met. The selection of the highest flow need as the protected flow magnitudes are tempered by the description of allowable and catastrophic "under threshold" durations keyed to their natural range of occurrence. However, specific inter-annual flow needs of entities other than fish are incorporated in PISF recommendations.

Comparison of daily stream flow at an index location to the protected instream flow conditions determines when flow management should be conducted under the Water Management Plan. For the Lamprey Designated River, the index location for tracking protected flows is the USGS stream flow gage at Packers Falls near Newmarket. The proposed protected flows are described in cubic feet per second (or cfs) at the gage. One cfs is equivalent to 449 gallons per minute or 0.65 million gallons per day. Protected flows may also be described in terms of flow per unit area as cfs per square mile of drainage area (cfsm). Using this term, the proposed protected instream flow can be prorated to upstream and downstream locations from the index location.

The recommended protected instream flow for recreation is 275 cfs (1.5 cfsm), which in an average year is met 37 percent of the time (see Part Two). If this human-related instream flow were to be the controlling instream flow, the protected flow for the Lamprey Designated River would be equal to the flows occurring only during spring snowmelt runoff, during the fall when water stored in Pawtuckaway Lake is released and/or during large storm events and as a result would not be continuously sustainable. As described earlier, the recreational use arose with the expectation of only a certain frequency of flows available at these magnitudes. The number of days of occurrence of flows equal to 275 cfs (1.5 cfsm) will be tracked by DES to ensure that the frequency of these events continues to match historical occurrence rates. The instream flow need for this use will continue to be met as it has been traditionally (that is, opportunistically) and the management strategy will consider this flow in the context of preserving the frequency of its occurrence, but will not attempt to meet recreation needs on a continuous basis.

The flow requirements for fish, as determined by the MesoHABSIM model, and for riparian wildlife and vegetation, as determined by the floodplain transect method, were identified as the controlling flow needs. In the case of the Lamprey Designated River, the defining proposed protected instream flows are those for fish (see Table 23). The requirements of riparian wildlife and vegetation are either lower than those of fish or need to be fulfilled on an inter-annual basis (e.g. every three years).

From a comprehensive analysis of protected instream flow needs for all investigated protected entities it was concluded that the flows necessary to support instream fauna also fulfill the criteria for all non-opportunistic water users. The needs of riparian wildlife and vegetation that are not obviously secured by fish specific flows are:

Winter Survival and Development

>130 cfs (0.71 cfsm) seasonal mean – wood turtle (December 1 through February 28)

>500 cfs (2.73 cfsm) for one week or more – Herbaceous Low Riverbank, mannagrass, hempweed (December 1 through April 30)

Spring Spawning/growth

>100 cfs (0.55 cfsm) seasonal mean – riverweed, knotty pondweed (May 1 through June 30)

<1,500 cfs (8.2 cfsm) daily mean except for natural events - floodplain vernal pools (March 15 through July 31)

Summer Survival and Development

<500 cfs (2.73 cfsm) daily mean except for natural events – wood turtle (June 1 through October 15)

≤60 cfs (0.33 cfsm) daily mean in August/September except for natural events – Herbaceous low riverbank

<100 cfs (0.55 cfsm) seasonal mean – August /September except for natural events – riverweed, knotty pondweed

The requirement for ≤60 cfs (0.33 cfsm) of daily mean in August and September for maintenance of herbaceous low riverbank conflicts to some extent with the needs of common shiner. During this time the flows for common shiner should fluctuate between 18 and 104 cfs (0.10 and 0.57 cfsm). However, because the flows between 60 and 104 cfs (0.33 and 0.57 cfsm) will not occur very often it’s recommended that the criteria specified in the Table 23 should be used for development of a Water Management Plan.

Table 23 - Instream protected flows for the Lamprey Designated River.

Lamprey Protected Instream Flows for Fish			**Common flow**				**Critical flow**				**Rare Flow**			
Time of Year	**Controlling IPUOCR Flows**	**Bioperiod**	**Common flow (cfs)**	**Common flow (cfsm)**	**Allowable duration (days)**	**Catas-trophic duration (days)**	**Critical flow (cfs)**	**Critical flow (cfsm)**	**Allow-able duration (days)**	**Cata-strophic duration (days)**	**Rare flow (cfs)**	**Rare flow (cfsm)**	**Allow-able duration (days)**	**Cata-strophic duration (days)**
Dec 9 – Feb 28	Flow	Overwintering	238	1.3	20	57	110	0.60	10	37	73	0.40	7	30
Mar 1 – May 4	Flow	Spring Flood	622	3.4	14	42	238	1.3	10	19	146	0.80	3	9
May 5 – Jun 19	Shad spawning	Clupeid Spawning	143	0.78	13	28	62 / **156**	0.34 / **0.85**	5	13	57 / **242**	0.31 / **1.3**	4	10
Jun 20 – Jul 4	GRAF spawning	GRAF Spawning	101 / **101**	0.55 / **0.55**	-- / **11***	15*	18 / **156**	0.10 / **0.85**	5*	10*	16 / **242**	0.087 / **1.3**	2*	3*
Jul 5 – Oct 6	Common Shiner	Rearing & Growth	104	0.57	46	82	18	0.10	15	32	16	0.087	5	15
Oct 7 – Dec 8	Atlantic Salmon	Salmon Spawning	90	0.49	17	55	40	0.22	11	33	20	0.11	6	11

Bold values are upper limits for instream flow for protection of GRAF spawning. Management activities should not create flow that exceed these magnitudes and durations.

Watershed area for calculating cfsm is 183 square miles at the index location used. Index location is the gage USGS 01073500 LAMPREY RIVER NEAR NEWMARKET, NH

-- No Common Flow Allowable duration is described for this bioperiod because high flows and Catastrophic durations are limiting.

* GRAF Spawning and Clupeid Spawning bioperiods partly overlap, so durations during this bioperiod begin counting May 5 (previous bioperiod) but apply only during this bioperiod.

Lamprey Protected Instream Flows for Natural Communities, Wildlife Habitats and Rare, Threatened or Endangered Wildlife and Plants	
Wood Turtle - Winter Survival	>130 cfs seasonal mean - December 1 through February 28
Herbaceous Low Riverbank, mannagrass, hempweed - habitat maintenance	>500 cfs for one week or more - December 1 through April 30
Riverweed, Knotty Pondweed - growth and development	>100 cfs seasonal mean - May 1 through June 30
Wood Turtle - avoid nest flooding during management	<500 cfs daily mean - June 1 through October 15, except for natural events
Floodplain vernal pools - protection/isolation	<1,500 cfs daily mean - March 15 through July 31, except for natural events
Herbaceous Low Riverbank - growth and development	< or = 60 cfs daily mean - August through September, except for natural events
Lamprey Protected Instream Flows for Boating	
Boating recreational use	>=275 cfs

VI. Maintenance of Protected Instream Flows for the Lamprey Designated River

The protected instream flows will be maintained by implementing a Water Management Plan. Under the Lamprey Designated River Water Management Plan, management actions will be implemented to offset catastrophic conditions. Implementation of management actions will be based on tracking river flows at the USGS Packers Falls gage and comparing them to the protected instream flows.

For recreational boating, the number of days of occurrence of flows equal to 275 cfs will be tracked annually by DES to ensure that the frequency of these events continues to match historical occurrence rates. The instream flow need for this use will continue to be met as it has been historically (that is, opportunistically) and the management strategy will consider this protected instream flow in the context of preserving the frequency of its occurrence, but will not attempt to meet recreation needs on a continuous basis.

The instream flows defined for fish will be assessed by DES on a day to day basis to determine whether flows below thresholds exceed catastrophic durations. Flows that continue below thresholds beyond allowable durations will be tracked. Repeated events occurring within successive bioperiods or occurring during the same bioperiod for three successive years represent persistent conditions. Persistent events will be tracked on an inter-annual basis and will be deemed catastrophic if they occur in three consecutive years within the same bioperiod, with management actions triggered at the beginning of the onset of the third event under these flow conditions. If the frequency of catastrophic events is found to increase, then long term management actions may be required to offset or reduce the frequency of these events.

The instream flows supporting riparian wildlife and vegetation will be assessed by DES each year, so that management of these protected flows will react to the previous year's conditions and apply flow protections the following year. If the watershed did not meet these instream flows, then management actions for the following year may have to be implemented. This approach recognizes the ability of many plants and semi-aquatic wildlife to survive occasional water level changes through relocation, dormancy, or other physiological adaptations not available to fish.

Management alternatives for the maintenance of the protected instream flows will be evaluated during the development of the Water Management Plan in the next phase of this project. This plan will include Conservation, Water Use and Dam Management Plans for affected water users or affected dam owners located within the Lamprey Designated River Water Management Planning Area.

VII. Error and Uncertainty

The task of establishing instream flows for the protection of the flow-dependent instream public uses, outstanding characteristics and resources (protected entities) identified for the Lamprey Designated River required an interdisciplinary scientific approach. This study included specialists in the fields of aquatic biology, botany, engineering, hydrology, geology, geographic information systems, remote sensing, wetland science, and wildlife biology. In planning this study, these researchers proposed the use of a range of scientifically based methods in their assessment of the protected entities and ultimately in the development of appropriate protected instream flows. The methods used for this study were presented in detail in the Task 4 Report for this project (DES 2006). This report underwent review by the Lamprey Technical Review Committee and the Lamprey Water Management Planning Area Committee, which provided comments on and approval of the methods used as part of this study. A scientific method was defined and followed to generate the Lamprey Protected Flows.

The MesoHABSIM modeling and floodplain transect assessments include measurements or estimates of biological or physical characteristics of the river. Biological studies of riverine systems include inherent variability and some uncertainty is expected, but was not quantified under the scope of work for this project. Current practices rarely include uncertainty analysis because of the lack of baseline controls, in general, and specific to the river, in particular. Poff et al. (1997) states that “Using science to guide ecosystem management requires that basic and applied research address difficult questions in complex, real-world settings, in which experimental controls and statistical replication are often impossible”.

The methods used to generate the Lamprey Protected Instream Flows represent the state of the art. However, Bradford and Heinonen (2008) stated that “there remains substantial uncertainty in the prediction of impacts of flow reductions or diversions. Some of this uncertainty is due to a lack of understanding of the relationship between flow and fish populations, but much is probably due to site-and time-specific variation in how stream biota responds to habitat changes.”

Standard methods were used for hydrologic assessments and for the floodplain transect method. Standard methods were used in the MesoHABSIM modeling and validation testing was performed on the MesoHABSIM results. Validation testing demonstrates that the model is accurately defining the habitat suitability criteria predicting the presence and abundance of fish. As a result, the results of this study should be repeatable and verifiable by others using the same data inputs. In the following sections the potential sources of error and uncertainty associated with the hydrologic, MesoHABSIM, and floodplain transect assessments is discussed along with how these issues were addressed.

A. Hydrologic Assessment and Stream Flow Estimates

The hydrologic assessment included the concurrent measurement of stream flow at two points on the Lamprey Designated River to develop a discharge-drainage area relationship, the analysis of stream flow data for the Lamprey River from the USGS gaging station at Packers Falls, and the development of a naturalized stream flow data set that was used in the

MesoHABSIM assessment. Each of these tasks utilized stream flow data that were recorded by the USGS at its gaging station at Packers Falls near Newmarket.

The USGS provides standard reporting for field data accuracy for its gaging stations. For the Lamprey River gaging station (01073500), the measured data are rated “good” indicating that about 95 percent of the daily discharges are within 10 percent of the true value. During some periods, USGS stream flow values are estimated and are rated “fair” indicating that about 95 percent of the daily discharges are within 15 percent of the true value. Of the 26,298 daily flow measurements, 1133 were estimated. In addition, values of daily mean discharge in this report are given to nearest tenths between 1.0 and 10 cfs; to whole numbers between 10 and 1,000 cfs; and to three significant figures above 1000 cfs. The number of significant figures used is based solely on the magnitude of the discharge value.

To develop a relationship between drainage basin area and stream flow along the Lamprey Designated River, concurrent stream flow measurements were recorded at Wadleigh Falls and the Lee Hook Road crossings in the designated segment. The concurrent stream flow measurements were recorded using the standard current discharge-current meter technique by wading. Stream flow data recorded at the Packers Falls gage were also obtained from the USGS for this analysis.

A linear regression relationship was then developed between the concurrent stream flows and their associated drainage areas to estimate the stream flow at different points along the mainstem of the river upstream of the USGS gage. A total of 16 concurrent flow measurements were recorded at each of the two locations. The range of stream flows recorded, relative to the USGS gage, was from 11 cfs to 300 cfs. The concurrently measured stream flows along with the stream flows recorded at the USGS gage were then analyzed using the regression methods. For the regression equations, the standard errors of the slope coefficients were 0.00741 and 0.0204 for Wadleigh Falls and Lee Hook Road, respectively.

The naturalized stream flow data were developed using estimates of affected water user (AWU) withdrawals, net of return flow, and estimates of flow alteration resulting from historical dam operation at the Dollof Dam on Pawtuckaway Lake in Nottingham, New Hampshire. These data most likely include some errors associated with their measurement and estimate. In addition, modifications to the flow condition may have occurred due to undocumented water uses, watershed land use changes, channel obstruction, and other undocumented conditions.

The withdrawal records were developed from the quarterly water use reports submitted to DES from the fourth quarter, 1988 through 2005, and applied on a daily basis. Errors may occur due to reporting errors, consumptive loss estimate errors, and time scale errors. With respect to the latter, with the exception of the University of New Hampshire (Water Use ID 20066) transfers, monthly reported withdrawals were assumed to be uniformly withdrawn throughout the month. Prior to quarterly reporting, during the 1976 to 1988 period, monthly withdrawals were estimated from historical data with input from AWUs.

The impact of dam releases and pool filling for Pawtuckaway Lake was estimated from 16 years of historic operation records to determine typical operations including fill and release start and end dates, and fill and release volume. Daily flow releases will differ depending on the reservoir stage. In addition, the upstream releases and local flow enhancement will likely result in lower flow rate increases and a longer period to deliver the total release volume due to the significant distance between the lake and the study reach.

The use of standard methods in the collection of concurrent stream flow data during the study and the availability of a lengthy stream flow data record from the USGS gage on the Lamprey River helped produce a reliable stream flow data set for this study. The estimated stream flows developed as a result of the hydrologic assessment were used in the assessment of fish and aquatic life, which is discussed in the following section.

B. MesoHABSIM Assessment

A number of new environmental models have been applied in this study. The first foundation has been created by the development of a Baseline Fish Community followed by the determination of the Target Fish Community from an analysis of fisheries data from reference rivers. This approach has been applied in a number of studies around the Northeastern region in tandem with the MesoHABSIM approach. Ten studies to date have been conducted by Rushing Rivers and Northeast Instream Habitat Program for government and non-profit organizations. The objectives were to develop watershed management plans, protected instream flows and development of river restoration scenarios. The method has been published repeatedly in peer-reviewed journals and has been utilized by government organizations, universities, and consulting companies in Connecticut, Wyoming, Missouri, Texas, and in Europe. A Master thesis study comparing the accuracies of MesoHABSIM with other habitat models such as the Physical Habitat Simulation (PHABSIM) model and RIVER2D has been conducted at the University of Connecticut (Schmit 2009).

This method was formally proposed to the Lamprey River Technical Review Committee (TRC) as part of Task 4 of this project. This method was selected after a thorough review of available literature, and it was selected as the best available science for this study. In this, as well as in any other case, the confidence interval of flow predictions is dependent on the variety of factors that are difficult to quantify. These factors range from data collection errors to the natural biological variability of dynamic ecosystems.

Some components of the MesoHABSIM modeling process have been validated as part of this study. For example, to establish habitat use criteria for fish, twenty models were developed for each species. Each model has been cross validated, i.e. 20 percent of the fish observation data has been set aside and compared to the model predictions. The results, included in Appendix 6 (Habitat Suitability) of this report, show the success of the calibration process and documents that the models predicted fish presence between 70 and 90 percent correctly. These values overestimate the error, because not all areas containing suitable habitat are occupied by fish. This means, that in reality, the model is even more accurate.

Another experiment investigating model certainty was tasked with comparing the protected instream flows selected using a habitat time series for different indicator species. To test the possible variability the most sensitive season of Rearing and Growth (with the lowest PISF recommendations) was chosen. The protected instream flow values computed for the summer Rearing and Growth season based on rating curves for Generic Fish, Common Shiner, and EPT taxa lead to very similar flow magnitudes for rare and critical habitat levels (refer to Table 24).

Table 24 - Selection of flow criteria using different rating curves.

Rearing & Growth	Generic Fish	Invertebrates	Common Shiner
Common habitat (%CA)	56	37	8
Allowable duration under (days)	18	20	46
Catastrophic duration (days)	85	85	82
Corresponding flow (cfsm)	1.2	0.52	0.57
Corresponding flow (cfs)	***220***	***95***	***104***
Critical habitat	42	21	4
Allowable duration under (days)	8	7	15
Catastrophic duration (days)	47	28	32
Corresponding flow (cfsm)	0.16	0.07	0.10
Corresponding flow (cfs)	***29***	***13***	***18***
Rare habitat (%CA)	33	17	0.04
Allowable duration under (days)	6	5	5
Catastrophic duration (days)	43	26	15
Corresponding flow (cfsm)	0.06	0.05	0.09
Corresponding flow (cfs)	***11***	***9***	***16***

Based on the results of the cross validation of the models used in MesoHABSIM and the general agreement of the modeling results for different indicator species it is believed that the proposed protective instream flows derived by this method are appropriate and representative for the conditions studied.

C. Floodplain Transect Method

The identification of protected flows for riparian species using the floodplain transect method relates the landscape position of the sensitive resource to the flow that provides the required water levels at that landscape position. There are several potential sources of uncertainty in the evaluation of the protected flows. These may be related to the use of the landscape by mobile species, the relative sensitivity of the riparian species, or the dynamic nature of the channel and floodplain itself. Some examples of these sources of uncertainty, although not quantified, are provided below.

- The riparian landscape is dynamic, and some sensitive entities, particularly herbaceous plant communities, change locations and positions relative to the river over time or sometimes very suddenly (in storm events). Levees are built up and broken through, beaver dams are built and abandoned, oxbows are created, and point bars shift. The sensitivity of the resource to changes in flow may change if the elevation of the hydrologic connection to the river is altered.
- Even if the landscape position of the sensitive resource doesn’t change, other factors may be more critical to the resource than flow. For example, vernal pool species near a floodplain vernal pool may not breed each year, or the pool may fail for other reasons (predation); or a single flow-related failure may not result in long-term population effects if the adults of the population survive and breed again.

- Other environmental factors may reduce the effects of low flow events. For example, drops in water levels in winter may not harm hibernating wood turtles if air temperatures are coincidentally above freezing.
- In many cases, the potential effects of a low or high flow event are assumed to have particular effects based on the known life cycle requirements of a species or community as reported in the literature. The full range of hydrologic tolerances is typically not known, and the available information is rarely based on measured responses to flow or water level changes.
- Highly mobile species with large home ranges, such as eagles, osprey, beaver etc. may be less reliant on the Lamprey at any given time. For example, the Lamprey may provide only a small portion of an eagle's foraging habitat in a given season, or beaver may move up tributary streams when conditions on the Lamprey are not favorable.
- Mobile species may also choose different landscape positions along a river in any given year for flow dependent life stages. For example, even if the precise location or elevation of turtle nests or hibernation places were identified (which was beyond the scope of this project), these locations may vary by individual and year, leading to variable flow sensitivity.
- The individual responses of flow-dependent species to changes in flow may vary. For example, the literature indicates that some individual wood turtles remain active under the ice while others appear to hibernate and remain relatively immobile. Hibernating turtles may be less able to quickly relocate to a submerged refuge in response to a sudden drop in January water levels.

Despite the uncertainties described above, the direct observation and measurement of river flow, water level, and resource elevation along transects is a standard, simple, and reproducible component of many riparian studies. It provides site specific information for the wide range of plants and dependent wildlife that can be found along a particular river corridor. The floodplain transect method used in this study is based on a technique used by Scott Jackson at the University of Massachusetts, Amherst. The results are specific to the Lamprey Designated River and take into account the adaptation of each species or community to the Lamprey River's flow regime, as recorded for many decades. Uncertainties associated with mobile species and species or communities for which water level dependence has not been extensively studied can only be eliminated by extensive, species-specific research. However, in many cases, "professional judgment" can be (and was) used to interpret and apply information from studies elsewhere in the northeast, or from closely related species, as long as the link between flow and landscape position can be made.

Lastly, the protected instream flow values presented in this report reflect the biological and physical state of the Lamprey at the time of this study and are also based on historical flow records. As a result, the protected instream flow values presented in this report reflect both past and recent conditions, but they may not be protective in the future if significant ecologic or hydrologic changes occur in response to climate change. The potential impact of climate change on the Lamprey's aquatic ecology and hydrology was not evaluated as part of this study. If climate change does result in significant changes to the ecological or hydrologic state of the Lamprey, the protected instream flow values presented in this report may need to be revisited and possibly revised in the future.

Part Two – Hydrologic Evaluation of Lamprey Protected Flows

Evaluations of the protected instream flows (PISFs) under several flow scenarios were conducted to determine how frequently streamflow on the Lamprey Designated River would meet the recommended protected flows for each of the protected entities under various hydrologic conditions. The hydrologic conditions identified were: wet years, dry years, average years, and the most recent five years. To perform this evaluation representative hydrographs were first developed for each of these hydrologic conditions. In addition, a representative 30 year flow record was developed and further analyzed for use in the MesoHABSIM modeling. The following sections discuss how the representative hydrographs were derived, how a naturalized 30 year flow record was developed and the results of the analysis of the PISFs with the flows for the four selected hydrologic conditions (wet, dry, average three year periods and the most recent five years period).

I. Representative Hydrographs

Daily stream flow data for the Lamprey River were collected from the United States Geological Survey (USGS) Packers Falls gage (gage no. 01073500 LAMPREY RIVER NEAR NEWMARKET, NH). The gage is located just upstream of Packers Falls where the Lamprey River goes under Packers Falls Road.

Stream gaging at two sites upstream of the Packers Falls USGS gage (see Table 25) was performed. By regressing these measured flows against the USGS reported flows at the same time (USGS flows are reported every 15 minutes), regression equations could then be developed to predict the flows at these same two locations from the USGS reported flows. These equations first reduced the absolute flow (in cfs) to flow per unit drainage basin area to those points (cfsm):

1) $Q_{LHR} = 0.8813 \text{ x } Q_{PFG}$

2) $Q_{WF} = 0.7849 \text{ x } Q_{PFG}$

Where: Q_{LHR} = Discharge at Lee Hook Road (in CFSM)

Q_{WF} – Discharge at Wadleight Falls (in CFSM)

Q_{PEG} – Discharge at Packers Falls Gage (in CFSM)

Stream flow values at two locations upstream of the USGS gage at Packers Falls (Table 25) were estimated from concurrent flow measurements that were conducted for flows ranging from 0.04 to 1.64 cfsm. Because of the relatively close proximity of the study reaches, linear schemes using watershed area were used as the basis for the regression relationships.

Table 25 - Concurrent flow results for locations upstream of the Lamprey River USGS gage using the relationship $Q_{upstream, cfsm} = a \cdot Q_{USGS}$.

Site Description	Area (mi²)	Ratio to USGS gage	Num. of Measures	A	R^2
Wadleigh Falls	135	0.738	16	0.7849	0.998
Lee Hook Road	161	0.880	16	0.8813	0.9902
USGS Gage	183	1.000	N/A	N/A	N/A

NOTE: Concurrent flows were measured from 7.4 to 300 cfs (0.04 to 1.64 cfsm). The accuracy of relationships decreases outside the measured range.

Representative hydrographs were then developed for the following scenarios: last five years, wet three years, average three years, and dry three years. The stream flow record for water years 1934 to 2007 was examined to identify three-year periods following 1955 having wet, dry, and average conditions. In addition, for stream flows recorded since 1955, stream flow values for the last five years and, for the development of the CUT curves, a typical 30-year period were identified. In order to develop these representative hydrographs, three-year average stream flow values were determined using a three-year moving window. When available, the annual precipitation record was examined to support the selection of three-year periods (wet, dry, and average).

The maximum annual average flow (452.6 cfs) occurred from 2005 to 2007 and had a correspondingly high precipitation value of 54.2 in. This period was identified as being representative of the wet conditions hydrograph. The minimum average flow (179.5 cfs) occurred from 1964 to 1966 with a very low average annual precipitation (35.7 in). This period was identified as being representative of the dry conditions hydrograph. Average conditions for stream flow (286.4 cfs) and precipitation (43.5 in) were found from 1990 to 1992. Over the last five years (2003 to 2007), the average stream flow (386.2 cfs) was well above the long-term average conditions. The selected 30-year period is 1976 to 2005. This period includes historically wet and dry periods and has an average flow (287.0 cfs) that is close to the long-term average. An IHA analysis performed on the 30-year period showed no trends for any month's average, maximum, or minimum values.

These representative hydrographs were then compared to the 30 years of record at the Packers Falls gage in Figure 52, in which the comparison is made with a flow duration plot. Figure 53 amplifies the low flow end of Figure 52 and Figure 54 amplifies the high flows. These plots show the expected results, where the three-year wet periods plot

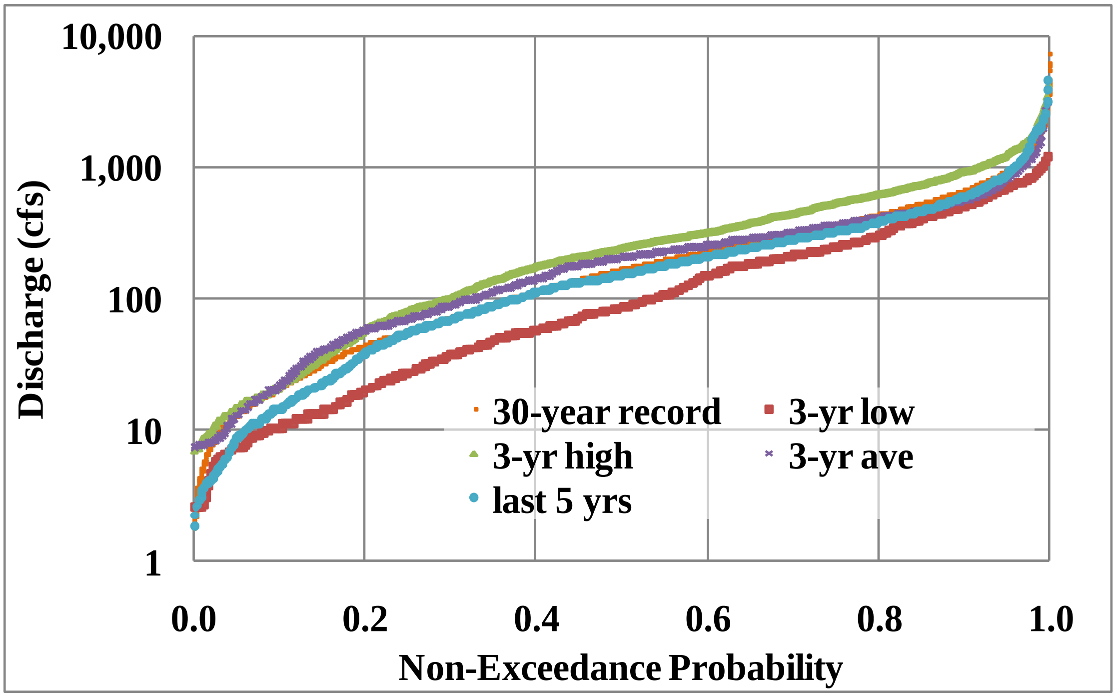

Figure 52 - Full flow frequency plot for the Lamprey River representative hydrograph datasets at the USGS Packers Falls gage.

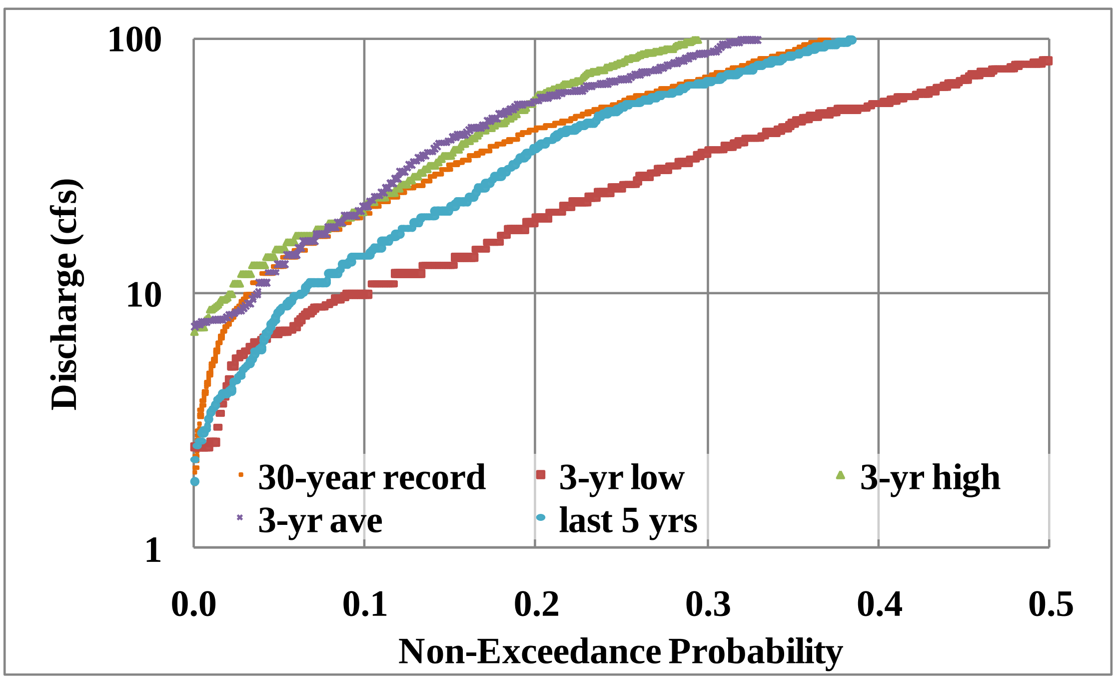

Figure 53 - Amplification of low flow duration flows for the representative hydrograph datasets at the USGS Packers Falls gage.

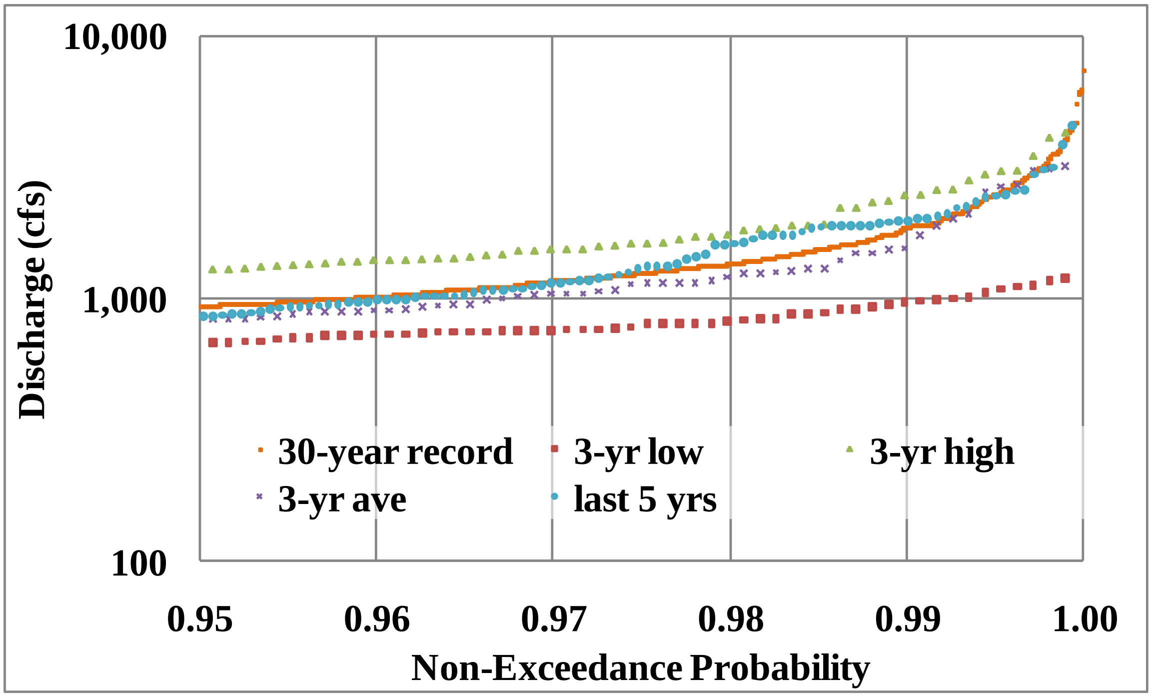

Figure 54 - Amplification of high flow duration flows for the representative hydrograph datasets at the USGS Packers Falls gage.

above (wetter) the 30-year average plot and the three-year low plots below the 30-year record. For flows less than 100 cfs, which most of the rare flow PISFs fall under, the flows for the last five years (2003-2007) are lower than those for the 30-year record and drop below the flows for the three-year dry period. Although this period is remembered as having high flows because of the flooding events in 2006 and 2007, it also included periods of below average flows.

In addition to the development of the representative hydrographs, naturalized flows were developed based on the 30-year hydrograph (1976-2005). The flows were naturalized by removing withdrawals and return flows and further modified accounting for the water put into and taken out of storage at Dolloff Dam at Pawtuckaway Lake. These “naturalized” flows were then used in the MesoHABSIM habitat time series analysis of the baseline condition for the development of the aquatic life and fish protected instream flows. Further discussion of the details on how the naturalized flows were developed can be found in Appendix 13.

II. Comparison of PISF to Representative Hydrographs

All recommended protected instream flows (PISFs) were then compared to four representative hydrographs derived from flows recorded by the USGS at the Packers Falls gaging station. The representative hydrographs included the three-year wet (2005-2007), dry (1964-1966), average (1990-1992) and the last five-year (2003 to 2007) periods. Each of the PISFs was compared with the streamflows for the selected hydrologic conditions, without having adjusted for any water withdrawals or discharges (existing conditions). This comparison demonstrates how the existing flow regime, including all withdrawals and return flows, meets the PISFs recommended for the protected entities on the Lamprey Designated River. The results will also be considered during the development of the Water Management Plan, which is the next phase of this project.

A. Recreation

The recommended PISF for recreational boating is 275 cfs. Table 26 delineates the number of days that the representative hydrographs meet (greater than) the recreational boating PISF and the probability of same. For example, over the last five years (2003-2007) the flow of the Lamprey River was greater than 275 cfs for 549 days, which represents 30.1 percent of the time.

Table 26 - Comparison of existing conditions stream flow to the boat recreation PISF.

Representative Hydrograph	Days	%
Last five years	549	30.1
Wet three years	510	46.5
Average three years	407	37.1
Dry three years	235	21.4

Note: Number of days per year (Days) stream flow in the reach meets the PISF (> 275 cfs) and the percent of time (%) in the representative hydrograph.

B. Fishing

The recommended fishing PISF use is dependent on the Lamprey River flow only to the extent that it protects the fishery resource. Therefore, this section defers the PISF to that for fish habitat (see Tables 45 to 48).

C. Water Supply

Although a PISF was not proposed for the one active Public Water Supply (PWS) diversion (University of New Hampshire/Town of Durham Water System) on the Lamprey Designated

River an analysis was performed using the 401 Water Quality Certification conditions for Wiswall Dam. Wiswall Dam impounds the segment of the Lamprey Designated River where the UDWS makes its' withdrawals. These conditions include flows in the ranges of: 45 to 21 cfs; 21-13 cfs, and less than 13 cfs. Table 27 identifies the number of days (Days) and the probabilities (%) of the river flow being in these ranges for the representative hydrographs. For example, during the last five years (2003-2007) flows on the Lamprey River fell within the range of 45-21 cfs 8.2 percent of the time or 150 days.

Table 27 - Comparison of existing conditions stream flow to the Wiswall Dam 401 Water Quality Certificate conditions.

Representative Hydrograph	45-21 cfs		21-13 cfs		<13 cfs	
	Days	%	Days	%	Days	%
Last five years	150	8.2	99	5.4	158	8.7
Wet three years	86	7.8	64	5.8	37	3.4
Average three years	73	6.7	52	4.7	53	4.8
Dry three years	149	13.6	82	7.5	146	13.3

D. RTE: Wildlife, Vegetation, and Natural/Ecological Communities

Refer to Rare, Threatened and Endangered (RTE) section in Part One of the report for details. The table of RTE flows are reproduced in Table 28.

Table 28 - Flow-dependent RTE wildlife, RTE vegetation, and natural/ecological communities on the Lamprey Designated River and the associated protective instream flows (PISFs).

Protected Entities	Conservation Status[1]	General Location	Sensitive Bioperiod(s)	General Flow Requirements.	PISF (at Lamprey Gage)
Low Floodplain Forest	S2	Newmarket pool, scattered elsewhere	Growing season	One to three year flooding (< two yr return flood)	>500 cfs every one to three years for five to 50 days.
High Floodplain Forest (incl. Swamp White Oak *Quercus bicolor*)	S2S3 S1	Narrow band along most of Lamprey, wider at tributaries and oxbows.	Growing season	Two to 100 year flooding (>two-year return flood)	> 1,500 cfs every two to 100 years for five to 30 days
Oxbow/Backwater Swamp	S3	North of Glenmere Village	Growing season	Flooding of backwaters/oxbows	>1,500 cfs every one to five years
Herbaceous Low Riverbank	S3/S4	Near Lee Hook Road and other locations	Winter/spring dormancy	Flood/ice scour of channel	December 1 to April 30 >500 cfs for 1 week
			Late summer flowering	Low flow to expose substrate	August 1 to September 30 ≤ 60 cfs mean daily flow

Table 28 (Continued)

Protected Entities	Conservation Status[1]	General Location	Sensitive Bioperiod(s)	General Flow Requirements.	PISF (at Lamprey Gage)
Riverweed River Rapid	S2S3	Near Lee Hook Road and other locations	Spring growth	Flooding of riffles	May 1 to June 30 >100 cfs mean monthly flow
			Late summer flowering	Low flow to expose riffles	August 1 to September 30 < 100 cfs mean monthly flow
Deep and Shallow Marsh	S4S5	Along tributaries and in pools above dams	Early-mid growing season	Flooding of marsh for dependent fauna	April 1 to July 31 >10 cfs daily mean flow
Vernal Floodplain Pool	S2	Near Wiswall Rd and Glenmere Village	Early spring to mid-summer breeding season	Hydrologic isolation of pools in high floodplain	March 15-July 31 <1,500 cfs every day
			Early spring to mid-summer breeding season	Maintain hydrology of river-connected pools in low floodplain	March 15-July 31 No impoundment drawdown > six inches for more than seven consecutive days

Table 28 (Continued)

Protected Entities	**Conservation Status**[1]	**General Location**	**Sensitive Bioperiod(s)**	**General Flow Requirements.**	**PISF (at Lamprey Gage)**
Climbing Hempweed *Mikania scandens*	G5S2	Tributary Stream floodplain	Spring/summer growing season	Forested wetland hydrology	April 1 to October 31 >500 cfs for 10 days (non-consecutive)
Star Duckweed *Lemna trisulca*	G5S1	Tributary Stream	Summer growing season	Maintain standing water or saturation	No PISF [3]
Water Marigold *Megalodonta beckii*	G4G5S1	River/Tributary Impoundments	Summer growing season	Maintain standing water	No PISF[3] Maintain summer water levels within 18 inches of mean elevation.
Knotty Pondweed *Potamogeton nodosus*	G4G5S1	River/Tributary Impoundments	Early summer growth	Maintain flowing water	May 1 to June 30 >100 cfs mean monthly
	G5S1	Fast shallow water	Late summer flowering	Low flowing water	August 1 to September 30 <100 cfs mean monthly
Slender Blueflag *Iris prismatica*	G4G5S2	Floodplains, riverbanks	Growing season	Maintain wetland hydrology	See requirements for shallow marsh

Table 28 (Continued)

Protected Entities	Conservation Status[1]	General Location	Sensitive Bioperiod(s)	General Flow Requirements.	PISF (at Lamprey Gage)
Sharp-flowered Mannagrass *Glyceria acutiflora*	G5S1	Fast shallow water	Growing season	Maintain wetland hydrology	See requirements for herbaceous low riverbank
Blanding's Turtle *Emydoidea blandingii*	G4S3 State Endangered[2]	Uplands near Backwater/oxbow wetland complex	Spring-summer nesting season	No flooding of high floodplain nest sites	June 1 to October 31 <1,500 cfs daily flow
Wood Turtle *Clemmys insculpta*	G4S3 Special Concern[2]	Uplands and floodplains near Tributary streams	Spring-summer nesting	No flooding during nesting in mid to high floodplain	June 1 to October 15 <500 cfs daily flow
		Lamprey River and Tributary streams	Winter hibernation	Avoid dewatering of in-channel hibernation sites	December 1 to February 28 >130 cfs seasonal mean >50 cfs daily mean most days
Spotted Turtle *Clemmys guttata*	G5S3 State-Threatened[2]	Uplands near Backwater/oxbow/VP wetland complex	Spring-summer nesting	No flooding of high floodplain nest sites	June 1 to October 31 <1,500 cfs daily flow

Table 28 (Continued)

Protected Entities	Conservation Status[1]	General Location	Sensitive Bioperiod(s)	General Flow Requirements.	PISF (at Lamprey Gage)
Osprey *Pandion haliaetus*	G5S2B[2]	Pools in lower Designated reach	Spring-summer nesting-rearing	Sufficient flows to protect prey (fish) in channel	Support prey fisheries (see GRAF Fish recommended flows)
Bald Eagle *Haliaeetus leucocephalus*	G5S1 State-Threatened[2]	Pools in Lower designated reach	Any time of year	Sufficient flows to protect prey (fish) in channel	Support prey fisheries (see GRAF Fish recommended flows)
Pied-billed Grebe *Podilymbus podiceps*	G5S1B State-Threatened [2]	Large emergent marshes in impoundments	Spring-summer nesting	Maintain water levels during nesting season	No PISF[3]. Maintain summer water levels within 18 inches of mean elevation.
Sedge Wren *Cistothorus platensis*	G5S1 State-Endangered	Wet meadows near impoundments	Spring-summer nesting	Maintain water levels during nesting season	No PISF[3]. Maintain summer water levels within 18 inches of mean elevation.

Table 28 (Continued)

1 – **G=Global Rank; S=State Rank; Numerical status is:**

Code	Description
1	Critically imperiled because extreme rarity (generally one to five occurrences) or some factor of its biology makes it particularly vulnerable to extinction.
2	Imperiled because rarity (generally six to 20 occurrences) or other factors demonstrably make it very vulnerable to extinction.
3	Either very rare and local throughout its range (generally 21 to 100 occurrences), or found locally (even abundantly at some of its locations) in a restricted range, or vulnerable to extinction because of other factors.
4	Widespread and apparently secure, although the species may be quite rare in parts of its range, especially at the periphery.
5	Demonstrably widespread and secure, although the species may be quite rare in parts of its range, particularly at the periphery.
B.	Indicates that the species is migratory and breeds in the state.

2 – In 2008 the New Hampshire Fish and Game Department made the following changes to the state protection status for these (and other) species:

Blanding's Turtle – added to the Endangered Species List
Spotted Turtle – added to the Threatened Species List
Osprey – removed from the Threatened Species List
Bald Eagle – down listed from Endangered to Threatened
Pied-billed Grebe – down listed from Endangered to Threatened

3 - These species are dependent on minimal standing water or water levels that are not greatly altered by changes in flow, and therefore, no PISF was assigned to them. They may, however, be vulnerable to rapid or prolonged changes in water levels associated with dam management. See text for more details

Table 29 - Comparison of existing conditions stream flow to the Low Floodplain Forest - growing season PISF for the representative hydrographs.

Representative Hydrograph	Days	%
Last five years	232	12.7
Wet three years	302	27.6
Average three years	143	13.0
Dry three years	109	9.9

NOTE: Number of days (Days) in the hydrologic record and bioperiod that stream flow in the reach meets the PISF (> 500 cfs) and percent of time (%) in the representative hydrograph.

Table 30 - Comparison of existing conditions stream flow to the High Floodplain Forest and Oxbow/Backwater PISF for the representative hydrographs.

Representative Hydrograph	Days	%
Last five years	38	2.1
Wet three years	35	3.2
Average three years	14	1.3
Dry three years	0	0.0

NOTE: Number of days (Days) in the hydrologic record and bioperiod that stream flow in the reach meets the PISF (>1,500 cfs) and percent of time in the representative hydrograph.

Table 31 - Comparison of existing conditions stream flow to the Herbaceous Low Riverbank - winter PISF for the representative hydrographs.

Representative Hydrograph	Days	%
Last five years	167	22.1
Wet three years	219	48.2
Average three years	93	20.5
Dry three years	101	22.2

NOTE: Number of days (Days) in the hydrologic record and bioperiod that stream flow in the reach meets the PISF (>500 cfs) and percent of time (%) in the representative hydrograph.

Table 32 - Comparison of existing conditions stream flow to the Herbaceous Low Riverbank – summer PISF for the representative hydrographs.

Representative Hydrograph		
	Years	%
Last five years	5	100
Wet three years	3	100
Average three years	3	100
Dry three years	2	66.7

NOTE: Number of years (Years) in the hydrologic record and bioperiod that stream flow in the reach meets the PISF ($\leq$ 60 cfs) and percent of time (%) in the representative hydrograph.

Table 33 - Comparison of existing conditions stream flow to the Riverweed River Rapid - spring PISF for the representative hydrographs.

Representative Hydrograph		
	Months	%
Last five years	9	90.0
Wet three years	6	100.0
Average three years	4	66.7
Dry three years	4	66.7

NOTE: Number of months (Months) in the hydrologic record and bioperiod that stream flow in the reach meets the PISF (>100 cfs) and percent of time (%) in the representative hydrograph.

Table 34 - Comparison of existing conditions stream flow to the Riverweed River Rapid - summer PISF for the representative hydrographs.

Representative Hydrograph		
	Months	%
Last five years	10	100.0
Wet three years	6	100.0
Average three years	4	66.7
Dry three years	6	100.0

NOTE: Number of months (Months) in the hydrologic record and bioperiod that stream flow in the reach meets the PISF (<100 cfs) and percent of time (%) in the representative hydrograph).

Table 35 - Comparison of existing conditions stream flow to the Deep and Shallow Marsh PISF for the representative hydrographs.

Representative Hydrograph		
	Days	%
Last five years	610	100.0
Wet three years	366	100.0
Average three years	351	95.9
Dry three years	355	97.0

NOTE: Number of days (Days) in the hydrologic record and bioperiod that stream flow in the reach meets the PISF (> 10 cfs) and percent of time (%) in the representative hydrograph.

Table 36 - Comparison of existing conditions stream flow to the Vernal Floodplain Pool - spring PISF for the representative hydrographs.

Representative Hydrograph		
	Days	%
Last five years	657	50.7
Wet three years	389	50.1
Average three years	405	52.1
Dry three years	417	53.7

NOTE: Number of days (Days) in the hydrologic record and bioperiod that stream flow in the reach meets the PISF (<1,500 cfs) and percent of time (%) in the representative hydrograph.

Table 37 - Comparison of existing conditions stream flow to the Climbing Hempweed PISF for the representative hydrographs.

Representative Hydrograph		
	Years	%
Last five years	5	100.0
Wet three years	3	100.0
Average three years	2	66.7
Dry three years	1	33.3

NOTE: Number of years (Years) in the hydrologic record and for the bioperiod that stream flow in the reach meets the PISF (>500 cfs) and percent of time (%) in the representative hydrograph.

Table 38 - Comparison of existing conditions stream flow to the Knotty Pondweed - early summer PISF for the representative hydrographs.

Representative Hydrograph		
	Months	%
Last five years	9	90.0
Wet three years	6	100.0
Average three years	4	66.7
Dry three years	4	66.7

NOTE: Number of months (Months) in the hydrologic record and bioperiod that stream flow in the reach meets the PISF (>100 cfs) and percent of time (%) in the representative hydrograph.

Table 39 - Comparison of existing conditions stream flow to the Knotty Pondweed - late summer PISF for the representative hydrographs.

Representative Hydrograph		
	Months	%
Last five years	10	100.0
Wet three years	6	100.0
Average three years	4	66.7
Dry three years	6	100.0

NOTE: Number of months (Months) in the hydrologic record and bioperiod that stream flow in the reach meets the PISF (<100 cfs) and percent of time (%) in the representative hydrograph.

Table 40 - Comparison of existing conditions stream flow to the Blanding's Turtle/Spotted Turtle PISF for the representative hydrographs.

Representative Hydrograph		
	Days	%
Last five years	765	100.0
Wet three years	451	98.3
Average three years	457	99.6
Dry three years	459	100.0

NOTE: Number of days (Days) in the hydrologic record and bioperiod that stream flow in the reach meets the PISF (<1,500 cfs) and percent of time (%) in the representative hydrograph.

Table 41 - Comparison of existing conditions stream flow to the Wood Turtle - summer PISF for the representative hydrographs.

Representative Hydrograph	Days	%
Last five years	670	97.8
Wet three years	374	91.0
Average three years	396	96.4
Dry three years	411	100.0

Note: Number of days (Days) in the hydrologic record and bioperiod that stream flow in the reach meets the PISF (<500 cfs) and percent of time (%) in the representative hydrograph.

Table 42 - Comparison of existing conditions stream flow to the Wood Turtle –winter (daily) PISF for the representative hydrographs.

Representative Hydrograph	Days	%
Last five years	414	92.0
Wet three years	270	100.0
Average three years	270	100.0
Dry three years	244	90.4

Note: Number of days (Days) in the hydrologic record and bioperiod that stream flow in the reach meets the PISF (>50 cfs) and percent of time (%) in the representative hydrograph.

Table 43 - Comparison of existing conditions stream flow to the Wood Turtle - winter (monthly) PISF for the representative hydrographs.

Representative Hydrograph	Months	%
Last five years	13	65.0
Wet three years	8	66.7
Average three years	9	75.0
Dry three years	12	100.0

Note: Number of months (Months) in the hydrologic record and bioperiod that stream flow in the reach meets the PISF (>130 cfs) and percent of time (%) in the representative hydrograph.

E. Fish

The protected instream flows for fish of the six bioperiods (Table 44) were compared with the last five years flow record (Table 45), three year high (Wet) flow record (Table 46), three year average flow record (Table 47) and three year low flow record (Table 48).

Specific notes on the fish projected instream flows and durations used in this analysis are as follows:

- For the rearing and growth bioperiod (July 5 to October 6) flows should not be under **0.57 cfsm (104 cfs)** for longer than 46 days, under **0.10 cfsm (18 cfs)** for 15 days, or under **0.09 cfsm (16 cfs)** for five days. Catastrophic durations for these flow levels (common, critical and rare) are 82, 32, and 15 days, respectively.
- During the Atlantic salmon spawning bioperiod (October 7 to December 8) the flows should not be under **0.49 cfsm (90 cfs)** for longer than 17 days, under **0.22 cfsm (40 cfs)** for 11 days, or under **0.11 cfsm (20 cfs)** for six days. Catastrophic durations for these flow levels are 55, 33, and 11 days, respectively.
- During the overwintering bioperiod (December 9 to February 28) flows should not be under **1.30 cfsm (238 cfs)** for longer than 20 days, under **0.60 cfsm (110 cfs)** for longer than 10 days, or under **0.40 cfsm (73 cfs)** for longer than seven days. Catastrophic durations for these flow levels are 57, 37, and 30 days, respectively.
- During the spring flood bioperiod (March 1 to May 4) flows should not be under **3.40 cfsm (622 cfs)** for longer than 14 days, under **1.30 cfsm (238 cfs)** for longer than 10 days,or under **0.80 cfsm (146 cfs)** for longer than three days. Catastrophic durations for these flow levels are 42, 19, and nine days, respectively.
- During the American shad spawning season two events take place: the spawning of Clupeids and GRAF species. Therefore, the criteria for both events need to be fulfilled. For Clupeid spawning (May 5 to June 19) the flows should not be lower than **0.78 cfsm (143 cfs)** for longer than 13 days, nor less than **0.34 cfsm (62 cfs)** or more than **0.85 cfsm (156 cfs)** for five days, or less than **0.31 cfsm (57 cfs),** or higher than **1.32 cfsm (242 cfs)** for four days. Catastrophic durations for these flow levels are 28, 13, and 10 days, respectively.
- During early summer, the spawning habitat for GRAF species mostly declines with increasing flow. Therefore, the recommendations for this bioperiod are different than for the others. Target flow levels and durations are recommended rather than a downward limitation of flows. For the GRAF spawning bioperiod (June 20 to July 4) the flows should stay under **0.55 cfsm (101 cfs)** for at least 11 days, but no longer than 15 days in the catastrophic case. Flow should not be above **0.85 cfsm (156 cfs)**, but no less than **0.10 cfsm (18 cfs)** for longer than five days, but no longer than 10 days in the catastrophic case. The flows should not be higher than **1.32 cfsm (242 cfs)**, but not lower than **0.09 cfsm (16 cfs)** for longer than two days, but no longer than three days in the catastrophic case. This indicates that in order to support spawning, the long durations of high flow events are rare and should be avoided or controlled. On the low flow end, rare flows cannot be lower than those in the preceding rearing and growth bioperiod, because the adult fish still need to survive.

Table 44 - Fish protected instream flows for the Lamprey Designated River.

Bioperiod Approximate dates	**Rearing & Growth** July 5 - Oct. 6 (94 days)	**Salmon Spawning** Oct. 7 - Dec. 8 (63 days)	**Overwintering** Dec 9 - Feb. 28 (82 days)
Indicator	**Recommended flows** Common shiner	**Recommended flows** Atlantic salmon	**Recommended flows** Flow
Watershed area (mi^2)	183	183	183
Location	**USGS Gage**	**USGS Gage**	**USGS Gage**
Common flow (cfs)	104	90	238
Common flow (cfsm)	0.57	0.49	1.30
Allowable duration under (days)	46	17	20
Catastrophic duration (days)	82	55	57
Critical flow (cfs)	18	40	110
Critical flow (cfsm)	0.10	0.22	0.60
Allowable duration under (days)	15	11	10
Catastrophic duration (days)	32	33	37
Rare flow (cfs)	16	20	73
Rare flow (cfsm)	0.09	0.11	0.40
Allowable duration under (days)	5	6	7
Catastrophic duration (days)	15	11	30

Table 44 (Continued)

Bioperiod Approximate dates	**Spring Flood** March 1 - May 4 (65 days)	**Shad Spawning** May 5 - June 19 (46 days)		**GRAF Spawning** June 20 - July 4 (15 days)	
Indicator	Flow	Min	Max	Min	Max
Watershed area (mi^2)	183	183	183	183	183
Location	**USGS Gage**	**USGS Gage**	**USGS Gage**	**USGS Gage**	**USGS Gage**
Common flow (cfs)	622	143		101	
Common flow (cfsm)	3.40	0.78		0.55	
Allowable duration under (days)	14	13		11	
Catastrophic duration (days)	42	28		15	
Critical flow (cfs)	238	62	156	18	156
Critical flow (cfsm)	1.30	0.34	0.85	0.10	0.85
Allowable duration under (days)	10	5		5	
Catastrophic duration (days)	19	13		10	
Rare flow (cfs)	146	57	242	16	242
Rare flow (cfsm)	0.80	0.31	1.32	0.09	1.32
Allowable duration under (days)	3	4		2	
Catastrophic duration (days)	9	10		3	
			GRAF Spawning	Common Shiner R&G	

Note: USGS gage at Packers Falls near Newmarket, New Hampshire (01073500)

Table 45 - Evaluation of Fish PISF against the last five-year's flow record (2003-2007) at the USGS Packers Falls gage.

Note: Numbers appearing on the Common, Critical, and Rare flow rows are the number of times in the record that the PISF were not met {stream flow below PISF value}. Numbers on the rows for Allowable and Catastrophic durations are the number of times in the record in which the PISF were not met {duration exceeded}.

Bioperiod Approximate dates	**Rearing & Growth** July 5 - Oct. 6 (94 days)	**Salmon Spawning** Oct. 7 - Dec. 8 (63 days)	**Overwintering** Dec 9 - Feb. 28 (82 days)
Indicator	Common shiner	Atlantic salmon	Flow
Watershed area (mi^2)	183	183	183
Location	**USGS Gage**	**USGS Gage**	**USGS Gage**
Violations of Common flow	412	107	264
Violations of Common flow (%)	87.7%	34.0%	64.4%
Violations of Allowable duration	3	1	4
Violations of Catastrophic duration	2	1	2
Violations of Critical flow	167	72	123
Violations of Critical flow (%)	35.5%	22.9%	30.0%
Violations of Allowable duration	2	1	2
Violations of Catastrophic duration	1	1	1
Violations of Rare flow	149	65	67
Violations of Rare flow (%)	31.7%	20.6%	16.3%
Violations of Allowable duration	6	4	2
Violations of Catastrophic duration	2	2	1

Table 45 (Continued)

Bioperiod Approximate dates	**Spring Flood** March 1 - May 4 (65 days)	**Shad Spawning** May 5 - June 19 (46 days)		**GRAF Spawning** June 20 - July 4 (15 days)	
Indicator	Flow	Min	Max	Min	Max
Watershed area (mi^2)	183	183	183	183	183
Location	**USGS Gage**	**USGS Gage**	**USGS Gage**	**USGS Gage**	**USGS Gage**
Violations of Common flow	228	39		26	
Violations of Common flow (%)	70.2%	17.0%		34.7%	
Violations of Allowable duration	6	1		1	
Violations of Catastrophic duration	0	1		0	
Violations of Critical flow	87	7	185	0	27
Violations of Critical flow (%)	26.5%	3.0%	80.4%	0.0%	36.0%
Violations of Allowable duration	4	1		0	
Violations of Catastrophic duration	1	0		0	
Violations of Rare flow	25	5	142	0	16
Violations of Rare flow (%)	7.7%	2.2%	61.7%	0.0%	21.3%
Violations of Allowable duration	2	1		0	
Violations of Catastrophic duration	1	0		0	
			GRAF Spawning	Common Shiner R&G	

Note: Numbers appearing on the Common, Critical, and Rare flow rows are the number of times in the record that the PISF were not met {stream flow below PISF value}. Numbers on the rows for Allowable and Catastrophic durations are the number of times in the record in which the PISF were not met {duration exceeded}.

Table 46 - Evaluation of Fish PISF against the three-year high (WET) flow record (2005-2007) at the USGS Packers Falls gage.

Note: Numbers appearing on the Common, Critical, and Rare flow rows are the number of times in the record that the PISF were not met {stream flow below PISF value}. Numbers on the rows for Allowable and Catastrophic durations are the number of times in the record in which the PISF were not met {duration exceeded}.

Bioperiod Approximate dates	**Rearing & Growth** July 5 - Oct. 6 (94 days)	**Salmon Spawning** Oct. 7 - Dec. 8 (63 days)	**Overwintering** Dec 9 - Feb. 28 (82 days)
Indicator	Common shiner	Atlantic salmon	Flow
Watershed area (mi^2)	183	183	183
Location	**USGS Gage**	**USGS Gage**	**USGS Gage**
Violations of Common flow	244	40	75
Violations of Common flow (%)	86.5%	21.2%	30.5%
Violations of Allowable duration	3	1	1
Violations of Catastrophic duration	1	0	0
Violations of Critical flow	81	8	17
Violations of Critical flow (%)	28.7%	4.2%	6.9%
Violations of Allowable duration	2	0	0
Violations of Catastrophic duration	0	0	0
Violations of Rare flow	63	7	0
Violations of Rare flow (%)	22.3%	3.7%	0.0%
Violations of Allowable duration	3	0	0
Violations of Catastrophic duration	1	0	0

Table 46. (Continued)

Bioperiod Approximate dates	**Spring Flood** March 1 - May 4 (65 days)	**Shad Spawning** May 5 - June 19 (46 days)		**GRAF Spawning** June 20 - July 4 (15 days)	
Indicator	Flow	Min	Max	Min	Max
Watershed area (mi^2)	183	183	183	183	183
Location	**USGS Gage**	**USGS Gage**	**USGS Gage**	**USGS Gage**	**USGS Gage**
Violations of Common flow	64	1		16	
Violations of Common flow (%)	32.8%	0.7%		35.6%	
Violations of Allowable duration	2	0		1	
Violations of Catastrophic duration	0	0		0	
Violations of Critical flow	12	0	133	0	18
Violations of Critical flow (%)	6.2%	0.0%	96.4%	0.0%	40.0%
Violations of Allowable duration	0	0		0	
Violations of Catastrophic duration	0	0		0	
Violations of Rare flow	0	0	103	0	13
Violations of Rare flow (%)	0.0%	0.0%	74.6%	0.0%	28.9%
Violations of Allowable duration	0	0		0	
Violations of Catastrophic duration	0	0		0	
			GRAF Spawning	Common Shiner R&G	

Note: Numbers appearing on the Common, Critical, and Rare flow rows are the number of times in the record that the PISF were not met {stream flow below PISF value}. Numbers on the rows for Allowable and Catastrophic durations are the number of times in the record in which the PISF were not met {duration exceeded}.

Table 47 - Evaluation of Fish PISF against the three-year average flow record (1990-1992) at the USGS Packers Falls gage.

Note: Numbers appearing on the Common, Critical, and Rare flow rows are the number of times in the record that the PISF were not met {stream flow below PISF value}. Numbers on the rows for Allowable and Catastrophic durations are the number of times in the record in which the PISF were not met {duration exceeded}.

Bioperiod Approximate dates	**Rearing & Growth** July 5 - Oct. 6 (94 days)	**Salmon Spawning** Oct. 7 - Dec. 8 (63 days)	**Overwintering** Dec 9 - Feb. 28 (82 days)
Indicator	Common shiner	Atlantic salmon	Flow
Watershed area (mi^2)	183	183	183
Location	**USGS Gage**	**USGS Gage**	**USGS Gage**
Violations of Common flow	242	8	90
Violations of Common flow (%)	85.8%	4.2%	36.6%
Violations of Allowable duration	1	0	1
Violations of Catastrophic duration	1	0	0
Violations of Critical flow	92	3	12
Violations of Critical flow (%)	32.6%	1.6%	4.9%
Violations of Allowable duration	2	0	0
Violations of Catastrophic duration	1	0	0
Violations of Rare flow	78	0	0
Violations of Rare flow (%)	27.7%	0.0%	0.0%
Violations of Allowable duration	3	0	0
Violations of Catastrophic duration	2	0	0

Table 47 (Continued)

Bioperiod Approximate dates	**Spring Flood** March 1 - May 4 (65 days)	**Shad Spawning** May 5 - June 19 (46 days)		**GRAF Spawning** June 20 - July 4 (15 days)	
Indicator	Flow	Min	Max	Min	Max
Watershed area (mi^2)	183	183	183	183	183
Location	**USGS Gage**	**USGS Gage**	**USGS Gage**	**USGS Gage**	**USGS Gage**
Violations of Common flow	148	81		45	
Violations of Common flow (%)	75.9%	58.7%		100.0%	
Violations of Allowable duration	4	2		3	
Violations of Catastrophic duration	0	1		0	
Violations of Critical flow	46	8	54	0	0
Violations of Critical flow (%)	23.6%	5.8%	39.1%	0.0%	0.0%
Violations of Allowable duration	2	0		0	
Violations of Catastrophic duration	0	0		0	
Violations of Rare flow	15	5	26	0	0
Violations of Rare flow (%)	7.7%	3.6%	18.8%	0.0%	0.0%
Violations of Allowable duration	2	0		0	
Violations of Catastrophic duration	0	0		0	
			GRAF Spawning	Common Shiner R&G	

Note: Numbers appearing on the Common, Critical, and Rare flow rows are the number of times in the record that the PISF were not met {stream flow below PISF value}. Numbers on the rows for Allowable and Catastrophic durations are the number of times in the record in which the PISF were not met {duration exceeded}.

Table 48 - Evaluation of Fish PISF against the three-year low flow record (1964-1966).

Note: Numbers appearing on the Common, Critical, and Rare flow rows are the number of times in the record that the PISF were not met {stream flow below PISF value}. Numbers on the rows for Allowable and Catastrophic durations are the number of times in the record in which the PISF were not met {duration exceeded}.

Bioperiod Approximate dates	**Rearing & Growth** July 5 - Oct. 6 (94 days)	**Salmon Spawning** Oct. 7 - Dec. 8 (63 days)	**Overwintering** Dec 9 - Feb. 28 (82 days)
Indicator	Common shiner	Atlantic salmon	Flow
Watershed area (mi^2)	183	183	183
Location	**USGS Gage**	**USGS Gage**	**USGS Gage**
Violations of Common flow	269	128	178
Violations of Common flow (%)	95.4%	67.7%	72.4%
Violations of Allowable duration	3	3	3
Violations of Catastrophic duration	2	0	1
Violations of Critical flow	188	63	113
Violations of Critical flow (%)	66.7%	33.3%	45.9%
Violations of Allowable duration	4	3	3
Violations of Catastrophic duration	3	0	1
Violations of Rare flow	176	15	60
Violations of Rare flow (%)	62.4%	7.9%	24.4%
Violations of Allowable duration	7	1	4
Violations of Catastrophic duration	4	0	0

Table 48 (Continued)

Bioperiod Approximate dates	**Spring Flood** March 1 - May 5 (66 days)	**Shad Spawning** May 6 - June 19 (45 days)		**GRAF Spawning** June 20 - July 4 (15 days)	
Indicator	Flow	Min	Max	Min	Max
Watershed area (mi^2)	183	183	183	183	183
Location	**USGS Gage**	**USGS Gage**	**USGS Gage**	**USGS Gage**	**USGS Gage**
Violations of Common flow	145	68		43	
Violations of Common flow (%)	74.4%	49.3%		95.6%	
Violations of Allowable duration	4	3		3	
Violations of Catastrophic duration	0	0		0	
Violations of Critical flow	39	25	65	11	0
Violations of Critical flow (%)	20.0%	18.1%	47.1%	24.4%	0.0%
Violations of Allowable duration	1	1		1	
Violations of Catastrophic duration	1	1		0	
Violations of Rare flow	0	21	23	9	0
Violations of Rare flow (%)	0.0%	15.2%	16.7%	20.0%	0.0%
Violations of Allowable duration	0	1		1	
Violations of Catastrophic duration	0	1		1	
			GRAF Spawning	Common Shiner R&G	

Note: Numbers appearing on the Common, Critical, and Rare flow rows are the number of times in the record that the PISF were not met {stream flow below PISF value}. Numbers on the rows for Allowable and Catastrophic durations are the number of times in the record in which the PISF were not met {duration exceeded}.

III. Water Quality Standards

RSA 483 Section 483:1 (Statement of Policy) states the general instream flow policy for the state of New Hampshire, which is for the "…state to ensure the continued viability of New Hampshire rivers as valued economic and social assets for the benefit of present and future generations." RSA 483 Section 483:2 (Program Established; Intent) further states that "…the New Hampshire rivers management and protection program shall complement and reinforce existing state and federal water quality laws, and that in-stream flows are maintained along protected rivers, or segments thereof, in a manner that will enhance or not diminish the enjoyment of outstanding river characteristics." The following sections discuss the existing water quality conditions documented for the Lamprey Designated River and the establishment of PISFs on this portion of the river.

The water quality of the Lamprey Designated River has been assessed as part of several state monitoring programs or studies. These include the Ambient Rivers Monitoring Program (ARMP), the Volunteer River Assessment Program (VRAP), and a short term Baseline Fish Sampling study performed in 2003.

The results of the DES water quality programs (ARMP and VRAP) are reviewed every two years as part of a statewide assessment of water quality conditions. The existing water quality conditions are evaluated to determine if they support the designated uses for the water body. If the water quality conditions do not support attainment of the designated use or threatens its designated use, the water body is considered to be impaired or threatened and included in the DES's biennial 305(d)/303(d) reporting to the USEPA.

Five portions of the Lamprey Designated River were included in the draft 2008 305(b) Report and 303(d) list (Edwardson 2008). These sections include the impoundments upstream of the Wiswall Dam and Macallen Dam and the river reaches though Wadleigh Falls, Lee Hook Road, and Packers Falls. The designated use of the river in each of these sections is for aquatic life, while the section through Wadleigh Falls is also designated for recreational use.

Water quality in each of these sections is impaired by low pH, while the river section through Wadleigh Falls is also impaired by *E. Coli*. The source of the low pH values is listed as unknown in the 303(d) listing, but they are believed to be the "result of natural conditions such as the soils, geology, or the presence of wetlands in the area. Rain and snow falling in New Hampshire is relatively acidic, which can also affect pH levels; after spring melt or significant rain events, surface waters will generally have a lower pH" (Walsh et al. 2007).

The other listed impairment is for *E. Coli.* The section of the Lamprey Designated River listed as impaired by *E. Coli* is located upstream of Wadleigh Falls. The source of this pathogen is listed as unknown (Edwardson 2008). The presence of *E. Coli* in this reach of the Lamprey is most likely associated with nonpoint sources since no permitted point sources are located on this portion of the river or immediately upstream.

Both of the identified water quality impairments in the Lamprey Designated River are the result of either existing natural conditions (pH) or due to nonpoint runoff to the river (*E. Coli*). Neither of these is believed to be flow dependent, but they are considered to be source dependent. As a result, the establishment of PISFs for the Lamprey Designated River would not impact existing water quality conditions or conflict with existing water quality standards applicable to the Lamprey Designated River.

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