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FINAL
Souhegan River
Protected Instream Flow Report

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Executive Summary

This report describes the development of the instream flow values for each flow-dependent protected entity on the Souhegan Designated River. Protected entities are identified in statute as instream public uses, outstanding characteristics, and resources (IPUOCRs). For the ultimate development of a Water Management Plan, the first step is the identification and field verification of the protected entities on the Souhegan River. The protected entities of the Souhegan River were identified in a report titled "Instream Protected Uses, Outstanding Characteristics, and Resources of the Souhegan River and Proposed Protective Flow Measures for Flow Dependent Resources" dated September 2004. That report defined which protected entities were flow dependent and identified the methods to be used for flow needs assessments. The results of flow needs assessments were used to propose protected instream flows designed to protect and maintain the protected entities.

Those assessments have been completed and protected instream flows (PISF) are proposed herein. For each flow dependent protected entity, the location, description, instream flow evaluation method, and instream flow recommendations are presented. Based upon this report, discussions with the Technical Review Committee, and input from public hearings, protected instream flows will be established for the Souhegan River by the Department of Environmental Services.

The development of the protected instream flows was performed within the framework of the Natural Flow Paradigm. The Natural Flow Paradigm recognizes that the natural variability of stream flows is what determines stream dimension, pattern, and profile, as well as the instream and stream corridor flora and fauna. The native ecosystem evolved under a natural hydrologic regime that had no diversions, discharges, or withdrawals and therefore the natural range of flow variation contains the ideal conditions for maintaining the native ecosystem. Five flow components are critical to describing the flow regime that determines and regulates river ecosystems: magnitude, frequency, duration, timing, and rate of change. Characterization of these components defines the entire range of flows that are critical to the integrity of river ecosystems. Subscribing to the Natural Flow Paradigm implies that the principal management objective is allowing streams to flow as closely as feasible to the natural pattern of flow variability. Low flows and floods are expected natural conditions. Typical human influences tend to reduce flow variability by removing extremes such as floods and droughts. This may make the stream more "reliable" for human uses, but is detrimental to biological integrity. Water for off-stream use under the Natural Flow Regime is available because the wide range of variability in stream flows provides flexibility in instream flow needs. Management is needed to maintain off-stream water uses when that flexibility is limited or absent.

It is important to understand that in the development of the instream flows, natural river flows (in the absence of any human intervention or water use) will not always meet the flow needs of protected entities, nor should they. The Natural Flow Paradigm, to which this study subscribes, dictates that rare natural extremes, such as floods and droughts, are important features of riverine ecosystems. That is, high flows and low flows, and flow variability itself,

is necessary to insure that the ecosystem possesses the competence to survive the extremes: organisms in the ecosystem have adapted to the natural occurrence of stresses.

After initial field study of the Souhegan Designated River, it was concluded that the Designated River should be subdivided into two reaches: the Upper Souhegan and the Lower Souhegan. The divide between these two reaches is at a change in slope upstream of Milford, NH. The Upper and Lower Souhegan have significant differences in characteristics like slope, size, elevation, ecoregion, etc. Separate protected flows were determined for each reach because of their different natures.

The river is fortunate to have a long-standing USGS stream gage in Merrimack, N H. This gage recorded over 70 years of daily flow data. When this data was analyzed and compared against the existing diversions of water, some general conclusions were that:

- Numerous small flood control structures in the watershed have somewhat modified flow variability, but due to their size are ineffectual at reducing large flood peaks greater than 10-year flood events.
- In the Upper Souhegan there is very little withdrawal of water. In the Lower Souhegan, cumulative withdrawals are very small compared to the average river flow, but significant compared to low flows. Much of the withdrawn water is returned back to the river.

Instream flow needs were identified for a variety of individual protected entities before developing the protected instream flows for the Upper and Lower reaches. Protected flows under the Natural Flow Paradigm include protection of variability across low and high flows. The instream flow needs for human-related protected entities in Table ES1 are low flow types of needs; meaning that to meet these needs the river flow should exceed these values.

Table ES1. Human-Related Instream Flows

<table>
<tr><th colspan="5">PISF for selected Human-Related IPUOCR</th></tr>
<tr><th rowspan="2">IPUOCR</th><th colspan="4">Reach</th></tr>
<tr><th colspan="3">Upper Souhegan</th><th>Lower Souhegan</th></tr>
<tr><td>Recreation</td><td colspan="3">150 cfs; 4.0 cfsm</td><td>Use is not dependent on Souhegan River flow.</td></tr>
<tr><td>Fishing</td><td colspan="4">Use is dependent on Souhegan River flow only to the extent that it protects the fishery resource. Fish and aquatic habitat apply.</td></tr>
<tr><td>Hydropower</td><td>~20 cfs; ~0.7 cfsm</td><td>No users</td><td>~42.2 cfs; ~0.44 cfsm</td><td>No users</td></tr>
<tr><td>Pollution Abatement</td><td colspan="3">2.4 cfs; <0.1 cfsm</td><td>9.4 cfs; <0.1cfsm</td></tr>
<tr><td>Water Supply</td><td colspan="4">Use is not dependent on Souhegan River flow</td></tr>
</table>

The protected instream flows are presented in two ways: the actual river flow in cubic feet per second (cfs) and the river flow per unit watershed area (in square miles) and reported as cfsm. Flows presented in cfs are specific to the Upper Souhegan and Lower Souhegan index points. For other locations, the protected flow is determined using the watershed area in square miles at the point of interest multiplied by the cfsm value.

An important point to recognize about the human-related instream flow needs is that they are time invariant: the desired flow is constant and does not vary throughout the year. These flows have components of magnitude, but not of duration or frequency. In reality, some human uses like recreation (kayaking) and hydropower have traditionally been opportunistic: taking advantage of high flows when they occur. The expected frequency and duration of events needs to be protected to meet these uses.

Flow needs were also identified for fish and other aquatic life, as well as the flow dependent wildlife, vegetation, and natural/ecological communities. Because of the differing flow needs during the life cycles of flora and fauna, their instream flow needs are time dependent. The calendar year was subdivided into periods, known as bioperiods, to accommodate these varying floral and faunal instream flow needs. The bioperiods identified are important to wildlife and vegetation (Figure ES1) and for selected fish species (Figure ES2).

Description of protected instream flows goes beyond the identification of timing. Besides the temporal variability of bioperiods, another difference between the instream flow needs of the human-related protected entities and other protected entities is that some non-human protected entities also require various flow magnitudes to occur with certain frequencies (Table ES2). For example with the Fowlers Toad, high flows are needed to fill oxbows and wetlands, but such flows only need to occur a few times in the spring. For some of the riverbank vegetation communities, high flows need only occur at a frequency between one to 10 years. Another difference is the duration of flows. Some fish species are able to tolerate a low river flow for one or two days, but as this low flow persists, the species may find growth, reproduction, or even survival difficult. Allowable durations below the protected flows were determined when appropriate so that naturally occurring low flows would not preclude water use.

For fish species studied on the Souhegan River, three instream flow magnitudes were defined for all bioperiods: common flows, critical flows, and rare flows (Table ES3). After analysis of the target fish community (TFC) for each bio-period, a group of species representing the aquatic community was specified. Hence, the habitat needs for the rearing and growth bio-period were represented by a select group of species dominating the TFC. These fish were referred to as generic resident adult fish (GRAF) and young-of-the-year life stage (YOY). These three flow magnitudes are associated with fish habitat availability: this availability ranges from optimal (common) to barely survivable (rare). These flows are developed based upon the changes in habitat availability with changes in river flow, the flow characteristics of that habitat (depth, velocity, etc), and the frequency of the flows supporting that habitat. The common flow can be thought of as the most frequently occurring habitat availability in which the fish exist in close to optimal habitat area conditions. The critical flow is the flow where habitat is dramatically reduced but occurs approximately every five to ten years). The rare flow is the flow that occurs on a frequency that, compared to other flows, is remarkably low (e.g. once every ten years or more) with attendant dramatic reduction in habitat availability. For each of these flow thresholds, two durations are defined: allowable and catastrophic. The catastrophic durations describe length of times for events that occur on a decadal frequency whereas the allowable duration is that which would occur in an average year.

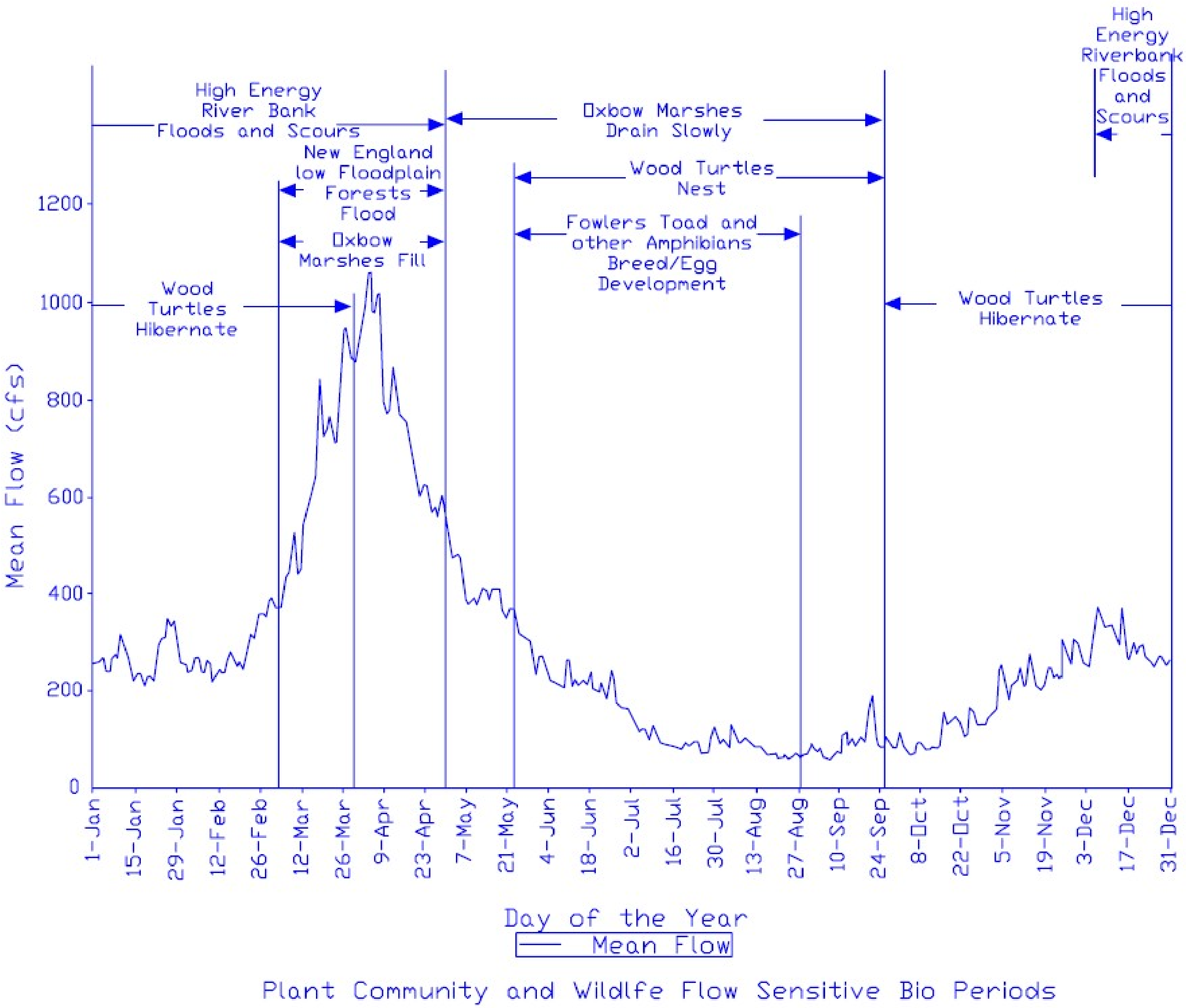

Figure ES1. Bioperiods for Rare, Threatened, and Endangered Wildlife and Natural Communities.

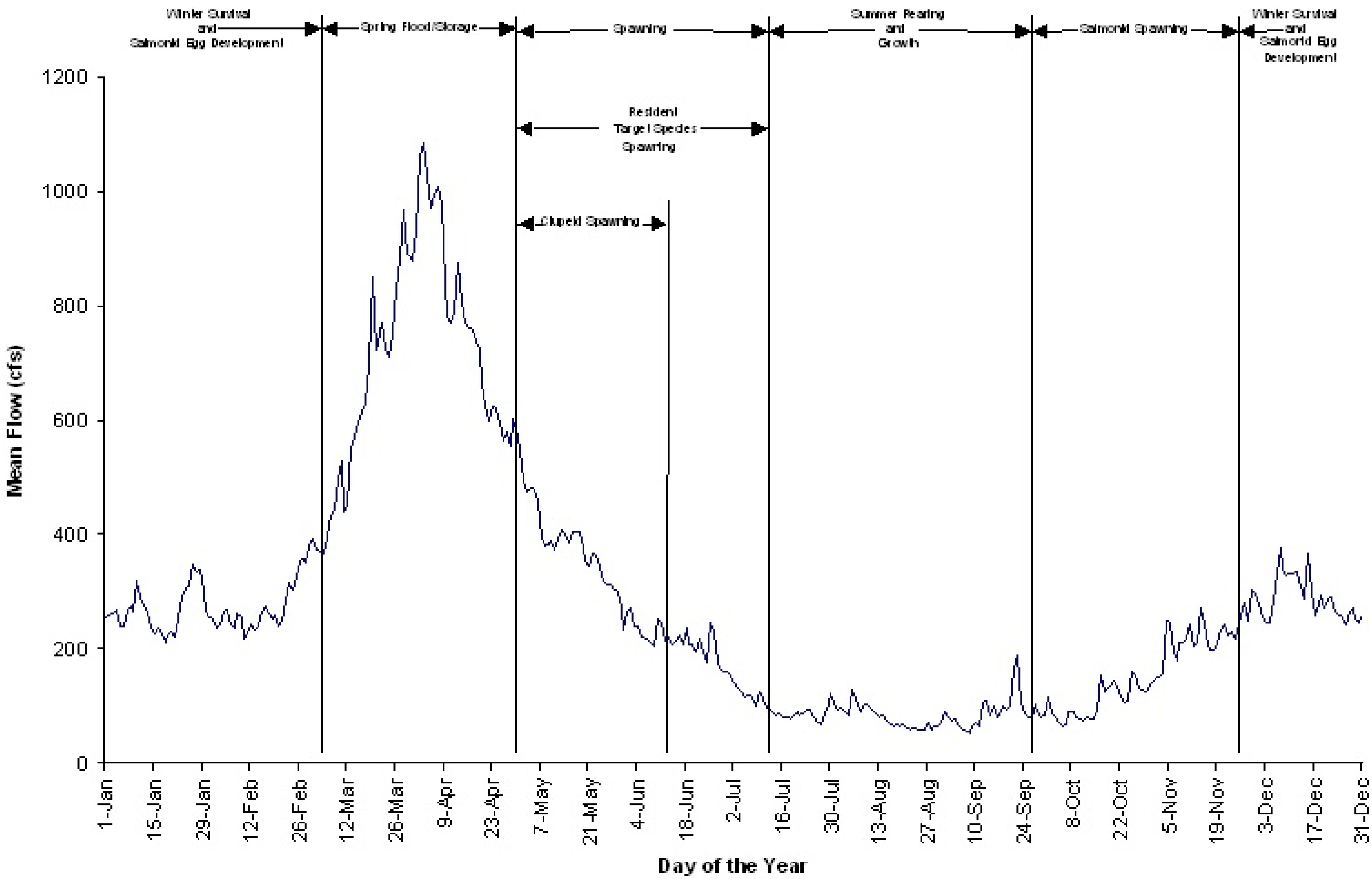

Figure ES2. Bioperiods for Selected Fish Species.

Table ES2. Wildlife and Vegetation Instream Flows

Species	Timing and value of instream flow
Wood Turtle (lower Souhegan only)	<5.85 cfsm (June through September) December through February flow should exceed the average flow of the last two weeks of the previous November
Fowler's Toad (lower Souhegan only)	>2.335 cfsm at least once to fill wetlands (March through May) >0.175 cfsm at least monthly to maintain breeding pools (June through mid-August)
Wild Senna and Wild Garlic	>18.7 cfsm on a frequency of once every 2-10 years
Twisted Sedge/Fern Glade (upper Souhegan)	>2.8 cfsm once every 1-3 years (December through April)
Silver Maple Floodplain Forest (lower Souhegan only)	>11.7 cfsm once every 1-3 years
Sycamore Floodplain Forest (lower Souhegan only)	>17.5 cfsm once every 1-3 years
Oxbow/Backwater Marsh (lower Souhegan only)	>3.5 cfsm at least once to fill (March through April) >0.2 cfsm at least monthly in summer (May through September)

To determine the protected instream flows, the timing and magnitude of all the various flow needs of all IPUOCR were compared. The emphasis of this comparison was to determine the highest low flow need of all protected entities: this is then controlling flow. By satisfying this flow, all other flow needs are then met. These flows are the protected flows within each bioperiod and each river reach.

When considering the flow needs of all IPUOCR, the controlling protected instream flow in the Upper Souhegan is recreation. If this human-related instream flow were to be the controlling instream flow, the protected flow for the Upper Souhegan would be 4.0 cfsm. As described earlier however, this flow need was historically developed consistent with the existing flow regime with the expectation of only a certain frequency of flows available at these magnitudes. It is therefore recommended that the instream flow need for recreation continue to be met as it has been traditionally (that is, opportunistically) and therefore the management strategy consider this flow in the context of preserving the frequency of its occurrence, but not regulating flows or withdrawals to meet recreation needs.

Table ES3. Instream Flows for fish (bold values are flows not to be exceeded)

Bioperiod Approximate dates	Rearing & Growth July 15 - Sept. 30		Salmon Spawning Oct. 1 - Nov. 14		Over-Wintering Nov. 15 - Feb. 28	
	Recommended flows		Recommended flows		Recommended flows	
Concurrent Gauge (SR#)	SR 25	USGS	SR 25	USGS	SR 25	USGS
Watershed area (mi^2)	102	171	102	171	102	171
Location	**Upper**	**Lower**	**Upper**	**Lower**	**Upper**	**Lower**
Common flow (cfs)	31	103	41	184	204	342
Common flow (cfsm)	0.3	0.6	0.4	1.1	2.0	2.0
Allowable duration under (days)	30	20	30	23	35	35
Catastrophic duration (days)	42	40	40	40	50	50
Critical flow (cfs)	16	26	10	96	51	86
Critical flow (cfsm)	0.16	0.15	0.1	0.6	0.5	0.5
Allowable duration under (days)	15	15	12	12	15	15
Catastrophic duration (days)	35	20	23	40	30	30
Rare flow (cfs)	10	17	10	70	31	51
Rare flow (cfsm)	0.1	0.1	0.1	0.4	0.3	0.3
Allowable duration under (days)	5	5	10	5	5	5
Catastrophic duration (days)	30	10	23	10	10	10
Bioperiod Approximate dates	**Spring Flood** March 1 - April 30		**Shad Spawning** May 1 - June 14		**GRAF Spawning** June 15 - July 14	
	Recommended flows		Recommended flows		Recommended flows	
Concurrent Gauge (SR#)	SR 25	USGS	SR 25	USGS	SR 25	USGS
Watershed area (mi^2)	102	171	102.3	171	102.3	171
Location	**Upper**	**Lower**	**Upper**	**Lower**	**Upper**	**Lower**
Common flow (cfs)	389	650	215	178	24	39
Common flow (cfsm)	3.8	3.8	2.1	1.0	0.23	0.23
Allowable duration under (days)	28	28	25	15	20	17
Catastrophic duration (days)	36	36	40	25	27	25
Critical flow (cfs)	113	188	61	96	11	**239**/26
Critical flow (cfsm)	1.1	1.1	0.6	0.6	0.11	**1.4**/0.15
Allowable duration under (days)	12	12	10	5	10	**13**/15
Catastrophic duration (days)	16	16	15	10	20	**23**/20
Rare flow (cfs)	82	137	38	88	8	**325**/17
Rare flow (cfsm)	0.8	0.8	0.37	0.5	0.08	**1.9**/0.1
Allowable duration under (days)	5	5	4	5	10	**10**/10
Catastrophic duration (days)	7	7	7	10	15	**10**/10

- Emboldened values for lower Souhegan GRAF spawning are the upper limit for the instream flow.
- Overwintering durations for the upper Souhegan were set at the values from the lower Souhegan, since little field information exists.

Therefore for the Upper Souhegan, flow needs excluding recreation were identified for the protected flow magnitudes. Additionally, in discussions with the Souhegan Technical Review Committee and NH DES, it was decided not to include the dilution of treated waste water from facilities along the river to be included in the establishment of the PISF. This criterion is met within the context of the discharge permit for the facility. The recommended instream flows for the RTE do not easily mesh with those for fish: the RTE flows do not prescribe a duration. In discussions with NHDES, it was determined that the fish instream flows would be the yardstick monitored on a daily basis, and that the RTE instream flows be periaodically (seasonally) assessed. If the system did not meet the RTE instream flows, the management for the following year would include increases in storage to ensure pulses to meet the required RTE flows. The developed protected instream flows may be found in Figures ES3 and ES4. These figures do not include the duration information of Tables ES2 and ES3. The controlling IPUOCR for the Upper and Lower Souhegan River may be found in Table ES4.

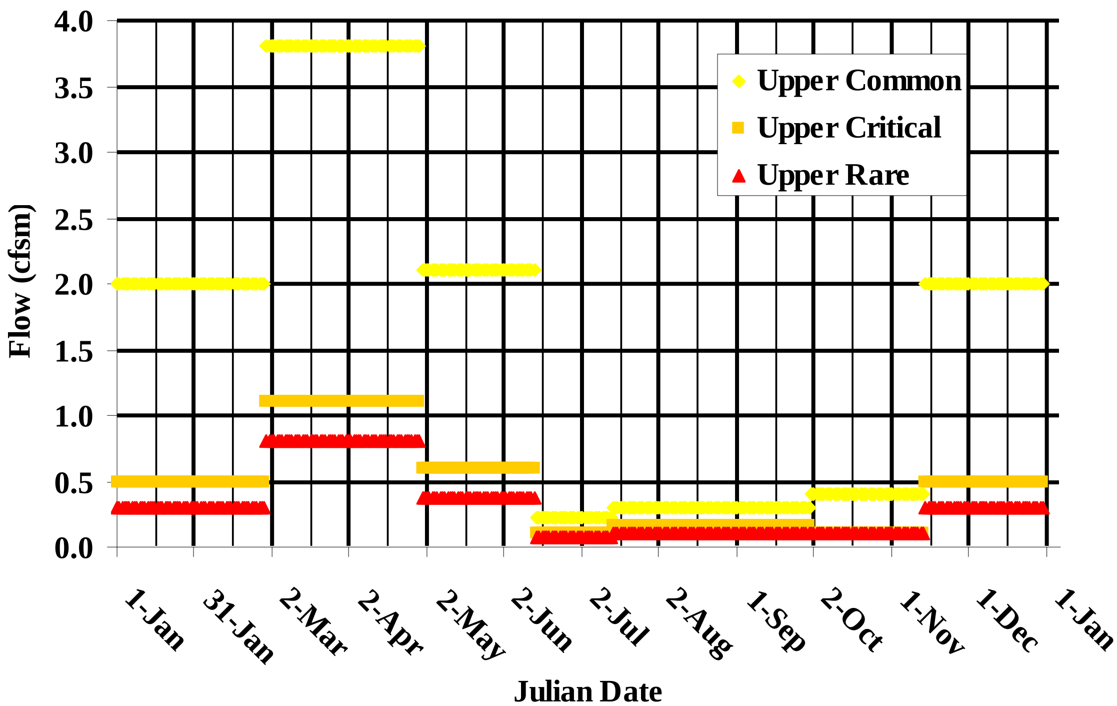

Figure ES3. Synthesized PISF for the Upper Souhegan River.

The status of the River may be monitored with respect to the protected instream flows in a unique type of graph called an ACTogram (invented specifically for this study), which plots the number of consecutive days (y-axis) flows have been ***below*** specified thresholds (x-axis). For example, in Figure ES5 the protected instream flow specifications for Lower Souhegan ***shad spawning*** from Table ES3 are plotted as green (allowable) and red (catastrophic) lines. Historic flows from calendar year 1964 are plotted as squares to show how the status of the River progresses from green (allowable) to yellow (impaired) to red (catastrophic) as dry conditions persisted. On 27 May 1964, flows were below 120 cfs for three consecutive days (and below 160 cfs for five consecutive days, 180 cfs for six consecutive days, and so on). Relative to the bioperiod specifications, the status of the River at the end of May remained green as the number of consecutive low flow days was well below the green "allowable" line. Under these circumstances, no water management action would necessarily be warranted. However, by 3 June 1964 (one week later), conditions had deteriorated. By now, the number of consecutive low flow days for the 80, 100, 120 and 140 cfs thresholds exceeded the "allowable" specification (the green line drawn between the 5 days flows may be below 96 cfs and 15 days they may be below 178 cfs, from Table ES3). Now the status of the River is depicted in yellow, suggesting that water management plan action should be implemented to avoid catastrophe. Such actions could include: additional conservation, reduction of withdrawals, use of alternate water sources, and/or relief flows. In this case, persistent dry conditions resulted in catastrophically low flows by 10 June 1964. Had rain (or management action, such as release of water from storage) resulted in higher flows for just two consecutive days, the string of *consecutive* low flow days would have been broken and the duration "clock" reset and the ACTogram plots returned to zero. It is important to note that when long low flow periods are interrupted even briefly, the relief provided to ecological communities can be significant. However, by the end of the bioperiod on 14 June 1964, the shad spawning season on the lower Souhegan may have been a total loss. Although Figure ES5 depicts the extremely dry flow conditions on 17 June (three days after the end of the bioperiod), technically the specifications for this bioperiod no longer apply. At the end of a bioperiod, all low flow durations are reset to zero and the ACTogram for the next bioperiod takes over. In general, relief flows are those flows that may provide relief from critical or rare flows occurring for catastrophic durations. Relief flows require flows at or above the next higher ISF level (critical or rare) for a minimum duration of two days. Relief flows reset the duration count to zero. These flows may be natural or may be artificially created by releases from storage.

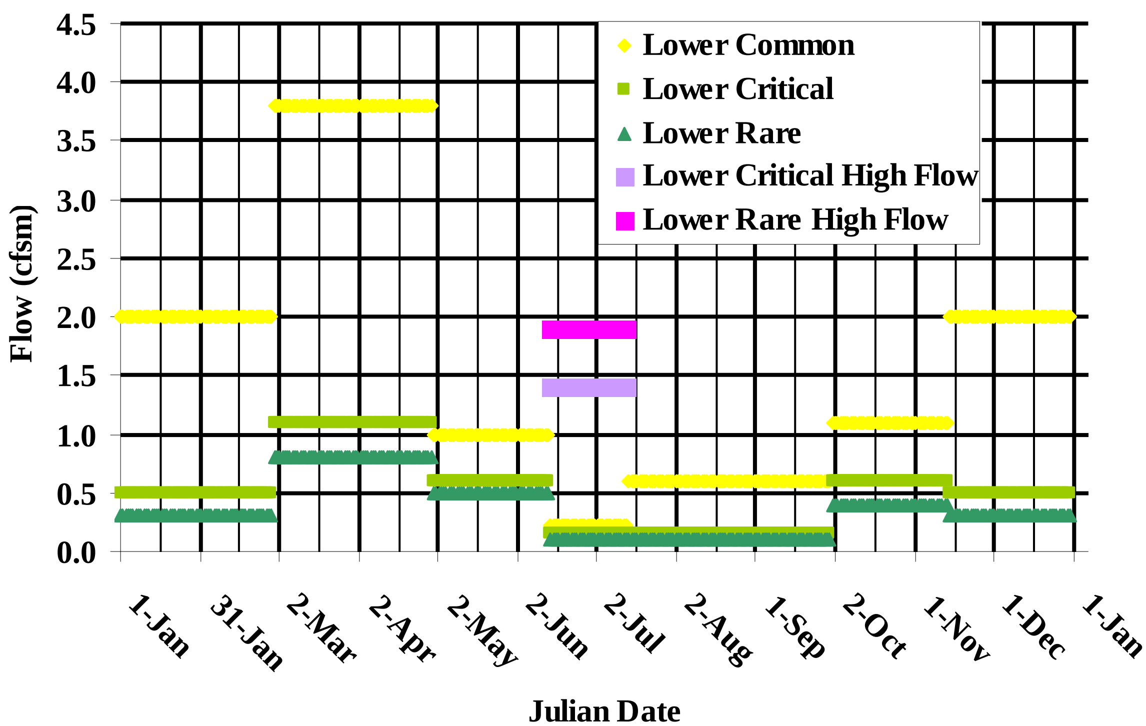

Figure ES4. Synthesized PISF for the Lower Souhegan River.

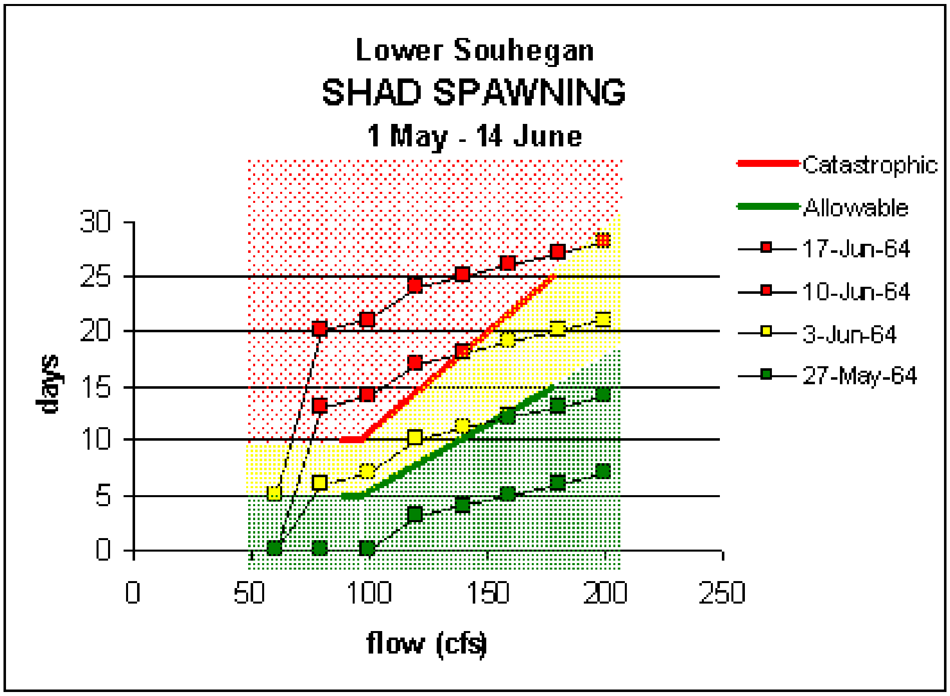

Figure ES5: Lower Souhegan Shad Spawning ACTogram depicting status of River and flow conditions relative to protected instream flow specifications.

Three and five year hydrographs were studied to determine whether historical flows met the flow needs for the flow dependent protected entities. As one would expect, often these flow needs were met, but there were times when they were not.

It should be noted that there are water withdrawals along the Souhegan River for a variety of other human uses not considered flow dependent protected entities (water supply, irrigation, etc.) These protected entities are not flow dependent because the withdrawal is not a function of river flow. These water withdrawals do not have instream flows established for them however the withdrawals themselves will be included in the water management plan.

The water management scenarios must take into account how, when, and where water is used along the river in order to determine if modifications to Affected Water Users or Affected Dam Owners uses can improve the river flow, even temporarily, to reset the allowable duration clock such that river flow meets the instream flow need. Water management strategies for the Affected Water Users and the Affected Dam Owners will not affect the instream flow if they are downstream of the instream flow need location.

It must also be underscored that the flow of water alone does not guarantee that the instream flow needs are met: just as important is the water quality associated with that water. This study has identified that ecologic and fish habitat might be improved without changing flows, and this would be through stream restoration measures. Water quality improvements (especially temperature) may offer more promising gains in meeting objectives than certain flow management alternatives. Certain stream restoration measures that improve woody debris in or along the river can dramatically improve upon the existing low flow habitat without additional flow of water. This was a very cursory analysis, and should be followed by a more rigorous study.

The protected instream flows identified in this report are the best scientific estimates of the river flows, timing, frequencies, and durations to protect and sustain the protected entities, when all other parameters, for example water quality, are assumed to be satisfactory. There are many times when the river system exhibits surplus water; however that does not mean that unfettered water resources development may ensue. Any future water resources development proposals must consider effects on all protected entities as well as be consistent with New Hampshire water law.

Table ES4. Controlling Instream Flow IPUOCR for the Souhegan River Reaches.

Time of Year	Controlling IPUOCR Critical		Controlling IPUOCR Rare	
	Upper	Lower	Upper	Lower
Jan 1 – Feb 28	Fish overwinter	Wood Turtle hibernation	Fish overwinter	Wood Turtle hibernation
Mar 1 – Apr 30	Fish spring flood	Fish spring flood	Fish spring flood	Fish spring flood
May 1 – Jun 14	Shad spawning	Shad spawning	Shad spawning	Shad spawning
Jun 15 – Jun 30	GRAF spawning	GRAF spawning	GRAF spawning	GRAF spawning
Jul 1 – Jul 14	GRAF spawning	Oxbow and backwater marsh maintenance	GRAF spawning	Oxbow and backwater marsh maintenance
Jul 15 – Aug 21	GRAF rearing & growth	Oxbow and backwater marsh maintenance	GRAF rearing & growth	Oxbow and backwater marsh maintenance
Aug 22 – Sep 14	GRAF rearing & growth	GRAF spawning	GRAF rearing & growth	GRAF spawning
Sep 15 – Sep 30	GRAF rearing & growth	GRAF rearing & growth	GRAF rearing & growth	GRAF rearing & growth
Oct 1 – Nov 14	Salmon spawning	Salmon spawning	Salmon spawning	Salmon spawning
Nov 15 – Dec 1	Fish overwinter	Fish overwinter	Fish overwinter	Fish overwinter
Dec 2 – Dec 31	Fish overwinter	Wood Turtle hibernation	Fish overwinter	Wood Turtle hibernation