DOWNEAST SALMON RIVERS
WATER USE MANAGEMENT PLAN

PLEASANT AND NARRAGUAGUS RIVERS
MOPANG STREAM

Maine State Planning Office

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EXECUTIVE SUMMARY

Introduction

When Governor King's Atlantic Salmon Task Force completed the Atlantic Salmon Conservation Plan for Seven Maine Rivers (Salmon Plan) in 1997, they recognized that a significant issue for the State and blueberry growers is adequate water flow to maintain productive habitat and water availability to satisfy a growing demand for irrigation. One of the Salmon Plan's 14 goals, as amended in March 1999, calls for the State of Maine and its partners to "ensure water withdrawals do not adversely affect Atlantic salmon." To achieve this goal, the Salmon Plan calls for the development of water use management plans for three downeast river basins (Narraguagus, Pleasant, Mopang) to help resolve a resource use conflict.

The Land & Water Resources Council, overseers of the Salmon Plan, established a committee to prepare water use management plans (WUMP) for the three downeast rivers. Diverse interests including landowners, lake association members, conservation groups, blueberry growers, and state and federal agencies formed the WUMP committee, working on the reports with the help of consultants over a two plus year period. A technical committee (a.k.a. Flow Committee) served the WUMP committee by examining all technical materials and advising on direction in the absence of data. The resulting water use management plan uses the best available hydrologic, habitat, and water use information to construct the rationale and basis of this plan's recommendations. This plan exposes policy issues for the State of Maine related to the conservation and prudent use of public waters. It forges new territory and calls for a cooperative relationship between industry and government. Finally, it lays out a prescribed set of actions that should result in the protection of salmon habitat, greater understanding of natural processes, better data for adaptive management, and some predictability for water users.

Major Findings

The Atlantic salmon streams subject to this WUMP provide specific physical and biological conditions allowing adult migration, spawning, incubation and juvenile nursery functions to succeed. (page 16)

Many of these needs are seasonal, and have evolved to coincide with naturally occurring seasonal cycles of stream flow and other environmental cues. For example, spawning occurs in the late fall, and relies on winter flows to circulate aerated water through gravel bars holding incubating eggs. Eggs hatch in spring, and fry remain in these gravels until after high spring flows subside. The high spring flows, however, serve to disperse nutrients throughout the watershed, maintain channels and allow smolts to emigrate rapidly to the marine environment. Summer base flows are required to provide foraging and shelter to juvenile salmon during the growing period.

The relationship between discharge and habitat suitability for spawning, incubation, young-of-year and juvenile lifestages of salmon varies among stream segments and among rivers. (page 17)

Instream Flow Incremental (IFIM) studies were conducted on the Pleasant and Narraguagus rivers, and Mopang Stream to quantify these relationships.

Due to precipitation, run-off and evapotranspiration, stream flow patterns in each river basin naturally varies daily and seasonally. Human consumptive demand for stream flow also results in flow variation, and demand is predominantly for agricultural irrigation. Consumptive demand varies among stream segments and river basins. (page 19)

Peak natural flows are typically in April, and lowest flows are typically in August and/or September. Consistent quality of product requires the wild blueberry industry to irrigate crops, particularly during July and August if rainfall is insufficient to maintain adequate soil moisture.

Some irrigation may also occur during May and June for frost protection. Irrigators pump water from various sources, including streams, lakes, ponds and wells.

State and federal agricultural agencies need to increase their technical assistance effort to growers so they can select and use more efficient irrigation best management practices (BMPs). (page 35)

These include:

- "Culture" BMP's such as: buildup of organic matter, replanting bare areas, windbreak development and weed control,
- "System Planning and Design," such as creating storage, replenishment of storage during times other than those when habitat-based flows are critical, use of appropriate wells, and minimizing transmission leakage
- "Water Application," such as strategic scheduling of irrigation.

Future expansion of crop irrigation cannot rely entirely on conservation and efficiency BMPs. Thus, growers and users will use a hierarchy to prioritize alternative water sources demonstrated to be the most benign to stream flow effects on Atlantic salmon habitat. These sources need to be available to a grower, be cost-effective solutions, and permittable. Management of these sources should avoid unacceptable risks to stream habitat. This hierarchy includes (page 43)**:**

- Groundwater alternatives with no or minor hydraulic connection to subject stream segments are given first preference unless it is possible to employ supplemental pumping into the stream to avoid unacceptable risks to habitat.
- Withdrawals from ponds or lakes with little or no hydraulic connection to subject stream segments, using methods that do not produce adverse ecological impacts to these water bodies.
- Stream flow withdrawals may be permissible if timed to occur during acceptable periods (such as high seasonal spring flow), when the magnitude of withdrawal can be shown not to adversely affect habitat and channel forming flows, or during periods of the low flow season when flow ranges are higher than the amount data indicates is acceptable to maintain habitat.

Existing storage areas may be opportunistically adapted to hold skimmed or pumped water until needed for crop application. (page 48)

The viability of these options depends on the degree of environmental impact, economical feasibility and proximity to croplands. The most favorable of those under consideration include existing ponds and lakes, natural depressions such as kettle holes, or newly constructed ponds.

Modeling data obtained and employed by the WUMP Committee can broadly assess the relative benefits and impacts of existing and proposed alternative irrigation withdrawals. (page 52)

This includes USGS hydrologic data (when available), salmon habitat and distribution data, IFIM output, and STELLA base flow model output. Flow duration curves and IFIM results are the basis for historically available salmon habitat modeling. Determination of deviations from historic flow ranges resulting from various irrigation alternatives allowing for the quantification and comparison of resulting shifts in habitat suitability. Results indicated discernable trends among alternatives. At this time, the best use of STELLA model resolution is as an order-of-magnitude planning tool. Direct withdrawals during July have a greater impact on habitat than do any of the alternatives involving reduced withdrawals, less intensive irrigation, or partial well water withdrawal. Monitoring the progress of the WUMP will require data from monitoring of stream flow, groundwater, water use, watershed characteristics, and salmon population biology. The frequency of collection, reporting and reviewing varies according to type of information.

It is desirable to establish a regulatory process that allows timely access to, and use of, water in these watersheds in manner benign to Atlantic salmon. (page 67)

Regulatory authority presently vary according to the type (wells, constructed ponds, impoundments and direct withdrawal) and jurisdictional location of withdrawals. To allow timely access to any use of water regulatory agencies should require applicants to provide:

- Purpose statement
- A whole-farm irrigation plan
- Detailed review of alternative sources with agency input
- Results of pre-application site visit by applicable agencies
- Land and wetland delineation, functional assessment, and minimization assessment (if applicable), pre-impoundment stream characterization (*optional*)
- Engineering design plans
- Mitigation plan

Proposed Actions, Research, and Analysis

The WUMP Committee developed the following items pertaining to agency actions and for further research and analysis (page 76)**:**

<u>Actions</u>

- Maintain USGS gauge on the Narraguagus River
- Make long-term commitment for gauges on the Pleasant and Machias Rivers
- Develop effective flow monitoring strategy
- Continue support for low-flow study
- Support Atlantic Salmon Commission habitat impact assessments
- Integrate water sources hierarchy as a guideline into state policies
- Promote sound water management
- Amend state permitting programs

Research and Analysis

- Assess impact of withdrawals during high flows on migratory life stages
- Research wild blueberry plant water requirements
- Research farm practices to further reduce water use

Conclusion

This Water Use Management Plan incorporates relatively basic information developed from and/or available to resource management agencies and other Maine stakeholders. These stakeholders have cultural, economic and management interest in the coexistence of Atlantic salmon and human water use in a specific and unique part of Maine.

Its strength is in:

- Portraying the most basic relationships between water use and salmon habitat quality with objective information,
- Providing general guidance for water use strategies that are potentially the most effective at protecting aquatic habitat,
- It is a "living" watershed planning tool that can and should be updated to account for changing biological and human demands, and the emergence of more accurate supporting data.

In its current form, this plan serves as a foundation for policy makers, water users (currently dominated by agriculture) and regulators to determine what the most environmentally acceptable and cost-effective means are to obtain water. This plan also allows water users to begin to plan strategically for future least-impact water use growth.

A limitation of this WUMP is that it relies largely on information developed over a relatively short period and through a process that was financially constrained. The WUMP

Committee members strongly feel that the research and monitoring initiatives discussed in this Plan will strengthen the future value of the WUMP.

1.0 WATER MANAGEMENT GOAL AND OBJECTIVES

The **Downeast Salmon Rivers Water Use Management Plan** examines water use management in the Pleasant and Narraguagus Rivers and the Mopang Stream (a tributary of the Machias River). Pursuing the goal and objectives, as stated below, achieve the intent of this Plan, as described in Maine's Atlantic Salmon Conservation Plan.[1]

1.1 Goal Statement

The goal of the Downeast Salmon Rivers Water Use Management Plan is to ensure that human uses of the water resources in the Pleasant and Narraguagus Rivers and Mopang Stream do not adversely affect Atlantic salmon or salmon habitat.

1.2 Objectives

Atlantic Salmon Habitat Protection

The first objective of the Downeast Salmon Rivers Water Use Management Plan is to protect Atlantic salmon habitat in all river reaches for all life stages through prudent water use management.

Underlying principles of this objective are:

- Recognize that salmon habitat requirements vary by month and river reach
- Minimize the hydrological, hydraulic and biological effects of withdrawals
- Minimize the effect of withdrawals on the functions of high flows (e.g., channel forming, flushing, etc.) and do not extend low flows

[1] As amended in March 1999

Water Resource Conservation

The second objective of the Downeast Salmon Rivers Water Use Management Plan is to conserve and use water resources efficiently for human benefit.

Underlying principles of this objective are:

- Conserve water resources and manage for multiple uses
- Develop water supplies that minimize adverse impact to salmon habitat
- Use existing water resources in the most efficient manner to support food production. This is done through best farm practices (e.g., increase moisture holding capacity of the soil, better monitor plant moisture requirements, improve water application technology, etc.) and education programs for growers

2.0 WATER RESOURCES IN THE THREE WATERSHEDS

2.1 Hydrogeologic Setting

The principal rivers in eastern coastal Maine include the Dennys, Machias and East Machias, Pleasant, Narraguagus, St. Croix, and Union Rivers. Together, these drainage basins cover approximately 2,343 square miles in Washington, Hancock, and extreme southeastern Penobscot Counties.

Relatively unsettled, the eastern coastal basins are made up primarily of forest, wild blueberry barrens, and heath. With few exceptions (for example, western portions of the Union River Basin, and Lead Mountain, Pleasant Mountain, and Peaked Mountains in the Narraguagus, Pleasant, and Machias River Basins), relief in the drainage basins is low to moderate.

The drainage basins are underlain by a variety of Precambian to late Paleozoic (>650 million to ~380 million year old) igneous and metamorphic crystalline rocks that limit the ground-water resources available from the bedrock (see below). Coarse-gained granitic bedrock is present beneath much of the area, influencing the nature of the overlying glacial deposits.

Overlying the bedrock is a sequence of Pleistocene glacial deposits including fine to coarse grained glacial till, extensive deposits of sand and gravel outwash material (which contain the area's most significant ground-water resources), and late Pleistocene marine silt and clay deposits.

The low to moderate relief and late marine silt and clay deposits combine to promote the development of extensive wetlands, including Denbow Heath in the Narraguagus River Basin, the Great Heath in the Pleasant River basin, and numerous smaller bogs and heaths.

The average annual temperature is 42°F and ranges from an average of 18° F in January to 64°F in July. The average annual precipitation is approximately 49 inches and is fairly evenly distributed throughout the year. The area is bounded by large (greater than 1,000 square mile) river basins, to the east by the St. Croix River basin and to the west by the Penobscot River basin.

2.2 Surface-Water Resources

The eastern coastal basins include five moderate size watersheds of less than 1,000 square miles each (Table 2.1). These five watersheds have similar topography, land use, and average annual streamflow per square mile. However, differences in surficial geology, wetland distribution, and ponds (including beaver impoundments) may contribute to variation in hydrology between the basins, particularly during periods of base flow.

A network of USGS gauges provide data on streamflow in this region (Table 2.2 and Figure 2.2). In general, flow in the basins is seasonally distributed. High flows typically occur in early spring and late fall. Low flows generally occur in the summer, and to a lesser extent, in mid-winter.

2.3 Ground-Water Resources

Ground water resources in Maine are found in both the underlying, crystalline bedrock and the overlying, unconsolidated glacial deposits. Igneous bedrock (such as the granites that are common in Washington and Hancock Counties) has no primary porosity to store and carry ground water. Other types of bedrock (originally sedimentary rocks such as sandstones, limestones, and shales) have undergone multiple episodes of heating and deformation, destroying any primary porosity that may have been present. As a result, porosity and transmissivity in the bedrock is limited to fractures developed after the rock had cooled. This limited porosity and transmissivity severely limits the yield that can be obtained from most wells. The median well yield for domestic bedrock wells

in Maine is slightly less than 4 gallons-per-minute, with less than 20-percent of the wells having a yield in excess of 10 gallons-per-minute and less than 1-percent of the wells having a yield in excess of 100 gallons-per-minute. While high-yield wells have been developed in bedrock, these are the exception, not the rule. However, the bedrock ground-water resource is highly utilized for domestic wells because it is universally present and most always provides sufficient yields for a typical household.

In contrast, coarse-grained, unconsolidated, glacial outwash deposits of sand and gravel may produce wells with yields in excess of 1,000 gallons-per-minute. These deposits of sand and gravel have a very high primary porosity, with a high rate of ground-water recharge from precipitation, high storage, and high transmissivity of ground-water to a well. Washington and Hancock Counties have extensive deposits of sand and gravel identified as significant gravel aquifers (Figure 2.1). These aquifers constitute the principal ground-water resource within the basins. Several aquifers on the edges of the drainage basins are presently utilized for public water supplies (towns of Machias and Milbridge), and ground-water is being investigated as a source for irrigation in several basins.

Sustainable ground-water resources and surface-water resources are together limited to the long-term annual runoff from a drainage basin (the precipitation minus the evaporation and plant transpiration). Extraction and utilization of ground water may have a short-term impact on rivers, streams, ponds, or wetlands if the well induces recharge from a surface water body. Ground-water withdrawals will have a long-term impact on the annual runoff from a basin as precipitation recharge replaces the ground water extracted from storage. The long-term impacts will be delayed and dampened, depending on the hydrologic connection between the aquifer and adjacent surface water bodies (rivers, streams, ponds, and wetlands).

Table 2.1 Drainage area of major river basins in eastern Maine.

River Basin	Drainage area (square miles)
Pleasant	126
Dennys	132
Narraguagus	243
Union	563
Machias	810
St. Croix	1468

Table 2.2 Average annual flow for selected historical stream gaging stations in eastern Maine.

USGS station number	Station name	Period of record	Drainage area (square miles)	Average annual flow (cubic feet per second)
1021200	Dennys River at Dennysville	1956-98	92.9	192
1021480	Old Stream at Wesley	1998-99	29.1	---[1]
1021500	Machias River at Whitneyville	1906-09 1910-21 1929-77	458	939
1022000	East Machias River near East Machias	1927-58	251	507
1022260	Pleasant River near Epping	1980-91	60.6	142
1022500	Narraguagus River at Cherryfield	1948-99	227	495
1023000	West Branch Union River near Amherst	1910-19 1929-79	148	270
1024200	Garland Brook near Mariaville	1964-82	9.79	22.3

[1] not calculated due to limited period of record

Figure 2.1 Significant Gravel Aquifers in Downeast River Basins.

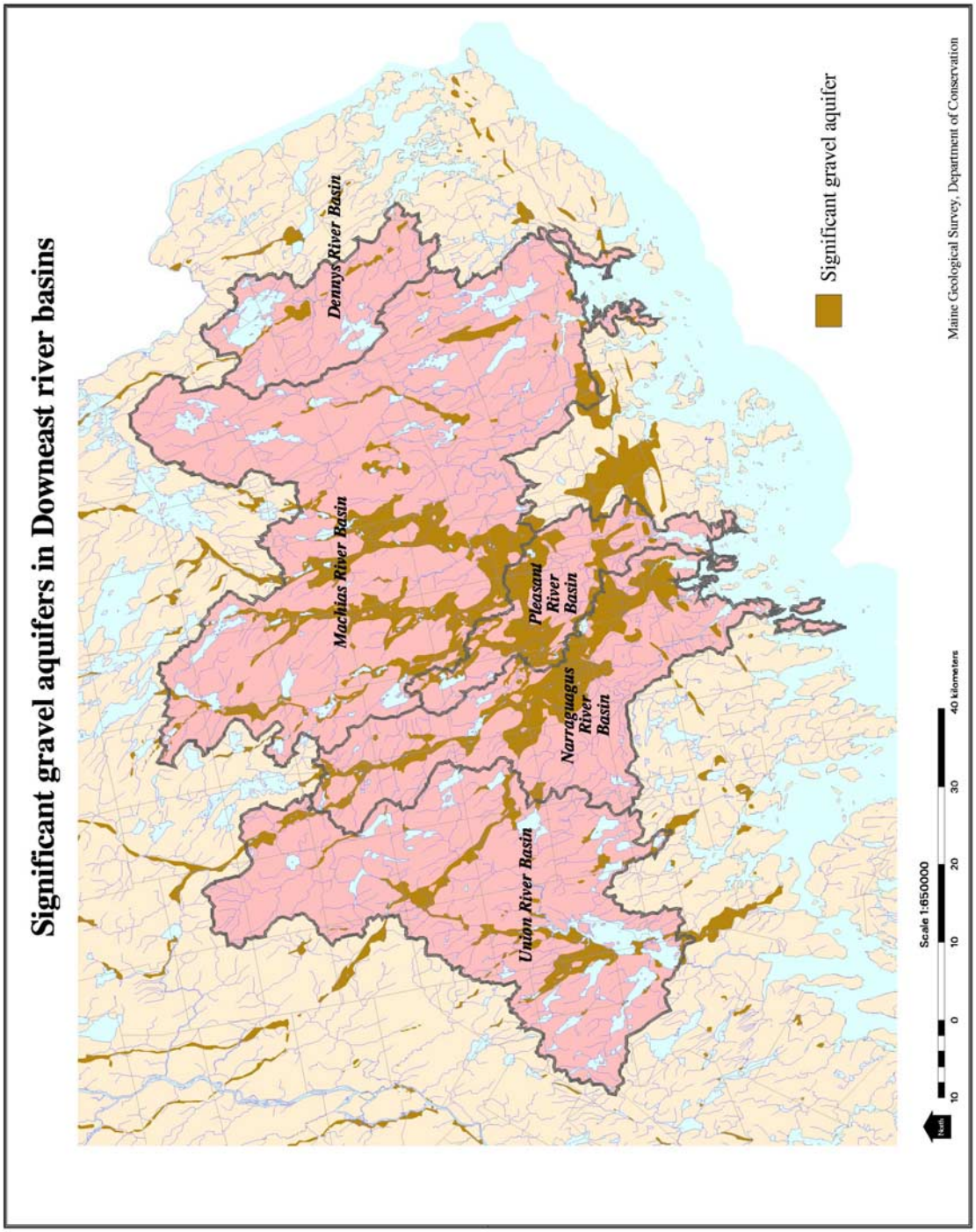
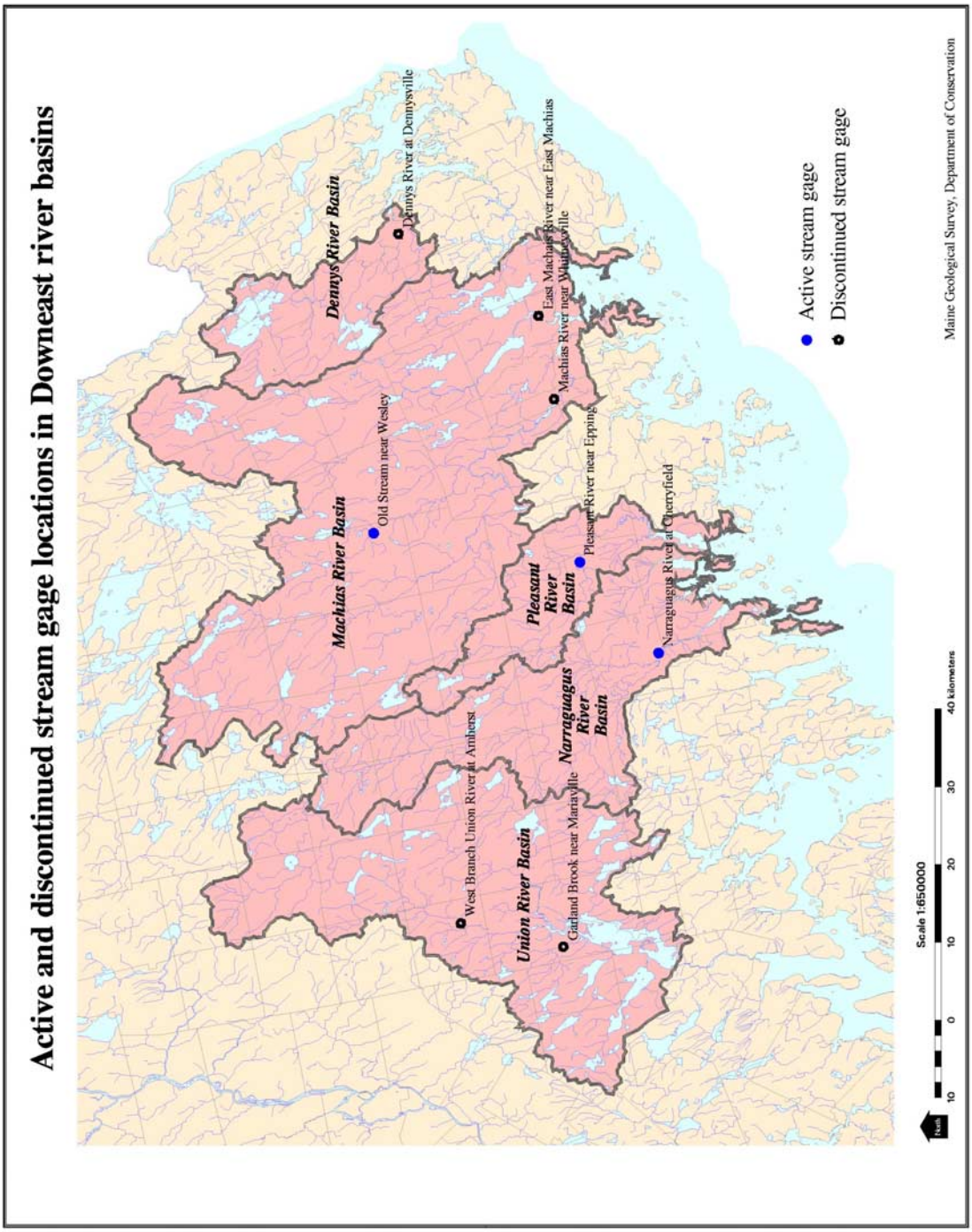


Figure 2.2 Active and Discontinued Stream Gauge Locations in Downeast River Basins.



3.0 ATLANTIC SALMON HABITAT AND FLOW NEEDS

3.1 General Physical and Hydrologic Requirements

Rivers and streams with naturally reproducing Atlantic salmon populations vary widely in physical characteristics. However, for salmon to survive and reproduce, habitat must exist within a river or stream for the following:

- Spawning in late autumn,
- Egg incubation during winter and early spring
- Feeding and sheltering during the growing period in the spring, summer, and autumn
- Overwintering
- Free migration among these habitats and the sea

3.2 Stream Habitat

Atlantic salmon habitat is best described using life stage-specific combinations of depth, water velocity, substrate, and cover (Elson 1975; Gibson 1993; Baum 1997). Young salmon prefer riffles or rapids with velocities ranging from 1.6 ft./sec. to 2.1 ft./sec., depths of 4 to 14 inches, and substrate consisting of gravel and cobble (fry) or cobble and boulder (parr). To overwinter, young salmon either move into pools or crevices between larger substrate. Spawning occurs on gravel bars or tails of pools where the current (1.0 - 2.6 ft./sec.) is accelerating and water depth (8 - 20 inches) is decreasing. Adult salmon require resting and holding areas as they migrate upstream. Holding pools are deep (> 2 ft.), well shaded, and have cool summer temperatures (spring holes or groundwater seeps). Resting pools typically lack either depth, cover, or cool temperatures.

An Atlantic salmon stream's gradient is characteristically moderately low (10 ft./mile. 0.2%) to moderately steep (75 ft./mile, 1.4%). Substrate is composed of gravel, cobble, and boulder, although there is usually some bedrock outcrop in steeper sections

and fine gravel to coarse sand in lower gradient sections. It is critical that bottom materials be sufficiently permeable to permit percolation of water, especially in spawning reaches. There should also be a regular occurrence of riffles and pools, with the average spacing of pools or riffles about five to seven times the channel width. The necessary physical attributes of bottom types and material ensure a high degree of oxygen saturation essential to salmon growth and survival.

3.3 Water Quality

Atlantic salmon require cool, clear stream water. All life stages require cool water and dissolved oxygen concentrations near saturation (Trial & Stanley 1995). Spawning occurs between 4.4 and 10° C, with 6° C, optimal for egg fertilization. Development can occur at temperatures as low as – 0.5^{o} C but not above 12° C. The best young salmon growth occurs at temperatures between 16° C and 18° C. However, salmon can survive daytime temperatures near 23° C if there is nighttime cooling of several degrees. Dissolved oxygen concentrations of 6 mg/l or greater are required for saturation at these temperatures. Water temperature, in conjunction with increased discharge, is a trigger for upstream movement of adult salmon and for smolt emigration. Atlantic salmon survival is optimal when stream pH is circumneutral (5.4 to 6.7). When pH ranges from 4.7 to 5.0, juvenile abundance is reduced. Naturally reproducing populations of Atlantic salmon cannot exist in rivers with mean annual pH less than 4.5. Atlantic salmon typically occur in clear streams, where turbidities do not exceed 40 NTU. The ability of salmonids to feed is compromised at higher levels, and (depending on the duration of the event) can potentially affect growth and survival.

3.4 Hydrology

The Pleasant, Narraguagus and Mopang drainages support naturally reproducing populations of Atlantic salmon. The variability of flow during the year and within months

has been described statistically for the Pleasant (Nielsen 1999) and Narraguagus (Dudley and Nielsen 2000) rivers. The naturally occurring annual flow cycle in these rivers includes:

- Low flows during the months of July, August, and September
- Increased flows during October and November as a consequence of autumn rains and reduced transpiration
- A period of winter low flow, particularly in February
- Peak flows in late March and early April due to snow melt and spring rain.

These patterns are responsible for maintaining the habitat structure within the river channel. The volume and timing of high flows facilitate effective sediment transport, cleansing fine sediment from juvenile and spawning habitat, building gravel bars, and maintaining channel morphology. The geomorphologic process of sediment transport and deposit are critical to maintaining productive Atlantic salmon habitat (Hill et al. 1991, Leopold et al. 1992, McBain and Thrush 1997). In part, as a result of geomorphologic processes, habitat for various life stages is not distributed evenly throughout the drainages (Tables 3.1, 3.2, 3.3), but occurs in different frequencies along the river (Abbott and Wright 2000).

Each lifestage of Atlantic salmon has evolved habitat use requirements in response to the general patterns of flow occurring in northern temperate rivers (Figure 3.1). In Maine, upstream adult movement occurs during the months of May through October. It is episodic, occurring during periods of increasing flow and changes in temperature (Shepard 1995). During their stay in the river, adults hold in pools and deadwaters within the river system. These deeper waters hold pre-spawn and spawning fish in the summer and fall and kelts (post-spawn fish) through the winter prior to their downstream migration in the spring. Spawning occurs in late October and early November (Beland et al. 1982), and is triggered by changes in day-length and temperature, and requires adequate flow in spawning areas. Eggs, which are buried within the spawning substrate, survive the winter when water flow through the gravel is

sufficient to bring oxygen, carry away wastes, and prevent freezing. Fry emerge from the gravel and are dispersed downstream from mid-May through early June in Maine (Gustafson-Marjanen 1982, MacKenzie and Moring 1988) by prevailing flows. Smolt migration begins during peak spring runoff as smolts travel down river to the estuary with spring freshets. Emigration coincides with increasing river temperatures (Fried 1977) and increasing river discharge (Jonsson and Ruud-Hansen 1985) resulting from spring runoff.

Juvenile Atlantic salmon (including both young-of-year (YOY) and parr) are present in the stream throughout the year. They survive high flow events by seeking refuge in the substrate. However, protracted low flow constrains available habitat and limits populations. During summer and winter, the two annual periods of low flow, juvenile salmon survival is directly related to discharge (Gibson 1993), with better survival rates occurring in years with higher flows during these seasons (Ghent and Hanna 1999). Survival is enhanced because discharge determines the amount of available habitat of suitable depth and velocity in the river. Increased habitat availability reduces population stresses resulting from competition, crowding, disease and predation. Juvenile salmon are territorial and each age (0+, 1+, 2+) has specific depth, velocity, and substrate preferences (Stanley and Trial 1995). The habitat that holds juvenile salmon in summer is also winter habitat. In fall as flows increase and temperature and day length decrease, juveniles shelter by burrowing in the substrate (Rimmer et al. 1983, Rimmer et al. 1984) and remain there through the winter (Heggenes 1990, Cunjak 1988). Fish within the substrate require adequate flows to bring oxygen, carry away wastes, and prevent ice formation in interstitial spaces.

3.5 Discharge

The relationship between juvenile salmon habitat suitablity [as measured by weighted usable area (WUA)] and discharge was quantified with IFIM studies for five reaches in the Pleasant River (Kleinschmidt Associates 1999A), five reaches on the Narraguagus and three on Mopang Stream (Kleinschmidt Associates 1999B). A reach is a

river segment considered to have relatively uniform habitat and hydrologic characteristics. Reach located boundaries are based on combined changes in hydrology, geomorphology and habitat use.

For each reach, the discharge identified as "optimal" for juveniles is one where the maximum overall amount of Atlantic salmon YOY and parr WUA exists, giving equal weight to both lifestages (Table 3.4). Similarly, the flows that produce optimal spawning and egg incubation WUA were identified in each applicable reach (Table 3.4). For most reaches there is a range of discharges rather than a single point that produce near-optimal conditions.

Natural river flows fluctuate, and thus do not necessarily maintain optimal habitat for juveniles or spawning and egg incubation throughout the entire critical season(s). Natural flows have the potential to limit salmon populations in months where optimum habitat flows for these particular life stages are greater than monthly median flow (Tables 3.5, 3.6, 3.7).

As discharge decreases, below that flow providing optimal habitat, there typically is also an inflection point where the rate of change in WUA and flow increased (Kleinschmidt Associates 1999A and 1999B). These habitat inflection discharges define the critical conditions below which the rate of habitat loss accelerates, and risk of stressing the salmon population therefore increases. These were identified for each reach of each watershed (Table 3.4).

Table 3.1 Distribution of habitat for different life stages of Atlantic salmon among five reaches along the Pleasant River, Washington County, Maine. Habitat for adults includes pre- and post- spawning holding areas.

				Juveniles		
Reach	Adults	Spawning	Eggs	YOY	Parr	Smolts
1	x	x	x	x	x	x
2	x	x	x	x	x	x
3	x				x	x
4	x	x	x	x	x	x
5	x	x	x	x	x	x

Table 3.2 Distribution of habitat for different life stages of Atlantic salmon among five reaches along the Narraguagus River, Washington County, Maine. Habitat for adults includes pre - and post- spawning holding areas.

				Juveniles		
Reach	Adults	Spawning	Eggs	YOY	Parr	Smolts
1	x	x	x	x	x	x
2	x	x	x	x	x	x
3	x	x	x	x	x	x
4	x			x	x	x
5	x	x	x	x	x	x

Table 3.3 Distribution of habitat for different life stages of Atlantic salmon among five reaches along Mopang Stream, Washington County, Maine. Habitat for adults includes pre - and post- spawning holding areas.

				Juveniles		
Reach	Adults	Spawning	Eggs	YOY	Parr	Smolts
1	x	x	x	x	x	x
2	x	x	x	x	x	x
3	x			x	x	x

Table 3.4. Discharge (cfs) at which optimum habitat for Atlantic salmon juveniles (YOY and parr) and spawning/egg incubation occurs within reaches along the Pleasant and Narraguagus Rivers and Mopang Stream in Washington County, Maine. Also listed are the habitat inflection discharges for reaches along the Pleasant River, where habitat dewatering accelerates as discharge decreases.

PLEASANT RIVER

	Optimum Habitat		Habitat Inflection	
Reach	Juvenile	Spawning	Juvenile	Spawning
1	16	60	10	30
2	21	56	8	44
3	12	---	8	---
4	60	120	24	90
5	40	160	30	120

NARRAGUAGUS RIVER

	Optimum Habitat	
Reach	Juvenile	Spawning
1	55	153
2	51	101
3	53	--
4	114	341
5	60	110

MOPANG STREAM

	Optimum Habitat	
Reach	Juvenile	Spawning
1	17	--
2	35	88
3	26	--

Figure 3.1 The relationships among Atlantic salmon life stages and generalized Maine river hydrology plotted median monthly discharge.

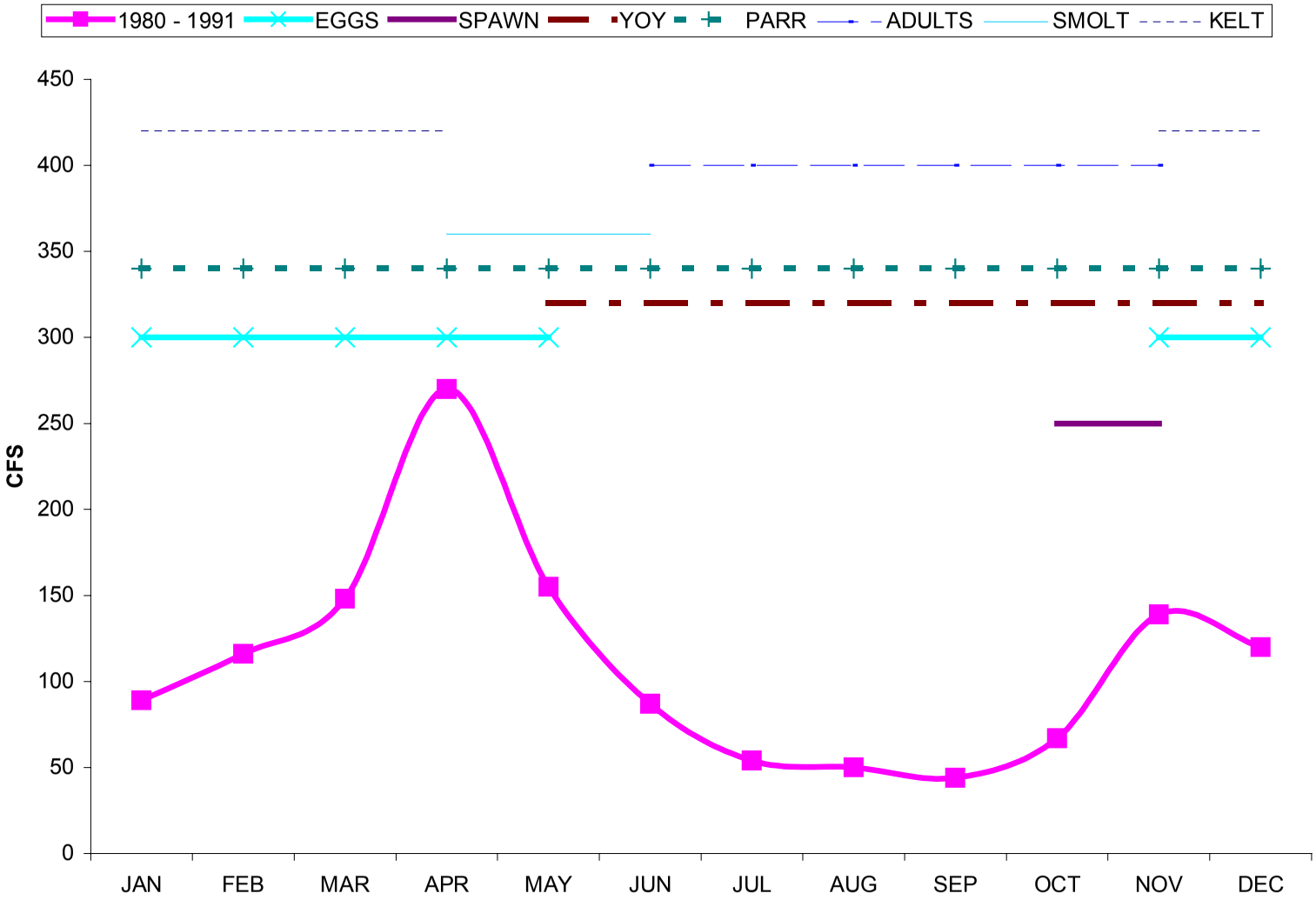


Table 3.5 The relationship between discharge for IFIM based optimal juvenile and spawning Atlantic salmon habitat (cfs) and median monthly discharge (cfs) in the Pleasant River. The discharges for reach 3 based on Nielsen (1999); other discharges throughout the watershed estimated using ratios developed by Horsley and Witten (2000a)[2].

		JUVENILE REARING: YOY & PARR									
		MAY		JUN		JUL		AUG		SEP	
REACH	RATIO	Median	IFIM Hab	Median	IFIM Hab	Median	IFIM Hab	Median	IFIM Hab	Median	IFIM Hab
1	0.25	41	16	21	16	12	16	9	16	9	16
2	0.37	60	21	31	21	18	21	13	21	13	21
3	1.00	162	60	84	60	48	60	35	60	35	60
4	1.01	164	60	85	60	48	60	35	60	35	60
5	1.57	254	40	132	40	75	40	55	40	55	40

		SPAWNING AND INCUBATION													
		OCT		NOV		DEC		JAN		FEB		MAR		APR	
REACH	RATIO	Median	IFIM Hab	Median	IFIM Hab	Median	IFIM Hab	Median	IFIM Hab	Median	IFIM Hab	Median	IFIM Hab	Median	IFIM Hab
1	0.25	15	60	32	60	34	60	28	60	26	60	37	60	69	60
2	0.37	22	56	47	56	50	56	41	58	39	56	55	56	102	56
3	1.00	60	Note 1	126	Note 1	134	Note 1	110	Note 1	105	Note 1	149	Note 1	276	Note 1
4	1.01	61	120	127	120	135	120	111	120	106	120	150	120	279	120
5	1.57	94	160	198	160	210	160	173	160	165	160	234	160	433	160

Hydrologic Data: Yellow cells = median discharge 1949 - 1998
IFIM Habitat: RED cells = median discharge < optimum life stage(s) habitat
GREEN cells = median discharge > optimum life stage(s) habitat

Note 1-No specific spawning flow required for reach 3, however, flow from this reach influences habitat suitability of reaches 4 and 5

[2] As of this writing the most current Horsley & Witten report was not available. The report has now been published and is included in the technical appendixes of this document

Table 3.6 The relationship between discharge for IFIM based optimal juvenile and spawning Atlantic salmon habitat (cfs) and median monthly discharge (cfs) in the Narraguagus River. The discharges for reach 4 are based actual gauge data; other discharges throughout the watershed estimated using ratios developed by Horsley and Witten (2000b).

		JUVENILE REARING: YOY & PARR									
		MAY		JUN		JUL		AUG		SEP	
REACH	RATIO	Median	IFIM Hab	Median	IFIM Hab	Median	IFIM Hab	Median	IFIM Hab	Median	IFIM Hab
1	0.28	149	53	69	53	36	53	25	55	25	55
2	0.43	231	53	107	53	56	53	38	51	38	51
3	0.71	383	53	178	53	93	53	63	53	63	53
4	1.00	538	114	250	114	131	114	89	114	89	114
5	0.28	151	60	70	60	37	60	25	60	25	60

		SPAWNING AND INCUBATION													
		OCT		NOV		DEC		JAN		FEB		MAR		APR	
REACH	RATIO	Median	IFIM Hab	Median	IFIM Hab	Median	IFIM Hab	Median	IFIM Hab	Median	IFIM Hab	Median	IFIM Hab	Median	IFIM Hab
1	0.28	47	153	115	153	118	153	95	153	89	153	135	153	277	153
2	0.43	73	101	177	101	183	101	148	101	137	101	209	101	429	101
3	0.71	122	135	294	135	303	135	245	135	228	135	347	135	711	135
4	1.00	171	341	414	341	426	341	345	341	320	341	488	341	1000	341
5	0.28	48	Note 2	116	Note 2	119	Note 2	97	Note 2	90	Note 2	137	Note 2	280	206

Hydrologic Data: Yellow cells = median discharge 1948 - 1998

IFIM Habitat: RED cells = median discharge < optimum life stage(s) habitat

GREEN cells = median discharge > optimum life stage(s) habitat

Note 1: Zone of passage flows are required for pre- and post-spawn adult fish, and affect flows in reach 3. This was not modeled with IFIM but to account for this need, is provisionally estimated by the Atlantic salmon commission from available IFIM transect and hydraulic data.

Note 2: Although there is no IFIM-based spawning flow identified for reach 5, flow from this segment influences spawning/incubation habitat in reach 4. Based on a reach 4 spawning flow target of 341 cfs, and a reach 3 zone of passage target of 135 cfs, an outflow from the West Branch Narraguagus 206 cfs would be required.

Table 3.7 The relationship between discharge for IFIM based optimal juvenile and spawning Atlantic salmon habitat (cfs) and median monthly discharge (cfs) in Mopang Stream. The discharges for reach 3 were calculated using watershed area ratios for median discharges at the Machias River gauge, other discharges throughout the watershed are estimated using ratios developed by Horsley and Witten (2000b).

		JUVENILE REARING: YOY & PARR									
		MAY		JUN		JUL		AUG		SEP	
REACH	RATIO	Median	IFIM Hab	Median	IFIM Hab	Median	IFIM Hab	Median	IFIM Hab	Median	IFIM Hab
1	0.41	80	17	31	17	20	17	15	17	13	17
2	0.73	143	35	56	35	35	35	26	35	23	35
3	1.00	195	26	76	26	48	26	36	26	31	26

		SPAWNING AND INCUBATION													
		OCT		NOV		DEC		JAN		FEB		MAR		APR	
REACH	RATIO	Median	IFIM Hab	Median	IFIM Hab	Median	IFIM Hab	Median	IFIM Hab	Median	IFIM Hab	Median	IFIM Hab	Median	IFIM Hab
1	0.41	18	38	40	38	43	38	35	38	31	38	47	38	129	38
2	0.73	33	88	72	88	78	88	63	88	56	88	85	88	231	88
3	1.00	45	88	98	88	106	88	86	88	76	88	116	88	315	88

Hydrologic Data: Yellow cells = median discharge 1929 - 1977 for Machias River gage
prorated to Mopang drainage by area (66.4/457sq miles)
IFIM Habitat: RED cells = median discharge < optimum life stage(s) habitat
GREEN cells = median discharge > optimum life stage(s) habitat

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4.0 HUMAN WATER DEMAND AND MANAGEMENT

4.1 General Water Uses in the Narraguagus, Pleasant and Machias River Basins

The water resources uses of these three river basins include domestic, agricultural, industrial, commercial, and recreational activities. There are homes, wild blueberry fields, cranberry bogs, canning and food processing plants, motels and laundromats, as well as lakes, ponds, and streams used for boating and fishing. The recreational uses are entirely non-consumptive. Among the consumptive uses, irrigation of wild blueberry fields is by far the only water use of any significance in these relatively unpopulated watersheds.

4.2 Wild Blueberry Irrigation

4.2.1 Why Blueberries are Irrigated

Long experience reveals that the quality and quantity of the wild blueberry harvest each year correlates directly with the timing and volume of moisture provided either by natural precipitation or as augmented by irrigation. The difference between a dry-year harvest (without irrigation) and a wet-year harvest approaches 2 to 4-fold, depending on characteristics of soils.

Sufficient water encourages vigorous root, rhizome, and stem growth, flower bud formation, flowering, fruit set, and fruit size. In addition, maintenance of such quality factors as flavor, color, size, firmness, and post-harvest keeping qualities is possible. Thus without dependable climatic conditions, the wild blueberry harvest is so variable from year to year that a steady market for the crop is difficult to establish and maintain. Without a doubt, there is clear incentive for wild blueberry growers to irrigate their crop using the plentiful water resources of the region.

4.2.2 Lands Managed for Wild Blueberry Production and Those Irrigated

Wild blueberry farming occurs on an estimated 30,000 acres of land in the Narraguagus, Pleasant, and Machias River watersheds. This represents about 4% of the total 754,560 acres that comprise these three watersheds. The two major growers, Jasper Wyman & Sons and Cherryfield Foods, farm a combined total of about 15,000 acres. So-called "small growers", who operate anywhere from a few acres to 1,000 or more acres, farm the remaining 15,000 acres. The two major growers irrigate a total of about 8,700 acres, while the small growers irrigate an estimated additional total of 1,500 acres, for a grand total of irrigated wild blueberry land amounting to about 10,200 acres. Thus, the total irrigated land in the three watersheds represents about 1.4% of the total land area.

4.2.3 Volume of Water Ideally Required by Wild Blueberry Fields

Wild blueberry lands produce a crop in alternate years, thus about half the total 10,200 acres of irrigated land is "bearing" (or "crop") while the remaining half is "non-bearing" (or "prune"). Natural precipitation and irrigation are necessary for both bearing and non-bearing blueberry lands in a given year, but the water requirement for each is different. The ideal water requirements of bearing and non-bearing blueberry fields are known from a combination of grower experience and technical investigation conducted by the University of Maine. For non-bearing fields, the ideal water requirement is one inch per week for each week of the months of June through August inclusive. The bearing fields that are producing fruit ideally require one inch per week for all of June and the first half of July, but two inches for the second half of July and all of August. The applied inches of irrigation goal is less than the ideal amount, particularly on the non-bearing fields during the typical growing season, due to physical limitations of existing irrigating practices.

4.2.4 Volume of Irrigation Water Applied to Wild Blueberry Fields

Growers perform irrigation scheduling to meet the water loss in the plant root zone due to evapotranspiration (plant demand plus evaporative loss). The goal of irrigation is to maintain the soil moisture of the root above 50% of its natural capacity. Since wild blueberry roots derive their water from the top six inches of the sandy soil, which has an average water holding capacity of one inch, water necessary to fill 50% of the root zone amounts to one-half inch. Irrigation occurs in several applications to match the weekly irrigation water demand. However, wild blueberry lands are irrigated only if natural rainfall is insufficient to supply the ideal volumes of water described previously, and they are irrigated only in the amount necessary to bring the total to the weekly ideal volumes.

In many years, irrigation water protects blueberries from frost. Such applications of water can occur during the bloom period in May and June, and later in the harvest during late August. Generally water used for frost protection in the spring exceeds the water holding capacity of the soil and therefore infiltrates past the root zone to the groundwater

In 1998, 1999, and 2000, the total volume of irrigation water used by Cherryfield Foods in the Narraguagus, Pleasant, and Machias River watersheds amounted to 358, 359, and 208 million gallons. Assuming that Cherryfield Foods irrigates about half of the irrigated land in the three watersheds, the estimated total irrigation withdrawal from all sources in all three watersheds amounts to about 700 million gallons during a typical growing season.[3]

4.2.5 Future Acres of Irrigated Wild Blueberry Land

Irrigation of wild blueberry fields requires a significant investment in labor, pipelines, pumps, and spray heads. Such investments are subject to the economic vagaries of the variable selling price of blueberries, and the possibility that conservation of wild Atlantic salmon in these watersheds may impose new standards of operation. Furthermore,

[3] Comparable data for all other growers was not made available as this plan was developed.

installation of the necessary equipment is at least very difficult (and probably will not occur) in the geographically extensive areas where the terrain is steep and numerous boulders occur at ground surface. Consequently, the expected increase in irrigated wild blueberry land within the Narraguagus, Pleasant, and Mopang River watersheds is modest. The actual projected acreage is unknown.

4.3 Percentage of Water Provided by Rainfall

Based on historical records from the years 1949 through 1999 inclusive, natural rainfall provided the ideal volume of water for the wild blueberry crop. This included from as little as none of the weeks out of the twelve-week growing period to as many as ten weeks. The long-term mean and median number of weeks that no irrigation is required during the summer growing season is four. Thus rainfall for the preceding 50-year period would have provided all of the wild blueberry crop water needs only 1/3, or 34% of the time.

4.4 Sources of Irrigation Water

The sources of irrigation water used for wild blueberries include streams and rivers, ponds and lakes, and wells. Constructed reservoirs are also included within the ponds and lakes category. Major growers use a mix of these available water sources, with wells being the newest variety of water source. High-capacity irrigation wells (water yields in the range of 1,000 to 2,500 gallons per minute) are not always available, and are very expensive to locate and construct. They are, however, desirable because of their potentially reduced effect on streamflow, salmon, and aquatic habitat. Additionally, wells are being developed to replace lake sources where there is water-use conflict with waterfront property owners (mostly pump noise, but also some concern with changing lake level and recreational use). Currently, Cherryfield Foods withdraws about half of the irrigation water from ponds and lakes with the remaining half evenly distributed between wells and streams. Jasper Wyman & Son currently draw most of their irrigation water from impoundments and natural lakes and ponds, with the remainder coming from rivers and streams.

Expectations are that the percentage of irrigation water derived from wells will increase over the next few years, while the percentage derived from rivers and streams is expected to decrease. The emphasis now and in the future is to withdraw irrigation water from sources that

have minimal effect on salmon and other fish in the Narraguagus, Pleasant, and Mopang River watersheds. The storage of irrigation water in constructed impoundments or natural kettleholes or kettlehole ponds, may increase significantly in coming years. It is possible to fill such storage facilities with water derived from wells that have little influence on fish habitat. During periods of spring runoff, or precipitation peaks, when there is little negative effect on fish habitat, rivers and streams may also provide storage augmentation.

4.5 Irrigation Withdrawals Relative to Available Water Sources

From the perspective of the total water resource available in the Narraguagus, Pleasant, and Machias River watersheds, the volume of water used for irrigation of wild blueberries is very small even during the summer period of lowest flow. Median stream flow is one way to characterize discharge on a "normal" water year. In New England, the US Fish & Wildlife Service considers unregulated August Median Flow to be a naturally occurring low flow that limits ecosystems. For example, using a baseflow of 0.38 cubic feet per second per square mile, as one way to characterize the long-term median flow during August for the 227 square mile Narraguagus River watershed, the resulting flow at the Cherryfield stream gauge is 86 cubic feet per second. Using a similar August statistic of 0.58 cubic feet per second per square mile for the 61 square mile Pleasant River watershed, the resulting flow at the Saco Falls stream gauge is 35 cubic feet per second. The 1930 to 1977 stream gauge records for the Machias River watershed at Whitneyville reveal an August median flow of about 0.54 cubic feet per second per square mile. The Machias River watershed is about 458 square miles in area. Therefore, its expected median August flow amounts to about 247 cubic feet per second at the river mouth. The stream flow for the combined Narraguagus, Pleasant, and Machias watersheds during a "normal" August streamflow add up to 368 cubic feet per second, or 238 million gallons per day. While this is a far greater volume of water than an estimate of total seasonal withdrawal (700 million gallons) for wild blueberry irrigation from these same three watersheds, withdrawals in subwatershed reaches, may represent a greater amount of August stream flows.

Assuming 700 million gallons is withdrawn equally over the 90-day irrigation period, wild blueberry irrigation uses about 3.3% of the typically available daily discharge from the three combined watersheds during the August period of low flow. Furthermore, withdrawal from streams through pumping does not comprise all of the irrigation water used during August.

Growers also pump from lakes, ponds, reservoirs, and wells. These activities have a smaller effect on summer streamflow than direct withdrawal from the streams of the Narraguagus, Pleasant, and Machias River watersheds.

4.6 Water Sources and Storage

Farmers need to develop water sources and storage sites that do not affect Atlantic salmon habitat. These new sources and sites represent large capital expenses when compared with current practices of direct stream withdrawals.

In Washington County there are an estimated 10,900 acres of wild blueberry land where growers irrigate or have indicated intent to irrigate. This may indicate a need for alternative irrigation sources. The basis for this estimate is solely from contact with growers who have come forward on their own. No systematic grower survey was conducted.

Based on information obtained from Maine soil and water conservation districts and from contractors and growers, who have developed alternative water sources, the commonly employed solutions range in cost from $400 to $6,000 per acre served. Many of the solutions cost $2,000 - $3,000 per acre served. Over the next eight to ten years, it is estimated that it could cost growers $25 million dollars to develop alternative water sources and storage. Actual costs and the rate of irrigation development will depend on many factors too numerous to cite.

4.7 Farm and Water Management

One key opportunity to ensure minimization of water needed is education and technical assistance to farmers on cultural practices (e.g., building soil organic matter to increase soil water holding capacities, planting windbreaks, etc.) and proper irrigation system design. Often Maine farmers buy used irrigation equipment from farmers in other states with little or no planning assistance. High inefficiencies can result from worn and mismatched sprinkler heads, for example, as well as improperly sized mainlines. Once installation of an irrigation system occurs, the other major opportunity for water conservation is technical assistance that focuses on best management practices in system management, operation, and maintenance.

The entities in Maine that provide technical assistance to growers (*e.g.,* Cooperative Extension Service, Maine Department of Agriculture, Soil and Water Conservation Districts and USDA Natural Resources Conservation Service, etc.) have experience and capacity to assist growers in water management and irrigation. However, the current workloads and competing priorities of these agencies limit the amount of assistance they can provide. Irrigation system vendors are a consistent and cost effective (free) source of available irrigation information for growers.

4.8 Risk Management and Irrigation

Federal policy related to farm risk management has changed significantly throughout the 1990's. The emphasis has been to move away from Federal disaster payments for crop losses and move producers to developing their own risk management plans that reduce their business risk. By moving to eliminate crop disaster programs, the Federal government is requiring farmers to take an active role in managing risk.

"All crop producers face output risk, but the risks are particularly great in non irrigated areas that are subject to frequent drought. Crop yield risk includes not only the possibility of low yields but also poor quality." [4] The USDA is encouraging farmers to plan for production output risk. According to the USDA, recent weather patterns have been more volatile and drought has been the cause of 47% of crop losses.

In a UDSA crop insurance seminar given on August 10, 2000 in Bangor, Maine, the Risk Management Agency stated that weather, price, and debt are major risk factors to producers. When addressing adverse weather, drought is a major risk factor. Irrigation is such an important tool in reducing production output risk that the Agency also lists "Failure of Irrigation Supply" as an unavoidable cause of crop loss.

Federal farm policy is moving producers to reduce their production risk by using all practices that reduce their adverse weather risk. Risk management is also encouraging farmers to look at all risk including factors such as price and debt. The challenge to farmers is to make major

[4] "Building a Risk Management Plan", US Dept. of Agriculture, Risk Management Agency, page 4, Aug. 1998.

capital investments to reduce the risk of drought while at the same time not adversely increasing their debt risk, especially where they have limited ability to manage their price risk.

4.9 Management of the Available Water Resource

The conflicts in water use within the Narraguagus, Pleasant, and Mopang River watersheds relate primarily to maintenance of fish habitat and secondarily to recreational use of the major lakes and ponds. The conflict centers on the timing and location of irrigation water withdrawals. During the natural yearly period of low flow in rivers and streams, and low water levels in lakes and ponds, demand for irrigation water peaks. Wild blueberry growers can manage the available water resource by several means, including the following:

- Restriction of summertime direct withdrawals from rivers and streams to short periods of high flow following rain storms (so called "skimming")
- Restriction of summertime withdrawals from lakes and ponds to volumes that do not exceed natural low lake or pond levels
- Pumping water from wells that have little or no influence on summertime lake and pond levels, or stream flows
- Maintaining pond levels by pumping to the ponds from wells,
- Constructing various kinds of reservoirs for storage of water obtained from rivers and streams during the late winter and early spring when flows are highest and potential damage to fish and aquatic habitat is very small.

Additionally, and very importantly, the wild blueberry growers are scientifically investigating and defining the fish and plant habitats that their irrigation water withdrawals and management practices may affect. They are collecting and analyzing information on streamflows, lake and pond levels, and groundwater table levels on a yearly basis. Utilization of these data can potentially improve water management techniques and ensure that negative environmental effects are insignificant.

5.0 ALTERNATIVES ANALYSIS

5.1 Introduction

The demand for water used for irrigation and other purposes can be dealt with in various ways, some of which will have little or no adverse impact to Atlantic salmon and other aquatic life. This chapter describes different alternatives for addressing water demands and ecological needs in the Downeast salmon rivers. In most cases, a multi-faceted approach is necessary. This should include proper agricultural practices (Best Management Practices, or BMPs) that are designed to avoid and minimize direct water withdrawals from streams and rivers, along with the least environmentally damaging alternative(s) for water sources and storage sites.

The following material provides a general description of the different ways to obtain, store, and apply water for purposes of managing wild blueberry and cranberry cropland. This material also qualitatively discusses environmental and economic considerations for the various alternatives. In the sections on alternative sources and storage sites, the various options are presented in a hierarchical manner, with the method that is likely to have the least impact on Atlantic salmon and other environmental values described first. While pursuit of the proposed hierarchical approach to minimize environmental impacts is necessary, selection of a particular option for conserving, withdrawing or storing water will depend upon a number of factors. These include availability to the particular user, economic feasibility, and the ability to secure permits, where needed.

5.2 Best Management Practices

Responsible irrigation involves water conservation. Water conservation, in turn, implies efficient irrigation applying the right amount of water for maximum crop response, when it is needed, at the lowest cost, and in such a manner as to minimize environmental impacts. Best management practices (BMPs) leading to water conservation in wild lowbush blueberry and cranberry crop management varies somewhat, based on the unique cultural and water requirements of each crop. In general, these measures fall into three categories: (1) cultural, (2) irrigation system planning and design, and (3) water application.

Cultural BMPs which minimize water losses include building up soil organic matter by flail mowing, topdressing with mulches, replanting bare areas, planting windbreaks to slow drying winds, and exercising good weed control. Experimental assessment and economic evaluation of the water conservation benefits of mulches and windbreaks in wild, lowbush blueberry production is necessary for a better understanding of these methods.

System planning and design BMPs that minimize environmental impacts during low flow periods in rivers and streams include:

- Avoiding the need for direct withdrawals
- Planning for storage
- Sizing storage to meet projected needs
- Limiting water withdrawals required to replenish storage to periods of high flow
- Using wells to supplement storage during low flow periods
- Using delivery systems which minimize water leakage (e.g., welded polyethylene pipe)
- Recycling irrigation, process, and waste water(in situations where practical)

Water application BMPs include the timing and scheduling of irrigations. In this regard, irrigation in the early morning, when winds are less than 3-mph and air temperatures are low, is recommended in order to reduce evaporative water losses and distortion of water application patterns. Avoidance of irrigation in the evening or at night in order to reduce disease development is important.

Once a grower has planned, designed and installed the irrigation system which best suits their needs and which minimizes environmental impacts, the single most important BMP leading to efficient water use is irrigation scheduling (i.e., deciding when and how much water to apply to the crop). The methods of irrigation scheduling commonly applied to wild lowbush blueberries and cranberries include (1) the feel method, (2) use of low tension tensiometers, and (3) the water balance method.

As the name implies, the "feel method," involves obtaining soil samples from the root zone of the crop and, judging from the appearance and feel of the soil, determining whether soil moisture is adequate. While it is the quickest and simplest method of determining crop irrigation needs, it is subjective and not especially accurate. In addition, while this approach estimates when irrigation is necessary, it does not answer the question of how much water to apply. Despite its limitations, this method is suited to both wild lowbush blueberries and cranberries.

In the tensiometer method, an instrument called a tensiometer measures the degree to which soil withholds water from plant roots; hence, it is essentially a measure of soil dryness. It consists of a sealed tube with a vacuum gauge and porous tip, initially filled with water. The instrument is inserted into the soil at rooting depth following a saturating rain, subsequently, as the soil dries out, water is pulled out of the tube and recorded as a tension (measured in centibars, cb) on the vacuum gauge. After a rain or irrigation, water moves back into the tensiometer, causing a decrease in vacuum gauge reading. The instruments are simple to prepare and install, easily monitored, and cost effective. Experience with the instruments allows for the determination of both when and how much water to apply. The recommendation for wild lowbush blueberries is only the use of low-tension (LT) tensiometers (0-40 cb range). They have been found to be unsuited for use in upland cranberry beds with clay bases typical of the Downeast watersheds because of their insensitivity to the relatively small changes in soil moisture which normally occur between irrigations.

In the water balance method, accurate scheduling of irrigation for both wild lowbush blueberries and cranberries is based on estimates of actual water loss from the plants (transpiration) and soil (evaporation), otherwise known as evapotranspiration. The method involves daily measurements of evaporation, either from an open, water-filled pan or as estimated from weather station data. This measurement is termed maximum daily evapotranspiration (ETmax).

Wild lowbush blueberry and cranberry plants differ in their daily water losses when compared to evaporation from an open pan. Therefore, it is necessary to know the relative water loss from the plant and soil vs. the pan for each crop and for each stage of plant development. This ratio of plant and soil water loss vs. pan loss, called the crop factor, must be determined experimentally. Knowing the crop factor for each crop and by tracking the daily precipitation and

ETmax, the grower can easily schedule required irrigation. This approach is the most widely accepted, cost-effective, and accurate means of scheduling irrigation for most crops. However, it does require a greater understanding of crop water losses compared with the feel or tensiometer methods. It also requires more time devoted to record keeping and tracking Successful application of the water balance method to wild lowbush blueberry and cranberry production still awaits experimental determination of crop factors for both crops.

Other methods of irrigation scheduling, such as the use of regular tensiometers (0-100 cb range), soil moisture blocks, time domain reflectometry, infrared thermometry, and neutron moisture meters are not recommended. These methods have been found to be either too insensitive, or are costly and require considerable professional expertise to understand and apply.

For a better understanding of the BMPs relating to irrigation practices, refer to Irrigation Management: Best Management Practices, 1995, which may be obtained from the Ontario Ministry of Agriculture, Food and Rural Affairs, Ottawa, Ontario, Canada.

5.3 Irrigation Systems

Probably the most critical best management practice for irrigation is choosing the right system. Growers manage wild lowbush blueberries and cranberries essentially as perennial, woody turf crops. In the case of wild blueberries, fields are usually irregular in shape and possess rough micro-topography. Therefore, only hand-moveable, semi-permanent (main supply lines buried), and permanent (all lines buried) sprinkler systems have been found to be suitable for irrigating these crops. Other irrigation systems such as drip irrigation, traveling guns, center pivot, lateral move, and sub-irrigation either have been tried or have other limitations. For example, drip irrigation is best suited to row crops grown on flat terrain, cannot be used for frost protection, is subject to rodent damage, cannot be in the way of field machinery, and, on sandy soils, would require close spacing of lines (12-18”) and emitters. Therefore, the following discussion does not consider these methods.

System designs commonly employed include:

- Above-ground, moveable systems
  - Big guns
  - Small sprinklers
- In-ground, permanent systems
  - Big guns
  - Small sprinklers

All of the above designs have been applied successfully to wild, lowbush blueberry production. Because of the need for frost protection and chemigation, however, cranberry culture is limited to small sprinkler systems. In all systems, a proper design is required to match the water supply, pump, pipe, and sprinklers in order to assure the desired application rate and even distribution of water. Since each growing situation is unique and proper design is critical, irrigation specialists normally design these systems. In choosing the system which best suits one's needs, it is important to consider the advantages and disadvantages of each type of system.

5.3.1 Above-Ground Systems

In general, the initial capital cost of above ground, big gun systems is the least of any sprinkler system, but the labor requirements for moving pipe and changing guns are the highest. The system is very portable and flexible to use, but the acreage that can be irrigated is limited by how many times the system can be moved. It cannot be used for frost protection as some crop damage results from moving lines. In general, high labor costs and the competing need to irrigate cropping fields during the same period, preclude its use for non-cropping wild blueberry fields. The common practice is to move pipe during the day and irrigate at night. It is not suitable for cranberries, and water losses resulting from leakage can be a problem.

Although the above ground small sprinkler system is capable of being moved like above ground big guns, it is generally left in place once put down because of the time and effort required for set up and take down. Its use for frost protection also requires that it

remain in place since 100% of the growing surface must be protected continuously during a frost event. The initial capital cost, as for moveable big gun systems is low, as is the operating cost, but the labor costs for setting up and taking down the system are highest. Minor crop damage may result from setting up the system, ground machinery is difficult or inconvenient to use once it is set up, and it is generally not used to irrigate non-cropping wild blueberry fields. It is possible to irrigate both cranberries and cropping blueberry fields with this system, irrigating the entire bed or field at the same time, with the application of small volumes of as needed. Water losses resulting from leakage are greatest for this type of system.

5.3.2 In-Ground Systems

The initial capital cost of in ground big gun systems is high, operating costs are moderate and maintenance costs are very low. Like the above ground big gun system, it cannot be used for frost protection and is limited to use on wild, lowbush blueberry fields. However, unlike above ground big gun systems, convenient irrigation of both cropping and non-cropping fields can occur, crop damage is more limited, and use of ground machinery is possible. Water losses resulting from leakage are least for this type of system.

The initial capital cost for in-ground small sprinkler systems is the highest, maintenance costs are moderate, while operating costs are the lowest. It has all of the advantages of above ground small sprinklers but none of the disadvantages, except that close spacing of sprinkler heads requires extra care while using machinery during normal field and harvest operations. Maintenance involves setting out sprinklers in the spring, keeping nozzles clean, and taking up sprinklers before or after harvest. Blowing out lines with compressed air is common on wild blueberry fields after sprinkler removal at harvest completion in order to minimize winter ice damage to lines. Water losses resulting from leakage are less than for above ground systems, but are somewhat greater than for in-ground big gun systems.

5.4 Alternative Water Sources

Water conservation and efficient delivery systems are essential to meeting the needs of growers while protecting Atlantic salmon habitat. However, growth projections for the wild blueberry industry, and other expanding uses of water, suggest that water conservation and increased delivery efficiency alone will probably not alleviate human water demand on these watersheds.

Surface water withdrawals from rivers have historically been the primary source of irrigation to maintain both wild blueberries and cranberries during low-flow periods. Alternative sources and strategies for irrigation water are essential because threats to Atlantic salmon and salmon habitat have generally arisen from indiscriminate surface water withdrawals that affect stream flow, especially during low-flow periods. A range of alternatives can reduce the risk to salmon populations as well as growers.

Potential alternative sources include groundwater, lakes, and ponds. Surface withdrawal strategies (from either riverine or lacustrine parts of a watershed) may provide for limited withdrawal at times other than during critical habitat-based flow conditions, (*e.g.* low flow periods), and/or in magnitudes that do not influence habitat suitability objectives or channel function. The viability of any of these alternatives depends upon several factors, including:

- Ecological impact on Atlantic salmon and their habitat
- Availability to any particular grower
- Ability to be permitted
- Affordability

Other alternative sources such as rainwater delivery systems, above-ground storage tanks, and transporting water from far-field sources via truck and use of long-distance pipeline and associated delivery systems occurs worldwide. Although technically feasible, they are presently not considered cost effective in this application, and thus are not discussed further.

The following is a description of potential groundwater sources hierarchical and ranking from the most to least preferred, based on their risk to Atlantic salmon, and salmon habitat.

5.4.1 Groundwater

Recently, large growers have explored the option of using ground water sources with wells. Relatively extensive sand and gravel aquifers exist in the blueberry barrens, making groundwater a viable irrigation source for some growers.

Access to groundwater sources is not, however, available to all growers for logistical and/or economic reasons. Their feasibility for any given grower requires a site-specific determination. Availability of ground water depends first upon whether a grower has access to a usable volume of groundwater on or close to fields requiring irrigation. Even given close proximity of groundwater, its use may not be feasible due to local soil conditions, such as fine textured soils with low hydraulic conductivity, depth to water table, and/or current cost-effectiveness of conveyance infrastructure.

With all groundwater options, monitoring is essential. Monitoring has the potential to provide data to support decisions on source identification, assessment of the viability of these sources, the design of delivery systems, and evaluation of potential impacts of use of the source on salmon habitat. Monitoring also poses a potential additional cost, depending upon the specific situation.

The following describes a hierarchy of groundwater options ordered from most to least ecologically protective, with consideration both to the groundwater resource itself, as well as resources dependent on groundwater:

Table 5.1 Ground Water Alternatives.

Alternative	**Notes**
Seasonal pumping from wells that have no hydraulic coupling to rivers or streams during the annual period of low river or stream flow.	Withdrawal from wells not hydraulically coupled is preferred because of the limited risk of impacts on surface waters. Adequate monitoring is essential, however, to assure those withdrawals do not exceed an ecologically protective standard.
Seasonal pumping from wells that have hydraulic coupling to rivers and streams, but with less than 25% of their discharge induced from the river or stream, so long as a previously established environmentally protective discharge (*e.g.*, a habitat-based surface flow target for the subject stream reach) is maintained by adding back at least the equivalent discharge from the well to the river or stream.	Withdrawal from hydraulically coupled wells poses an increased risk of unacceptable impacts to salmon habitat. Adequate monitoring, augmentation of stream flow, and maintenance of suitable water quality may avoid and/or minimize this risk. Augmentation implementation may have cost implications for growers.
Pumping from hydraulically coupled wells without augmentation of stream flow when it falls below a previously established environmentally protective habitat-based flow.	Like the second option above, pumping from hydraulically coupled wells poses the risk of unacceptable drawdowns of surface waters. If, in such cases, groundwater pumping lowers instream flow below a protective standard, it will, by definition, cause unacceptable impacts to salmon habitat and other ecological values.

5.4.2 Ponds and Lakes

Ponds and lakes provide an alternative to withdrawing water directly from rivers and streams during periods when water in salmon rivers naturally reaches low seasonal levels. As described in the following section, ponds and lakes also provide the significant additional benefit of providing storage of water withdrawn from other appropriate sources.

Lakes and ponds themselves provide significant ecological and recreational values such as habitat for brook trout and other fish species, wetlands, and fishing and boating. Regulators, as well as irrigators, must consider the impacts on these values during the permitting process.

Transferring water from one water body to another creates the potential for adverse impacts to water quality such as temperature increases, disease transmission, and the transfer of exotic plants or animals. There may be ways to prevent these potential adverse impacts such as withdrawing bottom water to avoid or minimize temperature impacts, and using screens to eliminate transfer of some aquatic organisms. Permitting agencies should examine such issues and where practicable, require measures to minimize or avoid those impacts.

Potential lake and pond withdrawal scenarios, as described and ranked in a hierarchy from the most to least preferred based on their risk to Atlantic salmon and their habitat, are as follows:

Table 5.2 Pond and Lake Withdrawal Alternatives.

Alternative	**Notes**
Seasonal pumping from natural lakes and ponds that are hydraulically isolated from surrounding groundwater so long as the maximum drawdown is no more than what occurs naturally.	The hydraulic isolation of these water bodies makes them vulnerable to unacceptable lowering of water levels detrimental to ecological and possibly recreational values. Avoidance of unacceptable impacts is possible if monitoring is adequate and withdrawals do not exceed environmentally protective standards. Use of this alternative will require knowledge of the range of natural water levels for the lake or pond, along with any site-specific environmentally sensitive resources.
Seasonal pumping from natural ponds and lakes that are hydraulically coupled to surrounding groundwater and have only seasonal outlets, so long as the maximum drawdown is no more than that which naturally occurs.	To the extent that ponds or lakes have only seasonal outlets, impacts to associated salmon rivers and other tributaries that provide important spawning habitat refugia for salmon and other species such as brook trout, and other habitat values will be minimized. The balance between instream flow needs and water availability for irrigation impoundments should be determined based on an environmental flow standard (e.g., ABF or IFIM flows) that is protective of salmon and other factors. Monitoring of seasonal outlet flows is important. Groundwater recharge will help avoid unacceptable lowering of water levels and related impacts. Use of this alternative will require knowledge of the range of natural water levels for the lake or pond.
Seasonal pumping from natural or artificial ponds and lakes that are hydraulically coupled to surrounding groundwater and have year round outlets, so long as a previously established environmentally protective flow (e.g., ABF or IFIM flows)is maintained.	The drawdown of ponds and lakes that are hydraulically coupled to salmon rivers will still result in the lowering of water levels in those rivers, as well as tributaries which may provide important spawning habitat or refugia for salmon and other species such as brook trout, and other habitat values. The balance between instream flow needs and water availability for irrigation impoundments should be determined based on an environmental flow standard that is protective of salmon and other factors. Monitoring of outlet flows is important. Groundwater recharge will help avoid unacceptable lowering of water levels and related impacts on resources such as wetlands.

5.4.3 Rivers and Streams

As noted above, water withdrawals from rivers and streams have been one of the most common sources of irrigation water to date. Both the Maine Salmon Conservation Plan and the ESA listing have identified certain magnitudes of direct withdrawals from rivers and streams during summer low-flow periods as a threat to Atlantic salmon and their habitat. However, withdrawal from rivers and streams in accordance with habitat maintenance objectives that protect ecosystem functions do provide a suitable irrigation source.

A description of potential river and stream withdrawal scenarios are described below and ranked in a hierarchy from the most to least preferred based on their risk to Atlantic salmon and their habitat.

Table 5.3 River and Stream Withdrawal Alternatives.

Alternative	**Notes**
Late winter and spring pumping from rivers or streams during annual period of high flow, as long as the maintenance of fish habitat occurs based on IFIM, ABF or other previously established environmental flow.	Not all high flows represent ecological "excess"; i.e., high flows perform important ecological functions for Atlantic salmon and other aspects of river systems. Therefore, the environmental protective flow standard should address high flow needs. Policies may be necessary to identify the timing and amount of withdrawal allowed during high flow.
Skimming high flows from rivers or streams during the low-flow season as long as fish habitat is maintained based on IFIM, ABF or other previously established flow	Similar to above, this alternative presents a higher risk to salmon because of their habitat needs during low-flow periods. Reduction of high flows also could affect migratory behavior and interfere with hydraulic processes such as channel formation and sediment transport. With appropriate monitoring, this may still be a viable option that accomplishable without unacceptable adverse impacts.
Direct pumping from streams during the annual low-flow period that reduce the flow below a previously established environmental flow limit.	As discussed in detail in Chapter 4, withdrawals during low-flow periods pose the greatest risk to Atlantic salmon and their habitat. Design of the IFIM and other environmental flows prevents unacceptable impacts. Therefore, by definition such withdrawals will cause adverse impacts to salmon and salmon habitat.

5.5 Storage Alternatives

Acceptable alternatives for storing water for irrigation include both natural and artificial lakes, ponds and impoundments, listed below, starting with the least environmentally damaging storage option:

Table 5.4 Storage Alternatives.

Alternative	**Notes**
Existing lakes and ponds in which the long-term naturally occurring range of water levels is maintained during the low-flow season by adding water from any acceptable source.	The feasibility of this alternative depends on the availability and proximity of the lake or pond relative to the land irrigated. It should not require raising of any dam or outlet control structure that may exist at the site. Major costs would likely result from the piping and other infrastructure needed to transport the water from the source to the storage site and then to the fields being irrigated. Maintenance of naturally occurring water levels in the lake or pond utilized for storage should help minimize environmental impacts to wetlands and associated fish and wildlife resources. This alternative assists in avoiding impacts to Atlantic salmon populations and habitat. The quality of the source water should be determined and monitored in order to avoid any adverse effects on conditions in the storage lake or pond.
Natural depressions, such as kettle holes, that will hold water added from any acceptable source	Kettle holes, found on many of the blueberry fields, often contain water for various lengths of time following spring runoff. The feasibility of this alternative for storage would depend on the ability of the kettle hole to retain water. It may be necessary to fill the bottom of the hole with clay or to use an artificial liner, both of which could prove costly. The ecological significance of kettle holes depends on the duration and amount of retained water. They undoubtedly provide seasonal habitat for some wildlife, including reptiles and amphibians. Increasing the presence of water in the kettle hole should not diminish its use by wildlife, although permanent flooding would probably alter existing vegetation, as would addition of clay or an artificial liner.

Alternative	Notes
New constructed ponds filled with precipitation, surface runoff, groundwater seepage alone, or by water added from an acceptable source.	Excavation of these storage facilities would occur in an off-stream location (in contrast to an impounded stream or spring, as described below). Economic feasibility of this option would depend on proximity of water sources and volume required meeting irrigation needs. Addressing impacts to existing wetlands or other sensitive environmental areas at the site of the proposed pond occurs during the permitting process. Impacts to salmon and other environmental resources would be minimal with this alternative. The artificial pond may provide some new aquatic habitat for wildlife depending on the duration and amount of water being stored.
Existing lakes and ponds where the long-term naturally occurring high water level is raised and/or the long-term naturally occurring low water level is diminished in order to increase the storage volume.	This alternative would requires raising an existing dam, or installing a new water control structure to provide an ability to manipulate water levels beyond what would naturally occur. Availability and proximity of the lake or pond relative to irrigated land would determine the economic feasibility of this option, along with the costs associated modifying the dam or outlet structure. Modifying historic water levels may affect existing uses of the lake or pond by fish, wildlife, and the public. Outflows from the lake or pond also could change, thereby impacting salmon and other aquatic life. Water quality conditions in the source water also would have to be determined and monitored to avoid any adverse consequences.
Impounded stream that may be filled with additional water from an acceptable source, so long as adequate outflows are provided, and all other environmental issues are addressed (e.g., alteration of existing wetlands)	This alternative would require construction of a dam or dike and a water control structure. Economic feasibility would depend on proximity of water sources and irrigated fields, and costs associated with installing a dam or control structure. Additional costs would also result from a need to address environmental issues in the permitting process, including mitigation of unavoidable impacts to wetlands. This alternative has the greatest potential to impact salmon and other fish and wildlife resources and habitats. Depending on the location, there could be direct losses in salmon habitat in the stream that is impounded, blocked access to spawning and nursery areas, and modification in temperature and other water quality conditions. Minimization or mitigation for any adverse impacts via the permitting process is necessary before implementation of this alternative.

6.0 EVALUATING THE EFFECTS OF ALTERNATIVE IRRIGATION STRATEGIES ON ATLANTIC SALMON HABITAT

6.1 Modeling and Monitoring

Both *modeling* and *monitoring* are required to support Water Use Management Plan (WUMP) decisions. Models provide an objective method of projecting the effects of various water use strategies on salmon habitat. Basic models were created to project monthly water use and water availability, to be used in conjunction with flow-based Atlantic salmon habitat suitability. However, as with all models their ability to simulate any process is limited to the quantity and quality of the data and how many of the key factors are represented by basic model concepts.

Monitoring develops the data necessary to better understand the hydrology of the watersheds, and assure that salmon habitat is being protected. In addition, the data can be used to verify and/or adjust initial model assumptions, provide a report card on WUMP implementation success, fill in existing information gaps, and provide an early indication and data on unforeseen or new factors affecting water flow, use, and salmon habitat.

Modeling hydrologic statistics have been estimated for the rivers included in this plan. These are based on USGS gauge data (supply), irrigation water use (demand), and the relationship between flow and Atlantic salmon habitat. In addition, the distribution of both Atlantic salmon habitat and blueberry fields throughout the Pleasant, Narraguagus, or Mopang watersheds have been estimated. The location and distribution of large grower acreage is known, but small grower information is still limited. The IFIM studies provide data on the relationships between discharge and habitat suitability (indexed as weighted usable area (WUA)) of Atlantic salmon habitat for three life stages in reaches within the three rivers (Kleinschmidt Associates 1999a, 1999b). Each river is divided into reaches of similar habitat and hydrology. Therefore, discharge and the loss due to water use are needed for different points along the rivers to predict Atlantic salmon habitat availability throughout the watersheds under alternative irrigation strategies.

6.2 Background

Horsley and Witten (2000a, 2000b) chose to estimate discharge at the downstream reach boundaries using the proportion of annual baseflow at the gauge contributed by sub-watersheds associated with the reaches. The over-riding assumption is that the ratio of precipitation infiltrating the ground surface (recharge) becomes groundwater and that groundwater ultimately becomes river baseflow. Different recharge rates were used for three basic surficial materials, sand and gravel, till, and wetlands. The baseflow contributions were modeled by summing the products of annual recharge and surface area in each sub-watershed. Because the model was simple, using average annual recharge , the effects of variation in recharge rate and precipitation on baseflow were not modeled. Their approach to estimating discharge using recharge rates for different soils has advantages over a straight ratio of surface area. However, the sensitivity of the baseflow proportions (ratios) to changes in recharge rates and to errors in the area of sand and gravel has not been evaluated.

Watershed-specific STELLA models were developed to estimate the potential baseflow loss from irrigation (Horsley and Witten 2000a, 2000b). STELLA is an object oriented model that is widely accepted for modeling all types of processes. In these watershed models the outflow of a reach was a function of the input of flow from upper river reaches, input from groundwater as previously described, and withdrawals due to water use. Water use could include direct stream withdrawals, interception of baseflow by impoundments, near-field well withdrawals, or far-field well withdrawals (which also includes ponds connected to the groundwater). Although these withdrawals may be for any water use, the only evaluations were for wild blueberry irrigation demand, because it was identified as the most significant user of water. Water use for irrigation was calculated based on different irrigation rates for bearing and non-bearing acreage (discussed in Chapter 4), assumptions on the proportion of the acreage irrigated with one of four sources (direct withdrawal, impoundment, near field well, or far-field well), and assumptions about how each of the sources affect baseflow.

6.3 STELLA Model Assumptions

There were many assumptions made to reduce naturally variable events to single numbers. For example, baseflow inputs were monthly averages calculated using RORA baseflow separation technique with Narraguagus and Pleasant River hydrologic data. Further assumptions were made to synthesize baseflow inputs for Mopang Stream based on the proportion of monthly to annual baseflow for the other rivers. As a result, the models are deterministic, in that random events are not included in the models. Wet and dry years are simulated using different levels of irrigation (Horsley and Witten 2000a, 2000b).

Horsley and Witten (2000a, 2000b) combined assumptions about irrigation acreage and water sources used to irrigate the acreage to simulate expansion. Application of different percentages of the set irrigation rate were intended to mimic dry, average and wet year irrigation, but were not tied to actual irrigation practices or compared to the precipitation record as was done in Chapter 4. As previously discussed, (Chapter 4), the amount of irrigation water needed to meet plant demand is between the 33% (wet year) and 50% (average year) used by Horsely and Witten. Another assumption of the model is that the normal flow is just baseflow, which would actually be the worst case flow, with no contribution from precipitation runoff. However, the fish experience streamflows (baseflow plus runnoff).

The Flow Team (a technical team component of the WUMP Committee) determined an estimate of the historically available salmon habitat based on flow duration curves for each reach. These curves were prorated from the USGS gauge data (using the Horsley and Witten reach ratios) and IFIM flow versus habitat curves. The result was habitat duration curves and look-up tables to predict juvenile and spawning/incubation Atlantic salmon habitat available under different flow rates (Kulik , *et al*. 2000 file document) The IFIM approach did not address the migratory lifestages of Atlantic salmon (smolts and kelts).

The Pleasant River was used to test the capability of the STELLA model to differentiate between irrigation strategies. Natural flows were included to determine the extent to which alternatives might deviate from an estimated “no-withdrawal” historical habitat availability. Prior to 1999, irrigation water was directly withdrawn from the Pleasant River. However, regulatory and voluntary withdrawal limits have eliminated most direct withdrawals. Irrigation in 2000 included substitution of a well for the largest direct withdrawal. Thus, the 100% irrigation of current acreage scenario with direct withdrawal provides an estimate of the maximum amount of habitat protected by these withdrawal limits.

The STELLA model was used to produce a table of cumulative baseflow losses by reach for these two irrigation scenarios. These scenarios used July flow data for reach 4 of the Pleasant River. The effect of irrigation on the streamflow was modeled by subtracting the baseflow losses for each scenario from the reach discharges in the flow duration curve (Table 6.1*)*. It was assumed that the losses occur on all days of the month. It would be much more complicated to determine the effect on the flow duration curve if losses were taken for only a portion of the month. Comparisons of irrigation alternatives can be made by predicting the habitat area (WUA) for discharges in the flow duration curves for the reaches and months that are being evaluated (Table 6.2) and plotting these lines in conjunction with "natural flows" (Figure 6.1).

6.4 Results of Model Test

The STELLA models indicates the effects of direct withdrawals on habitat. The STELLA models, as currently configured, are thus potentially useful in predicting trends in baseflow losses for selecting conceptual water management strategies (*i.e*. eliminate direct withdrawals during low flow periods) that protect Atlantic salmon habitat. They have not been subjected to rigorous sensitivity testing and contain enough untested assumptions so that their best use should remain as a planning tool.

The natural-condition and direct withdrawal-habitat-discharge duration curves demonstrate how to interpret the effect of any given strategy (Figure 6.1). There is an approximate 1,000 WUA units difference between the two lines at the natural and predicted discharge at 50 % exceedence (Figure 6.1).[5] Another way to look at the effect of a scenario is to determine how exceedence changes. The amount of habitat available at 50 % exceedence under the direct withdrawal scenario would be similar to amount available at 80 % exceedence under natural flow conditions. This relates to the amount of flow naturally occurring only during a relatively “dry” July. In a typical year with no irrigation diversion, Atlantic salmon parr have at least 80,400 ft^2 of riffle habitat available for approximately 11 days. However, if irrigation at the level modeled had occurred, the same amount of habitat would have been available for only 5 days.

[5] The WUA value represents the square foot area of optimal parr riffle habitat per 1000 ft of river, to convert it into estimated area of optimal habitat affected, multiply by 3.9 thousand feet, the estimated linear extent of parr riffle habitat in the reach (Kleinschmidt Associates 1999a, Table 3). Thus, the WUA difference between the two lines is approximately 3,900 ft^2 of parr riffle habitat.

Both of the simulated irrigation scenarios had some effect on juvenile Atlantic salmon habitat in July relative to modeled natural conditions. The irrigation of existing acreage with direct withdrawals deviates most from natural conditions in July. The other alternative, irrigation of existing acreage with a well replacing the major direct withdrawal seems to affect habitat only at the lowest flows.

The STELLA model thus is considered to presently provide only an "order of magnitude accuracy." The model may not have the accuracy to distinguish among alternatives with differing combinations of wells and impoundments if those alternatives result in only fine differences in stream reach discharge estimates.

6.5 Additional Data and Future Modeling

6.5.1 Monitoring

The ultimate purpose of future watershed modeling is a better understanding of watershed hydrology, with specific emphasis on those reaches with juvenile and spawning habitat and those at most risk due to water use. The following are currently five areas where additional data are required:

- Streamflow
- Groundwater
- Water Use
- Watershed Characteristics
- Biological

Table 6.3 summarizes the recommended interval frequency for collection of each data type.

- Streamflow

Ideally, gathering of sufficient flow data occurs at the boundary of each reach to develop average daily flows that relate to the USGS gauge. This allows for the development of monthly and annual flow statistics. It is possible to collect data via automatic datalogging

gaging stations, or manually or mechanically recorded data from staff gauges located at pre-calibrated river cross-sections. The exact type of data collection methods and materials may vary among sites, and should be determined based on hydrology, location of habitat, location of water use, funding, logistics, and resources available. USGS-type gauges (*i.e.* automated, remote-reporting) are the most expensive; manually recorded staff gauges are the least expensive, but may incur higher labor costs to maintain and monitor. Site selection should occur in consultation with the resource agencies and growers.

Flow data should be collected so that real-time analyses are possible, and cause and effect flow, precipitation and withdrawal phenomena can be field checked if necessary. Automated stations can report data almost instantaneously. It is necessary to actively download and/or report data from non-automatic stations at intervals sufficient to allow for review and response. This should occur at least during times of year when flows and withdrawals are relatively dynamic and/or critical to Atlantic salmon (summer).

- <u>Groundwater</u>

Existing data are limited to describe groundwater level. Limited test well data are available for certain locations within the Pleasant and Narraguagus basin where agricultural interests have tested for pumping locations. These data may or may not include seasonal changes in groundwater levels under existing conditions. Additional years of data are required to develop a seasonal time series of groundwater levels for each hydrologic reach on the rivers to establish baseline water tables for wet, normal, and dry years. These data are required to provide a more extensive baseline of information on aquifers Downeast, because head differential and aquifer permeability drives the base flow portion of streamflow. In addition, it is possible to use ground water levels to monitor for changes due to withdrawals from wells. Future water use strategies include proposed removal of groundwater, with allowances for attenuation of decreases through distance and time, in a manner that does not materially affect stream flow. However, the actual impact (if measurable) is unknown, and verification is necessary as the scale of groundwater pumping increases.

Monitoring well sites should be located in consultation with the MGS and USGS to supplement the existing groundwater monitoring network. Changes in water table level are

relatively slow; therefore, real-time reporting of these data is not required, as there is considerable lag time in effects on stream flow. Data, however, should be accurate to calendar date, so that temporal responses to pumping operations allow for subsequent evaluation.

- Water Use

Current irrigation and future water consumption come from both instream and off-stream surface and groundwater sources. Consumers presently withdraw surface water from streams, and in some cases, ponds, via pumped withdrawal. Groundwater is presently also obtained through pumping from wells. Also, reservoir operations may or may not capture stream flow as a source. The amount of water consumed will vary annually, according to such factors as localized crop management, climate-induced need to irrigate, and individually deployed irrigation technology and practices.

Presently, volumes of water applied for "large-grower" irrigation is estimation from these growers. However, little data are available to estimate water use by small growers who collectively influence a relatively large percentage of acreage under cultivation. These data may not be quantitative enough to fully understand localized effects, and are required to both collect basic information, to refine the STELLA which is currently based on inferential estimates of flow, and required to better meet plan objectives[6].

It is advisable to gather withdrawal data systematically within each reach at each withdrawal site. Each water consumption data site should indicate type (surface, groundwater, reservoir, *etc*.) and hydraulic connectivity to stream. In many cases, it is possible to meter water removed from a source via the removal pump. In other cases, an in-line flow meter or other device may be necessary to measure and record flow. For purposes of plan and supporting model evaluation, it would also be desirable to have rapid access to data, so that cause-and-effect flow, precipitation and withdrawal phenomena can be field-checked if necessary to better understand river hydrology. Surface water withdrawal data, should be accurate enough to provide average daily consumption rates, so that temporal responses to withdrawal operations to

[6] In the context of permitting, this may be required to document permit compliance, as appropriate.

allow for subsequent evaluation. Withdrawals from other sources such as reservoirs or groundwater may be reportable at longer frequencies, such as weekly or even monthly. These should be determined in consultation with hydrologic staff from Maine GS and/or USGS.

- Watershed Characteristics

Changes in land use may affect run-off or recharge characteristics of watersheds, for example from forest cover to field, field to gravel mining, or field to parking lot. These rarely happen instantaneously. However, the RORA model accounts for run-off and recharge rates in each sub-basin based on quantitative factors associated with the acreage subject to each significant land type. Changes in land use should therefore be periodically reviewed to update and revise estimated units of land associated with each type of run-off characteristics as well as to track the demand for water use. Because land use changes are not as dynamic as flow and water use, the suggested up-date would occur every five years.

The basis for updates would be a review of available information. This includes aerial photography, GIS information, and input from organizations such as large landowners (*e.g.* agriculture and forestry interests), Soil and Water Conservation Districts, watershed councils and land use data maintained by individual towns. Those performing the updates would then enter the information into both a GIS database as well as tabulate it in a format compatible with WUMP models.

Confirmation of surficial geologic mapping of the watersheds is necessary and digitized for better estimates of recharge contributing to baseflow. Rather than the basis for the determination of baseflows, this, in conjunction with the measured streamflows throughout the watersheds, allows for investigation of the relationship of surficial materials to baseflow.

- Biological

The Maine Atlantic Salmon Commission (MASC) currently does annual biological monitoring of Atlantic salmon. Examples of monitoring include annual spawning success (redd counts), electrofishing for juveniles, and smolt trapping. Collection of water quality data is a part of this program. The purposes of this program include providing an annual index of relative

production of early life stages of Atlantic salmon. This index allows for better understanding of environmental life stage changes cues such as smolt emigration. In addition, documentation of the distribution and habitat use of salmon within each watershed is possible.

Although the scientific literature is replete with information showing that habitat-based flow regimes benefit riverine aquatic populations, it is not possible to assign a quantitative threshold index of fish abundance and flow levels. Because this is a qualitative relationship, biological monitoring data generally should not be used as thresholds, or as a direct barometer of plan success. Rather, review of these data allows for the detection of trends. For example, the MASC has observed that parr production tends to be best on cool, wet years relative to warm, dry years. Therefore, over time, fluctuations in early life stage abundance may be traceable to flow management strategies and/or fluctuation events. This would only be possible if data collection occurs concurrently with other monitoring initiatives.

Other more direct and measurable flow related impacts, such as dewatering of spawning redds during the late fall through early spring incubation period can be recorded as part of biological monitoring. Redd loss directly translates to measurable year-class loss. Although not currently a summer low-flow concern, future groundwater withdrawals and/or reservoir operation could potentially influence fall and winter flows, and thus require such assessment.

6.6 Information Access

Database information generated by monitoring should be made easily accessible. Stream flow and withdrawal data should be made available to designated agencies and organizations as soon as possible, following appropriate Quality Control review and approval. In some cases, “provisional” data can be made available for short-term reference. Distribution of this information can be made via internet, email, as well as published hard copy to designated recipients

Other forms of less volatile data can be available annually. One possible vehicle would be an annual report with the responsible organization also hosting summary data via electronic medium, such as the Internet. A technical group comprised of a cross-section of water use disciplines and interests should review a draft annual report before finalization.

This group would also convene biannually to:

1. Review new data relative to the conceptual understanding of available habitat and potential water use impacts
2. Make revisions as needed, and
3. Circulate results to all stakeholders and the public.

At five-year intervals, the group would inform the LWRC on WUMP status, and recommend appropriate changes based on applicable new information.

Table 6.1 July streamflow (CFS) exceedence values for natural conditions and for two irrigation scenarios in Reach 4 of the Pleasant River. STELLA-modeled cumulative baseflow losses are subtracted from discharge.

Modeled loss (CFS)		13.50	1.60
% Exceedence	Natural	100% existing acreage direct withdrawal	100% existing acreage well replacing direct withdrawal
	CFS	CFS	CFS
1	294	281	292
5	177	164	175
10	122	109	120
15	99	86	97
20	83	70	81
25	72	59	70
30	65	52	63
35	59	46	57
40	54	41	52
45	51	38	49
50	48	35	46
55	45	32	43
60	42	29	40
65	39	26	37
70	37	24	35
75	35	22	33
80	32	19	30
85	29	16	27
90	27	14	25
95	23	10	21
99	18	5	16

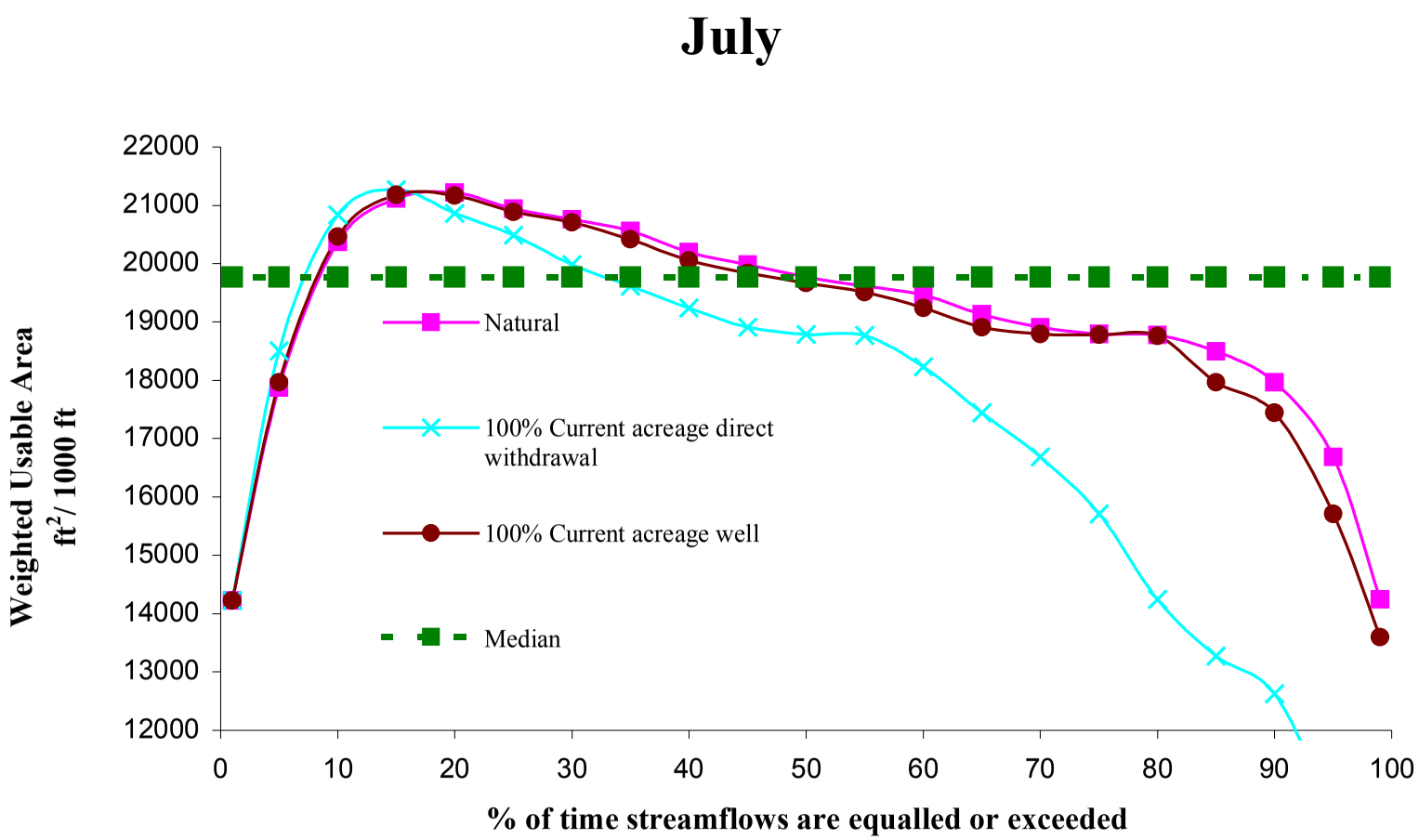
Table 6.2 Parr habitat (WUA) predicted with baseflow losses modeled for July for natural flows and two irrigation scenarios in Reach 4 of the Pleasant River. Habitat is predicted using look up tables.

% Exceedence	Natural	100% existing acreage direct withdrawal	100% existing acreage well replacing direct withdrawal
	WUA	WUA	WUA
1	14222	14222	14222
5	17875	18503	17965
10	20372	20837	20463
15	21117	21269	21179
20	21218	20860	21167
25	20937	20487	20886
30	20758	19984	20707
35	20559	19615	20415
40	20199	19241	20056
45	19984	18910	19841
50	19769	18787	19667
55	19615	18767	19513
60	19461	18233	19241
65	19130	17441	18910
70	18910	16687	18793
75	18793	15708	18780
80	18774	14240	18761
85	18497	13273	17969
90	17969	12629	17441
95	16687	10598	15708
99	14240		13596

Table 6.3 Water assessment and research

Category	Reportable Time Series	Monitoring Duration	Reporting intervals
Streamflow	Hourly & daily averages	Mixture of Year Round and Seasonal	Hourly (USGS); Weekly (other), & Annual
Groundwater	monthly	year round	Annual
Water Use	average daily	seasonal as applicable	Weekly or Monthly (as applicable) Seasonal Summary
Land Use	5 Years	N/A	5 Years
Surficial Geology	Once	N/A	Revised as new data available
Biological	annual	seasonal as applicable	annual

Figure 6.1 July habitat-streamflow duration curves for Reach 4 natural conditions and two irrigation scenarios based on calculations in Tables 6.1 and 6.2.



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7.0 DEVELOPMENT OF WATER SOURCES AND PERMITTING REQUIREMENTS

7.1 Introduction

The Downeast Salmon Rivers Water Use Management Plan requires an understanding and development of a process for access and use of water in the watersheds. Although recognizing that the primary users of water withdrawal is currently for agricultural purposes, there are other potential users of water such as processors, mills, and other entities for which this chapter may apply. Given the increasing demand for water and concerns about potential adverse impacts to natural resources, including Atlantic salmon habitat, a plan for better timing of access and reduction in direct withdrawals from rivers seems prudent. The following regulatory processes are important when considering improving water access and building off-stream impoundments that protect the rivers.

7.2 Regulatory Oversight of Water Use in the Salmon River Watersheds

7.2.1 Agencies Having Jurisdiction

The following agencies have jurisdiction over various water resources and review the permitting requirements for new impoundments, well, water withdrawals from rivers, streams, brooks, ponds and lakes:

- Department of Environmental Protection (DEP) - Natural Resources Protection Act 38 MRSA Chapter 3
- Land Use Regulation Commission (LURC) – 12 MRSA Sec. 681 et seq. Land Use Regulation, and Chapter 10 of the Commission's Land Use Districts and Standards
- Maine Department of Inland Fisheries and Wildlife (MDIF&W) - Essential Wildlife Habitat, Fishway Law (12 MRSA Part 10, Chapter 713, Subchapter III Sec. 7701-6602)
- Army Corps of Engineers (ACOE) - Clean Water Act Section 404

- US Fish & Wildlife Service (USFWS) – Endangered Species Act

- National Marine Fisheries Service (NMFS) – Magneson-Stevens Fishery Conservation and Management Act as amended by the Sustainable Fisheries Act of 1996 for protection of Essential Fisheries Habitat (EFH)

  The Essential Fisheries Habitat (EFH) provisions require that federal agencies planning to permit, fund, or undertake an activity in designated EFH zones must determine if the proposed activity is likely to result in adverse impacts to EFH. If adverse impacts are likely, the federal agency must consult with NMFS. NMFS would then issue conservation recommendations aimed at minimizing and mitigating the impacts to EFH. The federal agency would have to adopt the conservation recommendations or state in writing why any of the recommendations were not adopted.

7.3 Types of Water Sources and Regulatory Oversight

7.3.1 Wells

Wells in high yielding aquifers on the barrens have potential in limited situations where yield, location and storage capacity are sufficient to meet the water demand. Currently blueberry companies are exploring for well placement in locations where the wild blueberry fields may not have access to water, or where continued use of existing surface water sources is problematic.

In LURC jurisdiction, commercial development of irrigation wells and water withdrawal from wells requires a permit. In DEP jurisdiction, no permits are required for development of wells unless the construction of the well occurs in a wetland or within 100 feet of a water body. The Army Corps of Engineers does not regulate well development unless construction of the well is in a wetland.

7.3.2 Constructed Ponds

Constructed ponds are a potential source of water in locations where wetland kettleholes are present as well as where uplands converge with wetlands. In LURC jurisdiction, constructed ponds are a regulated activity regardless of

whether built in an upland or wetland. If built in an upland location, a permit may not be required if standards are met. If built in a wetland, the ACOE also regulates the activity. In DEP jurisdiction, agricultural ponds in freshwater wetlands are exempt although constructed ponds in rivers, streams or brooks require a permit. Earthwork within 100 feet of a waterbody also requires a permit. ACOE, under federal wetland regulations, also regulates most constructed ponds if construction of the pond is in a waterway or wetland. The only exception would be a pond dug by equipment operating from an upland, with the excavated material deposited in an upland location away from a wetland or waterway. Ponds constructed in an upland location with no other waterway or wetland impact do not require ACOE permitting.

7.3.3 Impoundments on Streams

Past development of impoundments occurred in locations throughout the Barrens. LURC, DEP and the ACOE regulate impoundments of any kind. In addition, the Maine Department of Inland Fisheries and Wildlife regulates dams and may require fish passage under the Fishway Law.

7.3.4 Direct Withdrawals from Surface Water Sources

Whether from rivers, streams, brooks, great ponds, or other natural or constructed ponds, most farmers use surface water for irrigation. LURC regulates direct withdrawals in unorganized areas. In organized areas, DEP has limited regulatory authority. DEP regulates permanent intakes or doing earthwork to get access. At the time of writing this plan, direct withdrawal does not require permitting, but enforcement of total de-watering requires review under 38 MRSA section 480-C.

7.4 Identification of Key Elements for a Permitting Process

The most efficient process is one that takes into consideration the need to coordinate with State and Federal permitting agencies before making substantial time or

financial commitments for developing irrigation projects. Probably the most crucial step an applicant take to streamline the permitting process is to develop and convey a clear understanding of the purpose and scope of the project and to complete an alternatives analysis. The applicant should then schedule a pre-application meeting and site visit with the appropriate agencies. At such a meeting one can obtain the appropriate application forms, discuss essential permitting criteria, and review site issues. Up-front site visits and study of the site will also help minimize review and processing time related to the permit application.

7.4.1 Generalized Process Yielding Expedient Results

Develop Project Purpose Statement

The ACOE would prefer to see a specific volume need. Thus, it is recommending preparation of a whole site irrigation plan including the amounts to be used currently and in the future, defined and estimated amount of need, and timing of the need for water. In this way, they can assess potential impacts cumulatively rather than in a piecemeal fashion.

Prepare Farm Irrigation Plan

The type of information required includes:

- The location and acreage of all areas of all crops to be irrigated
- The start and end dates of the irrigation season
- The anticipated number, timing and frequency of applications of irrigation water
- Duration of pumping for each application, pumping rates, and total anticipated withdrawal volume of water at the pump site
- Implementation of water management practices to minimize the amount of irrigation water used for the target acreage
- All potential sources of irrigation water, including other potential sources

Alternative Sources Analysis

The applicant must evaluate a range of options as detailed in chapter 6 and provide a rationale for why they cannot avoid or minimize an impact to the flow and reach of waterways, wetlands or other impacts to aquatic resources. An applicant should obtain interagency consensus on the scope of analysis for alternatives and the area within which the search shall occur. Typically, an alternatives analysis should include, but not be limited to, a discussion of the practicability of the following options, or combinations of options that will work or will not work for the applicant:

Avoidance Alternatives

- No Build

  Discussion of economic and other implications of the no build or no irrigation alternative is necessary. Will the grower lose income, close business, or will the fields fail to produce an economically viable crop if irrigation does not occur? What will these impacts be on the local and regional economy?

- Wells

  Wells are a viable option in certain locations, but not in others. If they are not an option, the applicant must have physical evidence that wells are not available, practicable, and/or their yield would not be enough to meet demand with or without supplements. In addition, an applicant must show that wells would have greater environmental impact than the wetland/waterway in consideration. The use of economics as an argument against practicability is an option, but a cost analysis is necessary. In addition, in order for the federal government to dismiss this as an alternative, it is necessary to show that the well would have greater adverse impacts than direct river withdrawal.

- Upland Impoundments

  The applicant must demonstrate that these sites are not available or practicable or that they are more environmentally damaging. The use of economics as an

argument against practicability is an option, but a cost analysis is necessary.

- Pipes in streams

  The applicant must demonstrate that this alternative is not available or that it is more environmentally damaging, or that is not practicable (does not provide sufficient yields with or without supplements). Dismissal of this alternative will occur only if there is evidence that low flow periods or limits on low flow would not yield enough water. USF&W can assist in establishing a drawdown limit to protect the streams from salmon habitat impact.

Minimization Assessment

If the potential for wetlands or waterways impacts exist, a minimization assessment is required. This assessment may include, but is not limited to, development of multiple, smaller reservoirs, placement of reservoirs at the wetland/upland edge rather than entirely in the wetland, and combining sources (e.g. wells with stream drawdowns to minimize the size of ponds).

Site Visit

All jurisdictional, regulatory agencies should attend to establish constraints and data requirements for permitting.

Desktop Topographical and Site Field Survey

This activity must include wetland delineation and, if applicable, functional assessment.

Pre-impoundment stream characterization (recommended but not required)

The applicant should provide an analysis of waterway for water quality information such as pH, temperature, and present flow as well as identification of existing fisheries, wildlife and aquatic resources. Use all available data.

Develop Engineering Design Plans

Plans should include sections and outlet structure design, based on calculated storm flows, soil and erosion control plan, instream flow maintenance plan for a pond or impoundment. Also, develop plans for fuel storage facilities, if applicable.

Develop Mitigation Plan for Unavoidable Wetland Impact

Applicants should note that mitigation might be a very large element of the overall cost of the project. At the Federal level, it is unlikely that mitigation will simply take the form of purchasing and preserving land. More than likely wetland restoration, creation or enhancement will be required. Applicants should consider mitigation costs when analyzing alternatives. For example, it may, in fact, be economically practicable to develop an upland pond compared to the cost of developing a wetland pond that would require identifying and implementing appropriate mitigation, and then monitoring the mitigation for a 5-year period. Mitigation planning also takes considerable time, which may lengthen permit processing times. Applicants should coordinate with State and Federal Agencies early in the mitigation planning process to avoid investing resources in mitigation projects that might be unacceptable.

Submit Application

Applicant should refer to the individual applications requirements for additional information needed to process the application.

7.4.2 Follow Up

After submittal, State and Federal Agencies will review the permit application for completeness. Regulator may contact applicants for additional

information and applicants may revise the permit application based on comments. Public notice of the application submittal also allows for review by other interested parties. Agencies may hold a public hearing if comments and public feedback indicates a need. Generally, after receipt of the final submittal, regulators make a permit decision within 30-90 days. It is important to note that anyone can appeal a permit decision.

7.5 Important Screening Criteria for Locating Potentially Suitable Sites

The applicant should consult with DEP, LURC, and the ACOE regarding criteria for permit or license approval. The following list of criteria were developed to assist the applicant in screening potential sites for their suitability for development of water impoundments in streams or wetlands and thus aid in the permitting process.

Table 7.1 Screening Criteria for Site Location.

Criteria	Description
A.	Project is not located in/adjacent to significant habitat for fish. (Fish spawning or nursery habitat, habitat required for migration of fish species, or habitat otherwise supporting a moderate or high population of salmonid species as determined by the Atlantic Salmon Commission, USFWS, and/or the Maine Department of Inland Fisheries and Wildlife)
B.	Project cannot be located in a wetland containing endangered or threatened plant species or containing a natural community that is imperiled (S2) or critically imperiled (S1) as defined by the Natural Areas Program (5 MRSA section 13076).
C.	Amount of flooding impact on adjacent upland/wetland is a criterion for section. Minimizing wetland impact is critical.
D.	When constructed, the proposed site impoundment must be able to store sufficient water to pass a minimum flow equal to inflow or site specific calculated ABF, whichever is less, at all times
E.	Water Quality Classification: The impoundment must be located in a water course that is NOT a Class AA river or stream.
F.	Zoning Issues in LURC Territory - Review LURC zoning regulations to determine if the zone allows such an activity.
G.	Cultural Heritage Resource Evaluation - Assure that no possible historical sites of significance are located in the area to be developed.

8.0 RECOMMENDATIONS

This Management Plan divides recommendations into two sections. Section 8.1 details Recommendations for Action which should be taken by the State of Maine, Federal agencies, and the companies that are using water resources within one of the three watersheds covered by this Plan (e.g., Pleasant & Narraguagus Rivers and Mopang Stream). Recommendations for Further Research and Analysis that require further discussion and analysis are detailed in Section 8.2.

The Plan assigns the following priority ratings to each recommendation to assist in Plan implementation:

- **Essential** to wise water use management
- **Very important** that action be taken
- **Important** that action be taken

8.1 Recommendations for Action

8.1.1 Water Monitoring

8.1.1.1 Maintain USGS Gauge on the Narraguagus River

Priority: Essential

Streamflow data have been collected for the Narraguagus River from 1948 to the present (2000) at the U.S. Geological Survey (USGS) streamgaging station at Cherryfield. This gauge provides accurate, reliable, and readily accessible streamflow information. Ongoing financial and technical support to operate the gauge is essential.

Lead --	U.S. Geological Survey
Partners --	Maine Department of Defense,Veterans Affairs, Emergency Management (River Flow Advisory Commission – in State statute)
Estimated Budget --	$10,000 per year ($5,000 Federal and $5,000 State)
Time frames --	Ongoing

8.1.1.2 Make Long-term Commitment to Support Gauges on the Pleasant & Machias Rivers

Priority: Essential

Thoughtful management of water resources in the Pleasant and Machias Rivers requires the input from an ongoing monitoring program. In 2000, a gauge was installed on the Pleasant River, while no such guage exists on the Machias River. Accessible, up-to-date streamflow information helps regulators and others ensure that minimum flow permit requirements are met. The Federal – State Agreement with the State's River Flow Advisory Commission should be amended accordingly. In addition, the Atlantic Salmon Commission should become a member.

Lead--	U.S. Geological Survey
Partners--	Maine Department of Defense, Veterans Affairs, and Emergency Management (River Flow Advisory Commission – in State statue)

Estimated Budget/River--	Operation and maintenance/year ($5,000 Federal and $5,000 non-federal) for both rivers, plus $30,000 to establish a gauge on the Machias ($15,000 Federal and State $15,000)
Time frames-–	Ongoing

8.1.1.3 Develop Effective Flow Monitoring Strategy

Priority: Essential

Monitoring and reporting river discharge throughout each watershed is critical input to wise management of the water resources. An effective flow monitoring strategy contains at least the following elements:

- River specific monitoring plan – In addition to USGS gauges at the base of each watershed, discharge data is necessary at different points along the rivers. These data might be related to water use practices; i.e. for the period when fields are irrigated, or to salmon behaviors; i.e. spawning and smolt migration periods. Developing a better understanding of basin hydrology, as it relates to salmon habitat, will be the basis of these points along the rivers.

- Standard methods for data collection - These will be based on the type of gauge: permanent, seasonal, discrete (single measurement) and will include a QA/QC plan to assure that quality data are being collected and reported.

- An integrated data management system - Monitoring data will need to be compiled such that common databases, with appropriate metadata, are available.

- Reporting system - The data collected need to be available to the partners and the public in a timely manner. This might include a web page and an e-mail list server.

MGS/USGS will consult with the resource agencies and industry in determining monitoring needs. This allows for development of a strategy that identifies responsible parties, how the monitoring system is funded, and how data are presented.

Lead--	Maine Geological Survey
Partners--	Water users; USGS, USFWS; MDIF&W; DEP; LURC; ASC; Watershed Councils
Estimated Budget--	Performed with existing resources
Time frame--	Submit monitoring strategy to Land and Water Resource Council by April, 2001

8.1.1.4 Continue Support for Low Flow Study

Priority: Essential

The Maine Geological Survey and the U.S. Geological Survey are conducting a 5-year study of low-flow conditions on eastern Maine rivers in order to support water management planning and the permitting of water withdrawals. With the assistance of stakeholders, 27 partial-record sites were selected in 1999 for low-flow measurements. In the summer of 2000 low-flow measurements were made twice at each site. Over the following summers a total of 10 measurements will be made at each site during independent low-flow periods. These data will be used to develop regression equations to estimate low-flow statistics at any ungauged, unregulated site in eastern Maine by calculating topographic, climatic, and geologic characteristics.

Lead--	Maine Geological Survey
Partners--	USGS and L&WRC
Estimated Budget--	$56,000/year (contains 50-50 cost share with USGS)
Time frame –	Report completed by 2004

8.1.2 Water Management

8.1.2.1 Support Commission Salmon Habitat Impact Assessments

Priority: Important

Plan implementation will require periodic analysis of hydrology, Atlantic salmon habitat, irrigation strategies, and water demands as irrigation strategies evolve. The Commission should convene a group to assist in these analyses and make recommendations to the Commission.

Lead--	Atlantic Salmon Commission
Partners--	USGS; USFWS; DIF&W; DEP; LURC; Wild Blueberry Industry; Watershed Councils; conservation organizations
Estimated Budget--	Within existing resources
Time frame--	Throughout the year as required

8.1.2.2 Integrate Water Sources Hierarchy as a Guideline into State Policies

Priority: Essential

Irrigation strategies in the Pleasant and Narraguagus Rivers and the Mopang Stream lend themselves to establishing a hierarchy ranging from least likely to impact salmon habitat to most likely. The Land and Water

Resources Council should request the appropriate agencies to develop a coordinated strategy to integrate hierarchy guidelines into state permitting, funding, educational and technical assistance programs.

Lead--	Land and Water Resources Council
Partners--	Agricultural community; conservation organizations; & federal agencies
Estimated Budget--	Strategy can be developed within existing resources
Time frame--	Report back to the L&WRC completed by September 2001

8.1.2.3 Promote Sound Water Management

Priority: Essential

Water conservation is a priority and is achievable through water management planning, proper design and construction of irrigation systems, alternative water sources, and management of irrigation systems. This approach must be supported by both technical and financial assistance to growers and include:

- Technical Assistance to Farmers -To ensure water resources are used as efficiently as possible, growers need technical assistance to develop and implement farm management plans and other best management practices (BMPs) for water management. These should include design of irrigation systems, sources, and storage options. Substantial material on these "practices" exists. These need to be complied and made available to growers. Integration of these farm and irrigation practices into technical assistance and financial incentives is necessary.

- Cost Share Assistance- Cost share programs should be created to assist growers develop water sources that minimize impacts on Atlantic Salmon habitat

As an initial step the L&WRC should request the Department of Agriculture to develop an implementation strategy that defines the programs described above as well as the funding sources. The Department should involve other agencies and organizations to ensure the strategy is widely supported.

Lead--	Maine Department of Agriculture, Food and Rural Resources
Partners--	Washington County Soil and Water Conservation District; Farmers, USDA Natural Resources Conservation Service; University of Maine Cooperative Extension; Maine Atlantic Salmon Commission, DEP, LURC, SPO, National fish and Wildlife Foundation.
Estimated Budget--	TA Programs -- $750,000 ($150,000/yr will support 2-people for 5 years)
	Cost Share Programs – Phase I, $4.5 million (state, federal and non-government funds)
Time frame--	DOA implementation strategy by September 2001 with concentrated TA effort between 2001-2007. Cost share for implementing water management efforts 2001-2003

8.1.2.4 Amend State Permitting Programs

Priority: Essential

The State Departments of Environmental Protection and Conservation should jointly develop, in consultation with others, a consistent approach to protecting Atlantic salmon habitat, as it relates to water withdrawals in the three river basins. The agencies should report to the Land and Water Resource Council by June 2001 and thereafter on their progress.

Lead--	Departments of Environment Protection and Conservation
Partners --	ASC; DIF&W; Wild Blueberry Industry and Federal agencies
Estimated Budget --	Can be developed within existing resources
Time frame--	DEP/DOC report to L&WRC October, 2001

8.2 Recommendations of Further Research and Analysis

8.2.1 Water Use Management

8.2.1.1 Assess Impact of Withdrawals During High Flows on Migratory Life Stages

Priority: Important

The 1998-99 Instream Flow Incremental Methodology (IFIM) study focused on the stream resident life stages of Atlantic salmon. However, there are migratory life stages that rely on natural hydrologic events to motivate and facilitate migration. The effects of water withdrawals on these life stages (*e.g.,* smolt emigration, adult immigration, etc.) are important. They require that models be developed to assess changes in hydrology resulting from proposed water withdrawals during high discharge (e.g. filling impoundments, groundwater recharge, cranberry bogs, frost protection). Integration of these models and the IFIM data for assessment purposes is recommended.

Task # 1 -- Develop models of smolt transport and discharge

There are published data in peer reviewed scientific journals on the many aspects and triggers of smolt migration. There is ongoing research in Maine whereby migrating smolts are live-trapped to determine overwinter survival of large parr as part of a large-scale juvenile salmon

production model. Literature search and project summaries from the Maine study will form the basis for understanding the relationship between flow and smolt migration.

Lead--	Atlantic Salmon Commission
Partners--	NMFS; MDIF&W; USGS; USFWS
Estimated Budget--	Within existing resources
Time Frame--	March, 2002

Task #2 -- Develop models of adult upstream movement and discharge

There are published data in peer reviewed scientific journals on the many aspects and triggers of adult upstream movements. The Atlantic Salmon Commission has adult enumeration data on a number of Maine rivers. A literature search and correlation of trap catches with flow from Maine will form the basis for understanding the relationship between flow and adult upstream migration.

Lead--	Atlantic Salmon Commission
Partner--	NMFS; MDIF&W; USGS; USFWS
Estimated Budget--	Within existing resources
Time Frame--	March, 2002

Task #3 -- Evaluate the effects of water withdrawals at high discharges on Atlantic salmon migration

The effects of the predicted changes in hydrology on salmon movement need to be assessed to assure that freshwater portions of the salmon's life cycle are not disrupted because migration is delayed or blocked.

Lead --	Maine Atlantic Salmon Commission
Partners --	USGS; USFWS; MDIF&W; DEP; LURC; Wild Blueberry Industry; Watershed Councils; conservation organizations
Estimated Budget--	Within existing resources
Time frame --	Ongoing

8.2.2 Irrigation Efficiency and Conservation

8.2.2.1 Research Wild Blueberry Plant Water Requirements

Priority: Important

While the industry has conducted some research regarding the water requirements of low bush blueberries there is limited peer reviewed, published literature. This lack of data impedes precise water management decisions. The companies are conducting research on this topic through the University of Maine.

Lead --	University of Maine
Partners --	Wild Blueberry industry
Estimated Budget --	$550,000 (funding is planned for from federal and private sources)
Time frames --	Research began in 2000 with goal to complete research and publish in peer-reviewed journal by 2007.

8.2.2.2 Research Farm Practices to Further Reduce Water Use

Priority: Very Important

The wild blueberry industry, in coordination with academia and irrigation equipment manufacturers, should assess farm practices,

including irrigation technologies, to allow for further reduction in water use. Small growers should receive this information

Lead --	Wild Blueberry Industry
Partners --	University of Maine; Natural Resources Conservation Service; Maine Department of Agriculture; Washington County Soil & Water Conservation District
Estimated Budget --	$20,000
Time frames --	Complete research and produce report 2002

Figure 8.1 Summary of Recommendations

Actions

Title	**Priority**
Maintain USGS gauge on the Narraguagus River	Essential
Make long-term commitment and fund gauge on the Pleasant & Machias Rivers	Essential
Implement effective flow monitoring strategy	Essential
Continue support for low flow study	Essential
Support Commission salmon habitat impact assessments	Important
Integrate water withdrawal hierarchy into state policies	Essential
Provide water management TA to farmers	Essential
Amend state permitting programs	Essential

Further Research and Analysis

Title	**Priority**
Assess impact of withdrawals during high flows • Develop models of smolt transport and discharge • Develop models of adult upstream movement and discharge • Evaluate effects of water withdrawals at high discharges	Important
Research wild blueberry plant water requirements	Important
Research farm practices to further reduce water use	Very important

TECHNICAL APPENDICES