

STREAMFLOW DEPLETION METHODOLOGY

**RI DEPARTMENT OF ENVIRONMENTAL MANAGEMENT
OFFICE OF WATER RESOURCES
DRAFT
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STREAMFLOW DEPLETION METHODOLOGY

I. PURPOSE

The Rhode Island Streamflow Depletion Methodology (SDM) establishes the volume of water that can be extracted from a stream (whether as direct stream withdrawals or indirect groundwater withdrawals) while still leaving sufficient flow to maintain habitat conditions essential to a healthy aquatic ecosystem. The methodology maintains natural variations of streamflow and considers ecological sensitivity of each resource. It also incorporates the concept of balancing human and ecological needs for water by differentiating the degree of allowable depletions according to watershed characteristics and current human influences. This methodology will help quantify the amount of water that may be available for human uses by defining the degree to which streamflow may be altered and continue to sustain environmental resources.

II. BACKGROUND

Natural stream flow is primarily affected by rainfall and runoff along with water recharged from groundwater as either interflow (precipitation that percolates into the ground and flows rapidly through shallow layers to streams in a matter of hours or days) or base flow (precipitation that recharges groundwater and then discharges to streams during all times of the year). It is widely understood that groundwater and surface waters are closely linked, and that in many cases, there is a 1:1 relationship between groundwater withdrawals from unconfined aquifers (found in Rhode Island) and reductions in streamflow. Thus, as watersheds are developed and forests and fields are converted to impervious surfaces, and surface and ground waters are tapped for water supply, alterations in natural stream flow occur.

Determining the amount of water that can be diverted from streams before impacts to aquatic ecosystems occur is a growing area of research nationally. Given the dynamic nature of streamflow and the diversity of aquatic life forms dependent upon flowing stream systems, there are many facets to be taken into consideration. A growing body of research supports the concept that managed flow regimes should consider the natural hydrological variability of river systems, both seasonally and inter-annually to maintain ecological integrity. The concept known as the natural flow paradigm considers the timing, duration, frequency, and rate of change in river flows over the course of the year and from year to year (Poff, et.al, 1997).

Past efforts by RIDEM and others to establish streamflow standards have focused on determining the minimum and alternatively optimum flows necessary to support aquatic life. Towards that end, RIDEM working with a committee modified the Aquatic Base Flow methodology developed by US Fish and Wildlife utilizing gauged stream flow data measured at selected Rhode Island and MA and CT rivers. The modified methodology known as the RI-ABF methodology establishes acceptable instream flow values presumed to be protective of aquatic life (RIDEM, 2005). In recognition of the natural flow paradigm concepts, the RIABF methodology establishes monthly flow values. The methodology is readily applicable to surface diversions (direct withdrawals and reservoirs and impoundments) that can be adjusted to

accommodate the need for increased flow to maintain the established ABF instantaneous flow rates. However, application of RI-ABF to groundwater diversions is more difficult given that they affect base flow over long periods and cannot be tailored to provide different base flows at different times of the year.

To address the shortfalls of the instream flow approach, RIDEM has worked to develop the Streamflow Depletion Methodology, which establishes the volume of water that can be extracted from the stream (whether as direct stream withdrawals or indirect groundwater withdrawals) while still leaving sufficient flow to maintain habitat conditions essential to a healthy aquatic ecosystem. The methodology draws upon research conducted by USGS studying fish assemblage response to water withdrawals from streams and instream reservoirs (Freeman and Marcinek, 2006), and data collected by RIDEM's Division of Fish and Wildlife. The Freeman and Marcinek study found that streams in their study area (lower Piedmont) to experience species losses if permitted withdrawal exceeds about one-half to one 7Q10 equivalent of water.

III. APPLICABILITY

This methodology may be applied to all new or increased water diversions, and may also be used in conjunction with the RI Water Resources Board's allocation process for new and existing withdrawals. New water diversion projects that include any single withdrawal or withdrawals in combination that divert greater than 10,000 gallons per day (GPD) should consult the Department for permit application guidance. New projects are evaluated by applying the SDM to the stream(s) nearest to the withdrawal and at the watershed level. In its simplest application, the withdrawal volume may be assumed to equal streamflow depletion. However, on a case-by-case basis, the effective depletion may actually be determined to be less than the withdrawal volume when taking into consideration site-specific conditions like backwater effects from impoundments, distance of wells from the stream, and/or immediate return flows. In other words, in these cases, the amount of water that may be withdrawn is actually greater than the calculated allowable streamflow depletion.

In reviewing groundwater withdrawal permit applications, DEM compares the existing streamflow depletion (taking into consideration withdrawals, return flows and other site specific conditions) to the calculated allowable streamflow depletion and a "net available streamflow depletion" is calculated. This can be a positive or negative number. If there is enough remaining capacity in the "net available streamflow depletion" to accommodate the proposed withdrawal, the permit application is then evaluated for any freshwater wetland alterations. If the request meets the streamflow depletion and wetlands review criteria, it is presumed to meet the applicable water quality and freshwater wetlands regulations.

The method alone does **not** specifically quantify the amount of water available for use at a given site or in a given watershed. It quantifies the allowable net depletion effect that the water withdrawal(s) can have on the stream. The effect of the withdrawal on streamflow depletion and thus determination of whether the proposed withdrawal meets the allowable streamflow depletion per the SDM, can be determined in at least 3 ways:

- 1) 1:1 Assumption: Withdrawals and returns in the watershed are calculated from the best available data and are assumed to equal depletion in the stream.
- 2) Jenkins-Barlow equation: The Jenkins-Barlow equation accounts for groundwater storage and interception. Applying this equation may reduce the depletion effects of the groundwater withdrawal on the stream of.
- 3) Surface or Groundwater Models: With this option, a model such as the HSPF or MODFLOW models is applied to the watershed and streamflow depletion is determined as one of the model outputs. With most of these models, adjustments can be made to consider monthly pumping scenarios, distance of wells from the stream, land use (imperviousness), and movement of water in and out of storage. As of this date (March, 2009), USGS has completed HSPF modeling in the Blackstone River and Pawcatuck River watersheds, and MODFLOW modeling in the Hunt, Annaquatucket and Pettaquamscutt watersheds, and portions of the Pawcatuck River watershed.

Absent site-specific studies, the SDM represents a useful tool for guiding water resources management efforts. It is important to note that in the case of watersheds where there are impoundments (surface water supply reservoirs and other run of the river ponds) or wastewater discharges, allowable streamflow depletion will need to be evaluated independently of the Streamflow Depletion Methodology. More specifically, allowable depletion from water supply reservoirs will utilize Safe Yield Analyses done consistent with WRB's Water Supply System Management Planning Regulations.

IV. DEFINITIONS

Bioperiod - the period (month or groups of months) during which certain biological processes dependent on stream flow rates occurs or is likely to occur.

Hydroperiod – the grouping of months having similar streamflows in a hydrograph representing natural (unaltered) flow conditions.

Department – the Rhode Island Department of Environmental Management

7Q10 - the lowest 7-consecutive day average flow that occurs (on average) once every 10 years.

Diversion - any activity which causes, allows or results in the withdrawal from or the alteration, modification or diminution of the surface or ground water flow to or from waters of the state.

Median Flow - the daily stream flow that is equaled or exceeded on fifty percent of days in a period of record calculated using methods developed by the U.S. Geological Survey or otherwise acceptable to the Director.

Unit Watershed - The smallest hydrologic unit boundary or catchment determinable from available elevation data that defines the extent of surface water drainage to a specified point. Readily available catchment delineations from the National Hydrography Dataset - NHD Plus were used in this application.

Modified HUC 12 Watershed - A modification of the federally accepted USGS 12-digit hydrologic unit code watershed boundaries adjusted to incorporate the groundwater aquifers and water use data as defined in the “Water Use and Availability Studies”.

Natural 7Q10 - The expected lowest 7 consecutive day average flow that would occur (on average) once every 10 years assuming little to no human effect on flows.

Net Streamflow Depletion- the quantity of water over a measured period of time that is diverted from a stream after accounting for all watershed withdrawals and return flows from the surface water or groundwater.

Managed Impoundments - a created body of water resulting from a dam, dike, reservoir, or other structure, constructed to seize and hold water by effectively blocking the flow of a watercourse. Impoundments shall include, but are not limited to, structures used for water supply, small retaining walls constructed for the sole purpose of keeping diversion pipes or structures submerged or dry flood control dams, but shall include all other combined impoundment-diversion structures. Managed impoundments do not include run-of-the river dams.

RI-ABF - RI specific modifications to the US Fish and Wildlife Aquatic Base Flow (ABF) methodology to better represent the climate and streamflow conditions found in Rhode Island

USGS – United States Geological Survey

V. LEGAL AUTHORITY

The Department regulates projects involving water diversions through two existing laws and associated regulations: the Water Pollution Control Act and Water Quality Regulations, and the Freshwater Wetlands Act and Freshwater Wetlands Rules and Regulations. Relevant excerpts of both the Water Quality Regulations and Freshwater Wetlands Rules and Regulations are provided in Appendix I. A brief discussion of these statutes and regulations is provided below.

Authorized by the Water Pollution Control Act (RI General Law Chapter 46-12), the state’s Water Quality Regulations (RIDEM, 2009) establish the framework for protecting all surface waters in order to meet the general purpose of the federal Clean Water Act, i.e. restore, preserve and enhance the physical, chemical and biological integrity of the waters of the state. The regulations recognize that adequate water quantity is integral to water quality. More specifically, the regulations’ stated purpose is that “...water quality standards should, whenever attainable, provide water quality, including quantity, for the protection and propagation of fish, shellfish and wildlife and for recreation in and on the water.”

The Freshwater Wetland Rules and Regulations (RIDEM, 2009) authorized by the state's Freshwater Wetlands Act (RI General Law Chapter 2-1-18 et seq) are promulgated to preserve, protect and restore the purity and integrity of all freshwater wetlands in the state of Rhode Island so that these wetlands shall be available for all beneficial purposes, and thus protect the health, welfare and general well being of the people and the environment of Rhode Island.

Water diversion permit applications are reviewed and evaluated based on these regulations. The Streamflow Depletion Methodology may be used as a tool to assist applicants and the Department when evaluating the potential for adverse impacts on aquatic resources from water withdrawals/diversions. Since the methodology is primarily focused on streamflow related impacts, localized impacts to nearby vegetated wetlands are evaluated separately.

VI. OVERVIEW OF THE STREAMFLOW DEPLETION METHODOLOGY

The Rhode Island Streamflow Depletion Methodology (SDM) establishes the volume of water that can be extracted from a stream (whether as direct stream withdrawals or indirect groundwater withdrawals) while still leaving sufficient flow to maintain habitat conditions essential to a healthy aquatic ecosystem. The methodology maintains natural variations of streamflow and considers ecological sensitivity of each resource. It also incorporates the concept of balancing human and ecological needs for water by differentiating the degree of allowable depletions according to watershed characteristics and current human influences.

The methodology allows for a fairly simple calculation of an allowable streamflow depletion by considering: existing withdrawals and returns, their locations within the watershed, the time of year, the watershed characteristics and the natural low flow conditions of the river/stream potentially impacted. The methodology involves three important steps:

- 1) Classify all Watersheds based on Watershed Characteristics
- 2) Link Seasonal Flow Variations and Ecological Needs
- 3) Quantify Allowable (or acceptable) Streamflow Depletions

The watershed classification process takes into consideration the fact that all watersheds are not of equal ecological value due to watershed characteristics and existing human influences that may alter habitat and/or natural streamflow characteristics within a watershed. To account for these differences among watersheds each was assigned a class from 1 to 5 based watershed characteristics and on actual or potential degree of deviation from natural conditions after considering a number of factors referred to as "human influence factors".

The second step takes into consideration the seasonal variations and the ecological importance of the seasonal variation in flow. Seasonal ecological needs were linked with natural streamflow patterns and a range of allowable deviations from natural conditions was established.

The final step describes the process to quantify allowable streamflow depletions. The following sections provide the details of each step in the process.

A. WATERSHED CLASSIFICATION

A five-class system was developed to define the range of human alteration and ecological integrity of the state's watersheds. Class 1 watersheds, the most ecologically sensitive, are considered to be in the most undeveloped/pristine condition, and are expected to exhibit little to no deviation from natural conditions. On the other end of the spectrum are the Class 5 watersheds which are substantially altered from natural conditions, and provide habitat to more tolerant species. Nine different factors representing the potential for human influence on streamflow were considered, as follows:

- **Diversions** – Existing diversions alter the natural ecological condition by altering the natural flow regime and reducing low flows even further. Existing water withdrawals/diversions identified by DEM and WRB and are measured as MGD. Details of the water withdrawal estimations are listed below:
 - **Public Supply** - Data from the RI Department of Health was used to locate all public drinking water supply wells. Withdrawal volumes for wells assume that the wells are pumped at capacity for 12 hours per day. For surface water supply reservoirs, withdrawal volume was assumed to be the calculated safe yield documented in water suppliers' Water Supply System Management Plans.
 - **Agriculture** - The RIGIS Landuse / Landcover data identify and quantify area of cropland in each unit watershed. The cropland was assigned a water usage of 1.2 MGD/mi². These values were consistent with the 1"/week and other agriculture use estimates by USGS contained in the water availability studies.
 - **Golf courses** were assigned 0.25MGD/9 holes.
- **Existing Impervious Cover** - Impervious cover alters the natural flow regime by reducing groundwater recharge and increasing surface runoff which creates channel erosion. Additionally, impervious surfaces warm runoff which in turn raises stream temperatures during the most critical summer periods. Streams with watersheds that have a high percent impervious cover will have only warmwater fish which are less sensitive to groundwater withdrawals. The 2001 National Land Cover Imperviousness data were used to calculate percent impervious cover for each catchment.
- **Future Development Potential** - Rhode Island is planning for the future development needs through their comprehensive plans and State Guide Plan Land Use 2020. The plan's Urban Service Boundary defines where utilities including water supply should be provided and towns should focus development. This factor anticipates development in those areas within the Urban Services Boundary and provides for some measure of water use. Because this factor characterizes a future condition, it is weighted less than the other factors.
- **Existing Conservation Lands**- Lands held in conservation are maintained in their natural condition. This factor is measured as percent of unit watershed held in some form of conservation agreement.

- **Future Conservation Lands** – As in future development, the Statewide Planning, RIDEM and other conservation groups have identified key priority conservation areas. This factor recognizes these efforts to maintain these lands in their natural conditions. Because this factor characterizes a future condition, it is weighted less than the other factors.
- **Water Quality** – This factor is measured by the water quality classification assigned to those water bodies within each watershed. The water quality classifications reflect the quality of the water and its ability to support the most sensitive species of fish. Class A and AA waters were assigned 1 point, Class B waters were assigned 5 points and Class B1 waters were assigned 10 points.
- **Water Supply Lands** – This factor accounts for lands designated for protection of existing and future water supply. These areas cannot be designated for anything other than water supply. The data are a subset of the Existing Conservation Lands layer –and is measured as presence or absence of such lands within the unit-watershed.
- **Farmlands (Croplands)** – These data are a subset of the 2003/2004 RIGIS landuse/landcover layer. Cropland is generally tilled land used to grow row crops. There is usually evidence of intense land management. The land is often flat, well drained and the field boundaries are generally very well defined. This category also includes turf farms that grow sod. Associated facilities include barns and other outbuildings. The percentage of cropland within each unit watershed was computed and then given scores of 1 through 10.
- **Coldwater Fisheries** – Identified as those waters listed in Appendix B of the Water Quality Regulations (as amended in 2009) as waters that support coldwater fisheries. This metric was weighted with a minus 10 to 5 score to reflect the sensitivity of coldwater fisheries to streamflow depletion and related temperature increases. If the fishery designation was unknown no score was given and a warmwater fishery was given 5 points.

For each unit watershed, the individual scores were added and a total unit watershed score was calculated, as depicted in Figure 1. Appendix II contains the details of the scoring system and the results.

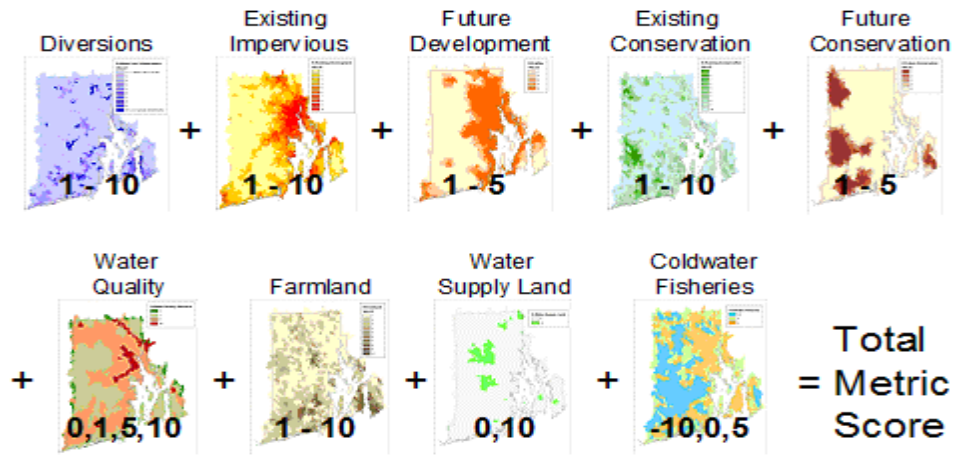


Figure 1 –Representation of Factors and associated scores used in Watershed Classification

Watersheds were assigned to one of the five classifications based on the total metric score, as shown in Figure 2. The higher the score, the higher the class, and the higher the presumed degree of deviation from natural conditions. The total metric scores for each class ranged as follows:

- Class 1: -3 - 10
- Class 2: 11 - 17
- Class 3: 18 - 28
- Class 4: 29 - 37
- Class 5: 38 – 54

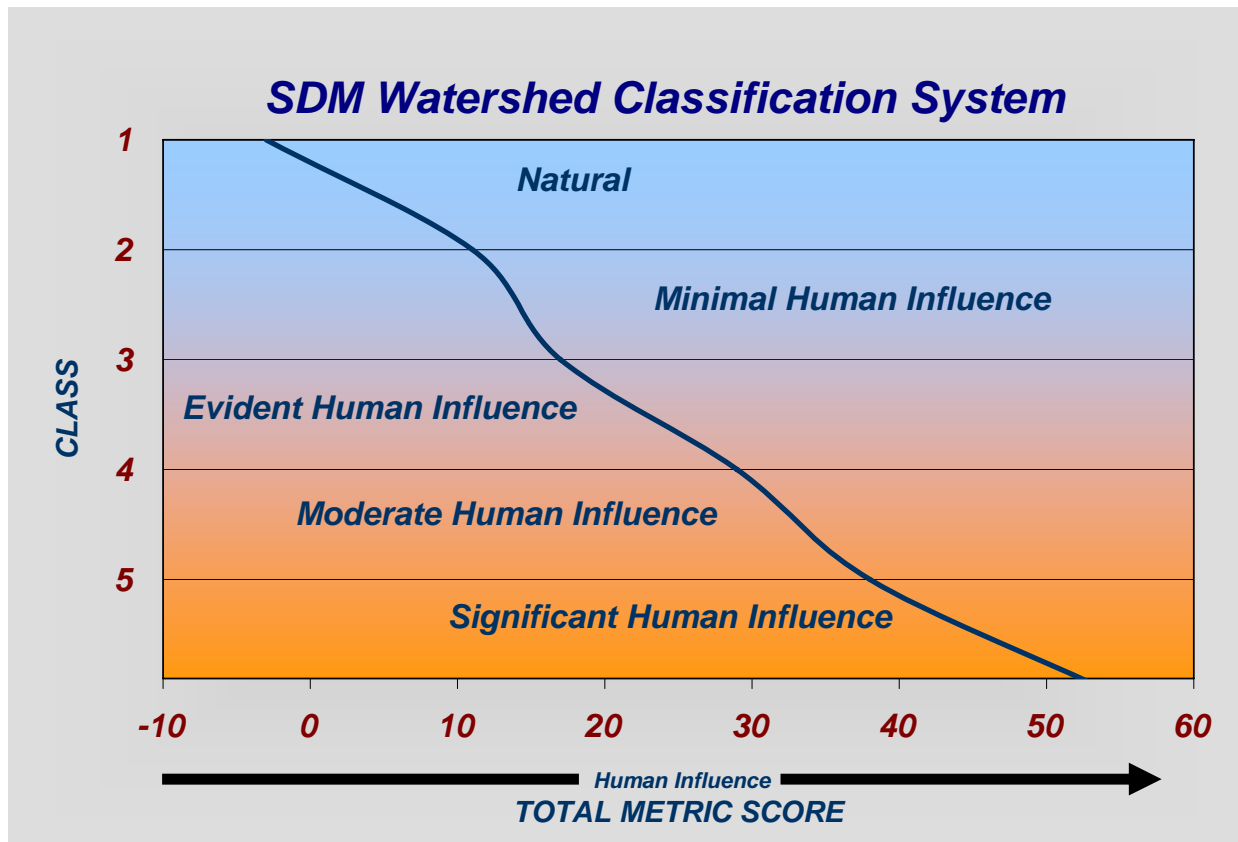


Figure 2 – SDM Watershed Classification System

The Watershed Classification System developed as part of this SDM is based on the Hydrologic Unit Classification (HUC) system developed by USGS in the mid 1970s. Hydrologic units are watershed boundaries organized in a nested hierarchy by size. As part of the statewide basin specific Water Use and Availability Studies completed by USGS, modified HUC 12 watersheds were delineated. As depicted in Figure 3, total metric scores at the catchment level (shown on left side) were generalized into the larger HUC 12 Watershed Units (shown on right side) using area weighted score averaging.

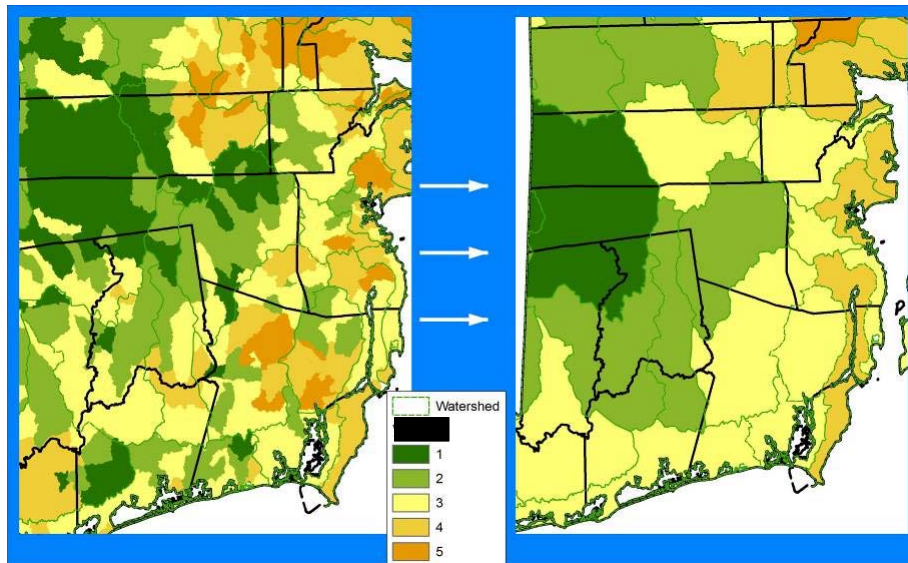


Figure 3 – Graphic depiction of the aggregation of smaller hydrologic units into Modified HUC 12 watersheds

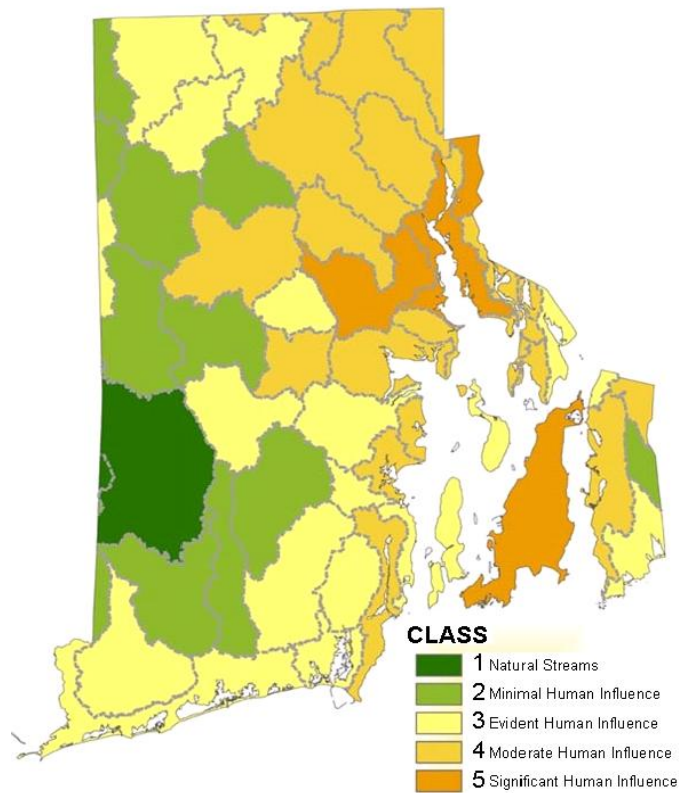


Figure 4 – SDM Watershed Classification System at modified HUC 12

B. ESTABLISHING THE LINK BETWEEN STREAMFLOW AND ECOLOGICAL NEEDS

The second important step in the development of the methodology links natural variations in flow patterns to ecological needs or more specifically, critical life stages of native fish (known as bioperiods). To determine the natural variation in flow, available streamflow data was analyzed to develop a natural RI hydrograph as represented by the monthly median stream flow (Figure 5). Four hydroperiods were identified, as shown in Figure 5:

- Low Flow: < 0.5 cfs/m
- Med – Low Flow: 0.5 – 1.0 cfs/m
- Medium Flow: 1.0 – 2.0 cfs/m
- High Flow: > 2.0 cfs/m

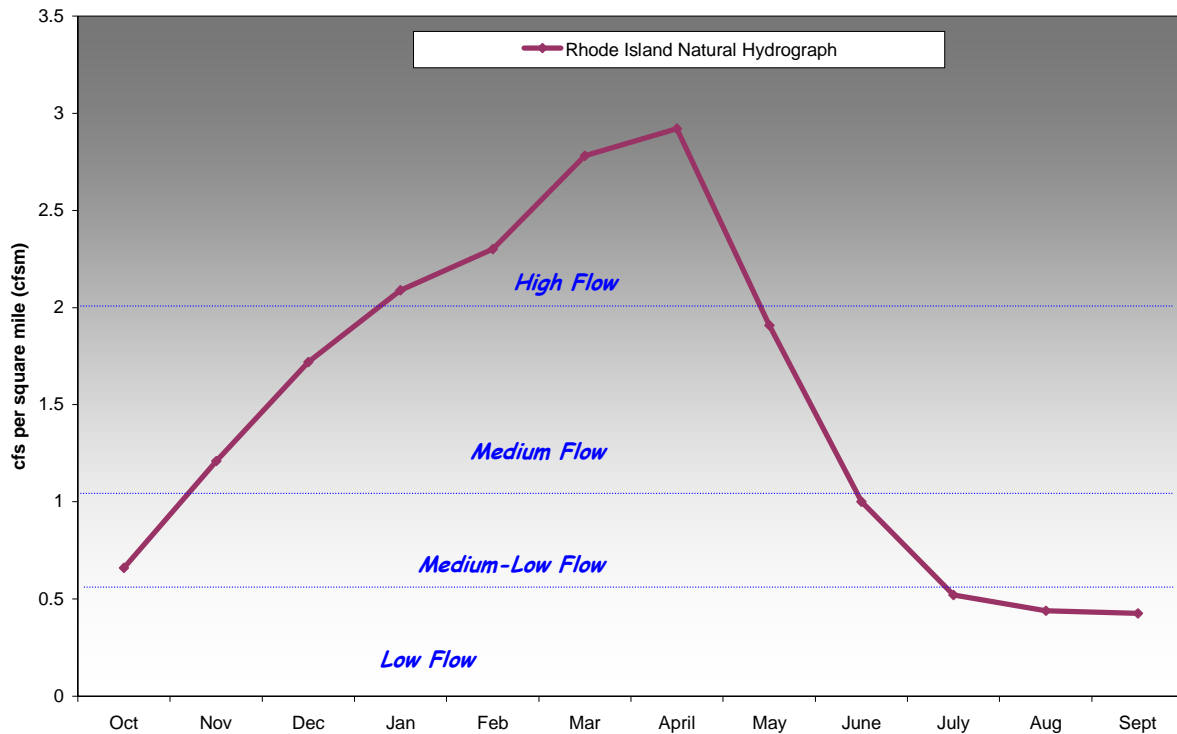


Figure 5 – Annual Natural RI Hydrograph (monthly median river flows) and Associated Hydroperiods

The next step in establishing the link between natural flow variations and ecological needs involved identification of sensitive life stages of native river fish for each month, known as bioperiods. The main premise in establishing this linkage is that by maintaining a river’s natural flow variations (represented as hydroperiods) the ecological processes or functions dependent upon the varying flows throughout the year (represented as bioperiods) are protected. The bioperiods are determined according to the RIDEM F&W identified sensitive life stages of native “river fish” for each month of the year (see Table 1).

The life stages of river fish were selected because they are the fish species that require flow for all or part of their life cycle. Their sensitive life stages are divided into 4 primary categories:

- Upstream Migration (M) – returning from sea
- Spawning (S)
- Rearing and Growth (R) - sensitive time period after eggs have hatched
- Outmigration (O) – heading out to sea

Table 1 – Life Stages of River Fish Found in Rhode Island

Species	O	N	D	J	F	M	A	M	J	J	A	S
Blacknose Dace								S	S	S	R	
Longnose Dace								S	S	S	R	
Fallfish							S	S	R			
Creek Chubsucker						S	S	S	R			
Atlantic Salmon						O	O	M	M	M		
Brook Trout	S	S										S
Tessellated Darter								S	S	R		
River Herring	O	O				SM	SM	SM	MO	RO	O	O
American Shad	O	O					SM	SM	SM	RO	O	O
Common Shiner								S	S	S	S	R
White Sucker							S	S	R			

M = upstream migration, O=outmigration, R=Rearing and Growth, S=spawning

Finally, to depict the link between the natural flow regime and ecological needs, the hydroperiods for each month in Figure 5 are matched up with the life stages in Table 1 to produce the graph relating hydroperiods to bioperiods shown in Figure 6. This graph demonstrates linkages between the varying flow stages and the biological functions occurring during each hydroperiod. Table 2 describes bioperiods and corresponding hydroperiods on a monthly basis.

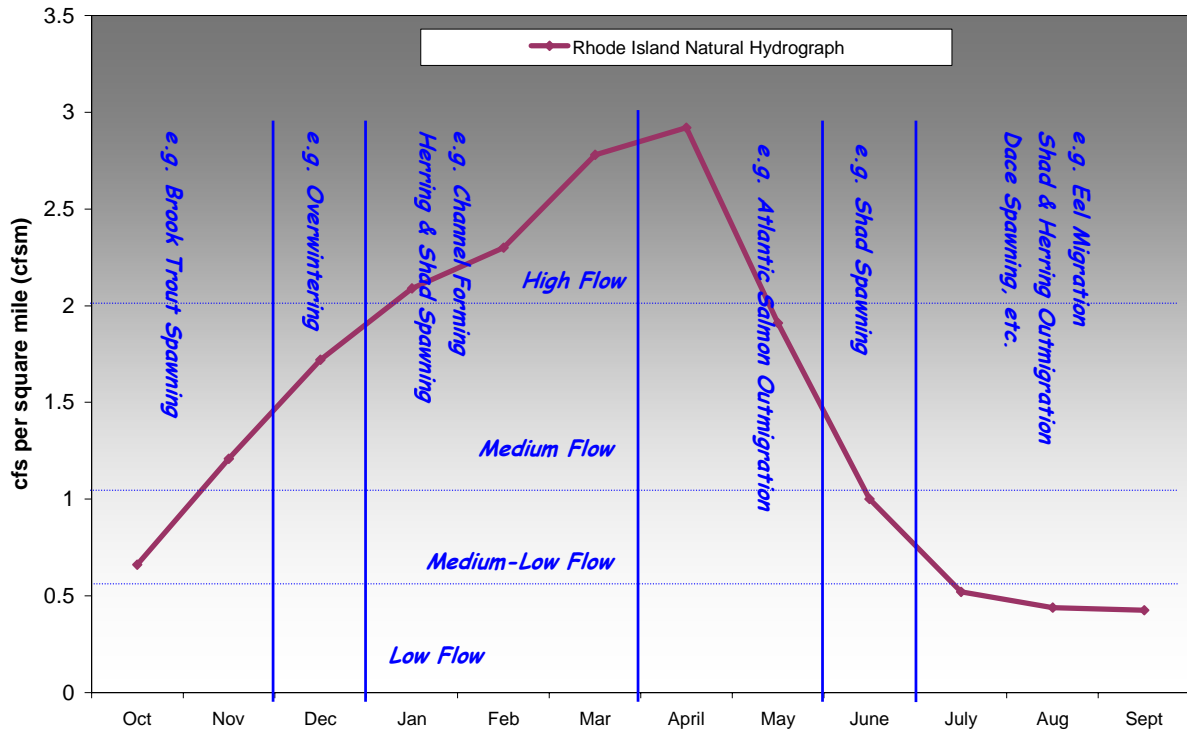


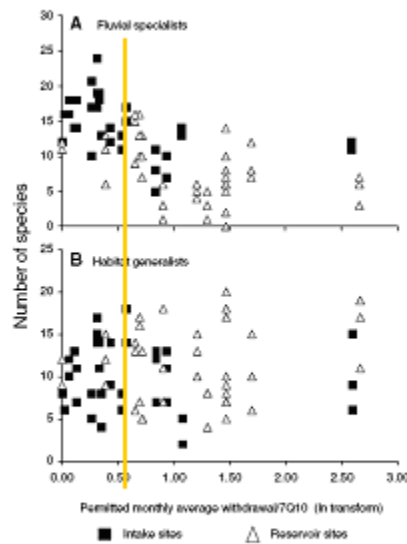
Figure 6 – Annual Natural RI Hydrograph with associated hydroperiods and life stages of fish found in Rhode Island

Table 2- Bioperiods and Associated Hydroperiods on a monthly basis

MONTH	BIOPERIOD	HYDROPERIOD
OCTOBER	Brook Trout Spawning; River Herring, Shad and Eel Outmigration	Medium - Low
NOVEMBER	Brook Trout Spawning; River Herring, Shad and Eel Outmigration	Medium
DECEMBER	Overwinter	Medium
JANUARY FEBRUARY	Overwinter Channel Forming	High
MARCH	River Herring Spawning	High
APRIL	River Herring and Shad Spawning	High
MAY	River Herring, Shad and Resident Spawning	Medium
JUNE	Peak Resident Spawning	Medium-Low
JULY AUGUST	Resident Spawning, Rearing and Growth	Low
SEPTEMBER	Brook Trout Spawning; River Herring, Shad and Eel Outmigration	Low

C. QUANTIFYING ALLOWABLE STREAMFLOW DEPLETIONS

The final step in the methodology is determining the streamflow depletion that is allowable while still maintaining the natural streamflow variations described by the hydroperiods. The Streamflow Depletion Methodology is based upon studies conducted in the southern Piedmont area of Georgia by the USGS and the US Fish and Wildlife Service. The studies by Freeman and Marcinek (2006) evaluated fish assemblage responses to surface water withdrawals and instream reservoirs, and documented that the richness of fluvial specialists declined as permitted withdrawal rates increased above 0.5 to one 7Q10 equivalent of water. They also found that increasing withdrawal rates increased the odds that a site's Index of Biotic Integrity (a measure of the macroinvertebrate population health) score fell below a regulatory threshold indicating biological impairment. Figure 7 depicts the observations made by the USGS. Here they relate the response of fluvial specialist (i.e. riverine) fish assemblages (graph A) to permitted water withdrawals at intake sites (indicated below by the black squares) in Piedmont, Georgia streams. More simply stated, USGS scientists found significant losses of river fish associated with withdrawal rates greater than 50% of the 7Q10.



Freeman, M. C. and P. A. Marcinek. 2006. Fish assemblage responses to water withdrawals and water supply reservoirs in Piedmont streams. *Environmental Management* 38: 435-450.

Figure 7 – Fish Assemblage Responses to Water Withdrawals and Water Supply Reservoirs in Piedmont streams as reported by Freeman, M.C. and P.A. Marcinek. 2006

Correspondingly, RIDEM Fish and Wildlife studies on the Hunt River resulted in congruent findings, as shown in Figure 8. Fish samples were collected from the Hunt River at Davisville, RI during late summer (August – September) over six years. The yellow section of the pie charts represents the pond fish community, the purple and blue sections represent the river fish community. The y-axis is the percent of 7Q10 extracted from the stream. The red line represents 50% of the 7Q10. As can be seen in Figure 8, in 1997 when withdrawals were 43% of the 7Q10, the percent composition of river fish (known as fluvial dependent and fluvial specialist species) was roughly equal to pond fish (known as macrohabitat generalist species). However, in subsequent years as withdrawals exceeded 50% of 7Q10, the percent composition of river fish declined fairly significantly. With reduction in withdrawals to less than 50% of 7Q10, there is evidence that the percent composition of river fish rebounds.

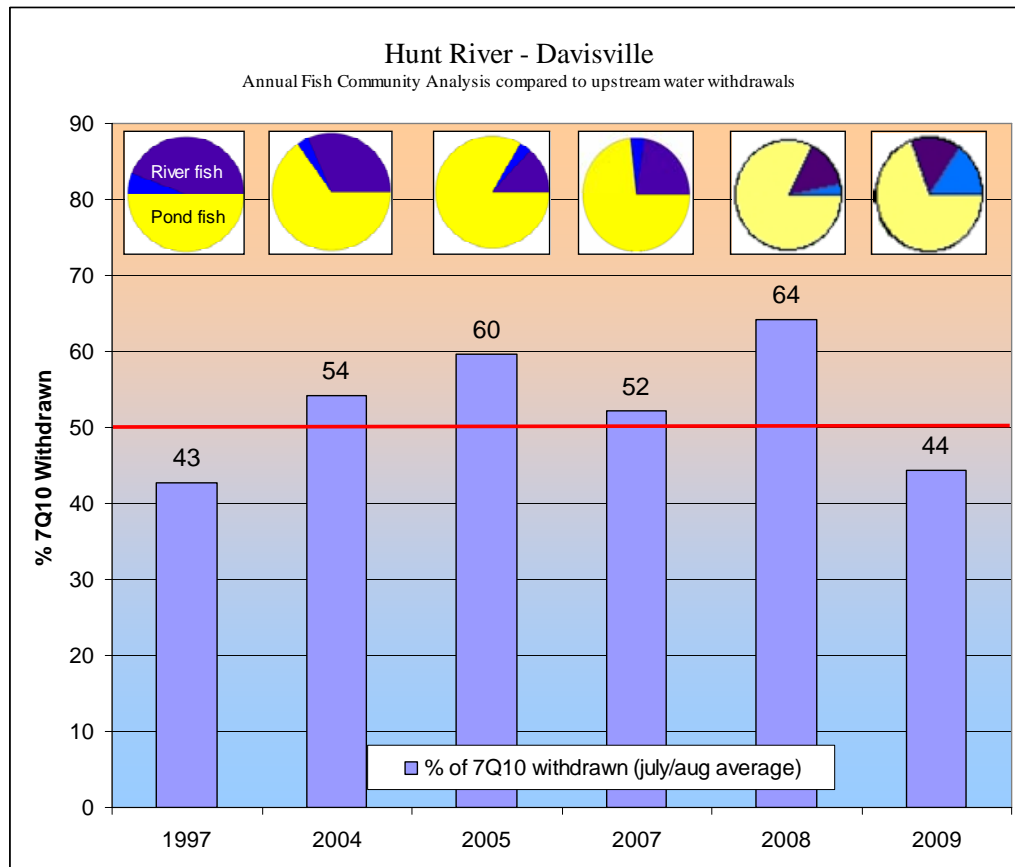


Figure 8 – Annual Fish Community Analysis compared to upstream water withdrawals from the Hunt River at Davisville, RI

Based on the Freeman and Marcinek study with general support from the RI data shown above, the Department applied the 50% threshold as identified by USGS. This threshold was used to set the limits of the allowable streamflow depletion during the most sensitive time of the year when flows are at their lowest (July – September) to not exceed 50 % of 7Q10 in Class 5 watersheds (containing the most significantly altered streams). In order to consider a proportional degree of

protectiveness for those watersheds in more natural conditions (i.e. those with a lower classification) the allowable streamflow depletion during this low flow period, as represented by percentage of 7Q10, is reduced in a linear fashion, as shown in Table 3. The resulting allowable streamflow depletion thus does not permit greater than 50% of 7Q10 reduction in any stream during the low flow period of July through September.

Table 3 – Allowable Streamflow Depletion by Watershed Class as a percentage of 7Q10 flow during the Low Flow period

Class	Human Influence	Allowable Streamflow Depletion as % of 7Q10
1	Natural Streams	10
2	Minimal Human Influence	20
3	Evident Human Influence	30
4	Moderate Human Influence	40
5	Significant Human Influence	50

Given that more water is flowing during the other seasons of the year, as shown in Figure 5, the methodology allows for more depletion during these periods. The allowable seasonal or hydroperiod depletions were determined using the following method. The average of each monthly median flow per area of watershed (cfs/m) during each hydroperiod was calculated. Then using the nearest whole number, hydroperiod multipliers as a function of the Low Flow period average median flow were determined. The multiplier for each hydroperiod is as shown in Table 4.

Table 4 – Hydroperiod multipliers

Hydroperiod	Average median (cfs/m)	Average Median as Whole Number	Multiplier
Low Flow	.45	0.5	1
Medium Flow	.83	1.0	2
Medium High Flow	1.6	2.0	4
High Flow	2.5	3.0	6

Each hydroperiod multiplier was then used to scale the allowable streamflow depletion for all hydroperiods. Thus, the methodology recognizes that flows during the Medium-Flow hydroperiod are generally 2 times higher than during the Low-Flow hydroperiod, and therefore, twice the amount of depletion would be allowed in the stream, and so on with the higher flow periods. Table 5 presents the resulting seasonal allowable streamflow depletions as a percentage of 7Q10 flows.

Table 5 – Monthly Allowable Streamflow Depletion as a Percent of 7Q10 for each Watershed Classification

ALLOWABLE STREAMFLOW DEPLETION AS PERCENTAGE OF 7Q10							
MONTH	BIOPERIOD	HYDROPERIOD	CLASS 1	CLASS 2	CLASS 3	CLASS 4	CLASS 5
OCTOBER	Spawning & Outmigration	Medium - Low	20%	40%	60%	80%	100%
NOVEMBER DECEMBER	Overwinter	Medium	40%	80%	120%	160%	200%
JANUARY FEBRUARY	Overwinter & Channel Forming	High	60%	120%	180%	240%	300%
MARCH APRIL	Anadromous Spawning	High	60%	120%	180%	240%	300%
MAY	Anadromous Spawning	Medium	40%	80%	120%	160%	200%
JUNE	Peak Resident Spawning	Medium-Low	20%	40%	60%	80%	100%
JULY AUGUST SEPTEMBER	Resident Spawning Rearing & Growth Herring & Shad Out	Low	10%	20%	30%	40%	50%

VII. CALCULATING ALLOWABLE STREAMFLOW DEPLETION

For purposes of calculating allowable streamflow depletion for a specific withdrawal or basin using SDM, the percentages of 7Q10 from Table 5 are applied to the natural 7Q10 for the relevant stream or river. The natural 7Q10 represents the expected lowest 7 consecutive day average flow that would occur (on average) once every 10 years assuming little to no human effect on flows. Using the best available tools, there are a number of ways that natural 7Q10 can be determined. In order of increasing accuracy they are:

1. USGS LOW FLOW REPORT (USGS REPORT 93-4046)

In this report, 7Q10s in Washington County were estimated to be correlated to the distribution of the percentage of stratified drift and till in the upstream watershed.

2. USGS LOW FLOW REPORT (USGS REPORT 95-4299)

In this report, 7Q10s in Northern Rhode Island were estimated to be correlated to the best fit of five long-term gaging stations within Rhode Island. Estimated 7Q10s are reported within the document for 18 partial record stations. This method is similar to method 3 however, the work has been documented.

3. CORRELATE THE LOCATION TO A GAGE IN ANOTHER WATERSHED WHICH IS NATURAL

If the basin characteristics are similar, one watershed can be correlated with another watershed and the 7Q10s can be calculated by multiplying by the ratio of the watersheds. If the percent stratified drift within the watershed is known, then the correlation will include an adjustment for stratified drift and till.

4. WATER AVAILABILITY STUDIES (BASIN SPECIFIC USGS REPORTS)

The Water Use and Availability studies calculated the Estimated Gross Yield from the drift and till in each basin. The 7Q10 was extracted from this analysis by subtracting the

Estimated Gross Yield for 7Q10 scenario for July (in MGD) from the Estimated Gross Yield for July (in MGD)

5. CORRELATE A GAGED NATURAL RIVER TO A POINT WITHIN ITS WATERSHED

The natural 7Q10 of a point within a gaged watershed is calculated by multiplying by the ratio of drainage area to the point of analysis to drainage area to the gauged location.

6. MODFLOW MODEL

To date, MODFLOW reports are available for the Hunt-Annaquatucket-Pettaquamscutt (HAP) Basin. The depletion from wells was added to the calculated 7Q10 to determine the natural 7Q10. Gages at the bottom of the Annaquatucket and Pettaquamscutt sub-basins were not available, so the 7Q10 values reported in the Low Flow Report were used.

7. HSPF MODEL

To date, HSPF models have been developed for the Pawcatuck River and Blackstone River Basins. An HSPF model generates natural flow-duration curves as well as existing flow duration curves. The flow duration for the existing 7Q10 is calculated at the gage and then projected to the existing withdrawals flow duration curve. This determines the percent duration of 7Q10 under existing conditions. The percent duration is then projected upwards to determine the natural flow or natural 7Q10.

Appendix III provides an example of how an allowable depletion for a river reach during the summer critical months would be calculated. Appendix IV provides streamflow depletion estimates applying SDM at selected locations statewide. Finally, Appendix V includes a blank worksheet to calculate allowable streamflow depletion.

VIII. REFERENCES

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APPENDIX I

DEM STATUTORY AND REGULATORY AUTHORITY

APPENDIX I - DEM STATUTORY AND REGULATORY AUTHORITY

WATER POLLUTION CONTROL ACT AND WATER QUALITY REGULATIONS

WATER POLLUTION CONTROL ACT (RIGL 46-12)

The act designates the Department of Environmental Management as the “State water pollution control agency for this state for all purposes of the Clean Water Act, as amended”. In accordance with this charge, the Department developed and promulgated the Water Quality Regulations, which are the State’s water quality standards.

WATER QUALITY REGULATIONS

The water quality regulations set the framework for protecting all surface water in order to meet the general purpose of the CWA, ie to restore, preserve, and enhance the physical, chemical, and biological integrity of the waters of the state. The regulations recognize that adequate water quantity is integral to water quality.

RULE 6 – APPLICATION OF THESE REGULATIONS

B. These regulations apply to all waters of the State, all systems or means of wastewater treatment, including sewers, all discharges into surface waters, all activities which will likely impact water quality and/or activities that will likely cause or contribute to flow alterations....

RULE 8A – PURPOSE

Explains that a water quality standard defines the water quality goals of a surface waterbody, or portion thereof, by designating the use or uses of the water and by setting criteria necessary to protect the uses. Water quality standards are intended to protect public health, safety and welfare, enhance the quality of water and serve the purposes of the Clean Water Act and Chapter 46-12 of the General Laws of Rhode Island. "Serve the purposes of the Act" (as defined in Section 101(a)(2) and 303(c) of the Clean Water) means that water quality standards should, whenever attainable, provide water quality, *including quantity*, for the protection and propagation of fish and wildlife and for recreation in and on the water and take into consideration their use and value as public water supplies, propagation of fish and wildlife, recreation in and on the water, agricultural, industrial, and other purposes including navigation.

RULE 8D – WATER QUALITY CRITERIA

- (1) General Criteria – The following minimum criteria are applicable to all waters of the state, unless criteria specified for individual classes are more stringent:
 - (a) At a minimum, all waters shall be free of pollutants in concentrations or combination *or from anthropogenic activities subject to these regulations* that:
 - (i) Adversely affect the composition of fish and wildlife;
 - (ii) Adversely affect the physical, chemical, or biological integrity of the habitat;
 - (ii) Interfere with the propagation of fish and wildlife
 - (iv) Adversely alter the life cycle functions, uses, processes and activities of fish and wildlife; or
 - (v) Adversely affect human health

RULE 8E – APPLICABLE CONDITIONS

(1) For activities that will likely cause or contribute to flow alterations streamflow conditions must be adequate to support existing and designated uses.

RULE 13 – APPROVALS

Specifically requires that projects involving flow alterations receive a Water Quality Certification from the Department indicating that the proposed project complies with the Water Quality Regulations. The WQC is often times provided in conjunction with a Freshwater Wetlands permit or may be applied for separately if the project requires a federal permit or a CRMC approval.

RULE 18 – ANTIDegradation OF WATER QUALITY STANDARDS

Under the Clean Water Act, States are required to develop and implement Antidegradation standards as part of the water quality regulations. The primary purpose of Antidegradation is to ensure that any existing in-stream water uses and the level of water quality to protect the use be maintained and protected.

FRESHWATER WETLANDS ACT AND FRESHWATER WETLAND RULES AND REGULATIONS

FRESHWATER WETLANDS ACT (RIGL 2-1-18 ET SEQ)

Very generally, the Act recognizes the importance of freshwater wetlands in reducing flood damage, recharging groundwater supplies and providing wildlife and recreational values. It provides that wetlands should be protected from the harm caused by drainage, excavation and other forms of disturbance or destruction. Towards that end, the Act requires prior written approval for any activity including, inter alia draining, diking, damming, diverting water flows into or out of , adding to or taking from or otherwise altering the character of any freshwater wetland – inclusive of rivers, streams and watercourses.

FRESHWATER WETLANDS RULES AND REGULATIONS

RULE 2.02(C) - Briefly enumerates the function and values of wetlands that the Act intends to protect including:

1. Protection of life and/or property from flooding or flood flows by retaining, storing, metering, or slowing floodwaters from storm events.
2. Providing and maintaining surface and/or groundwater supplies by acting as a recharge or discharge area.
3. Providing and maintaining valuable wildlife habitats.
4. Providing and maintaining high value recreation areas.
5. Protecting and maintaining water quality

RULE 5.01 PROHIBITIONS

Generally states that proposed projects or activities that may alter freshwater wetlands require a permit. Explains that activities partially or wholly within wetlands or activities taking place outside of FWW which in all likelihood due to their close proximity, size or the nature of the activity will result in an alteration, requires a permit. Such projects include those that result in diversion of GW into or away from freshwater wetlands by the installation of wells (as well as other activities).

RULE 10.02

Describes what applicants must evaluate with respect to a proposed project's impacts on those functions and values provided by wetlands as described in Rule 10.02 including:

For wildlife and wildlife habitat, the applicant must identify and describe the project's impact to wildlife functions due to changes in water quality, water velocity, flow patterns, water elevations, water temperature, etc.

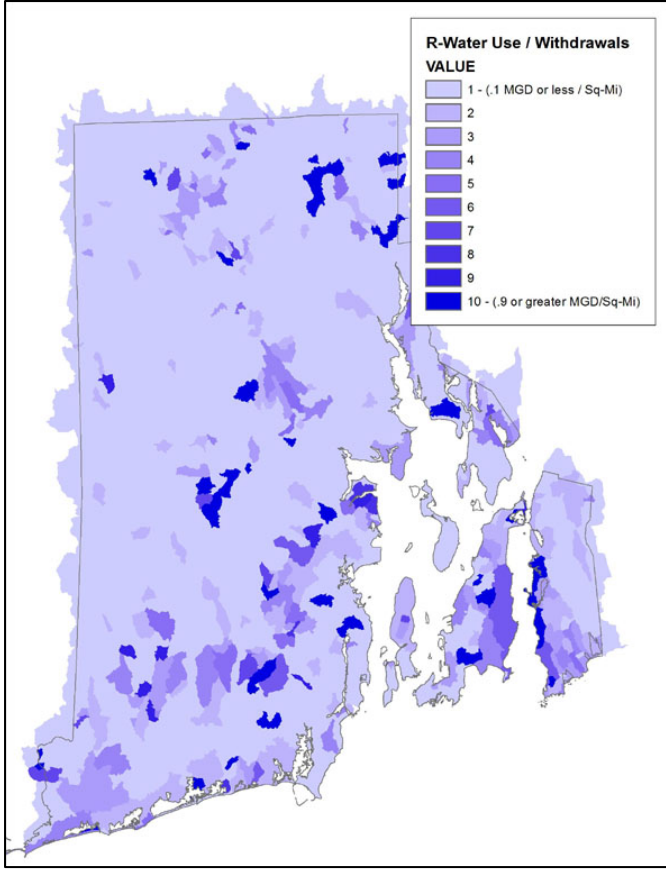
For groundwater and surface water supplies, the applicant must identify and describe how the project might directly or indirectly divert, reduce or contain surface and/or groundwater flow to, away from or within any wetland(s), including a description of the volumes of water which may be diverted, reduced or contained, and the rate and duration of such diversion, reduction or containment.

For water quality, the applicant must address whether the project might degrade the water quality associated with wetlands by increasing pollutant sources, nutrient loading, increasing turbidity, decreasing oxygen, altering temperature regimes, reducing stream or river flows, altering the wetland's ability to retain or remove nutrients or by withdrawing water from or near any wetlands.

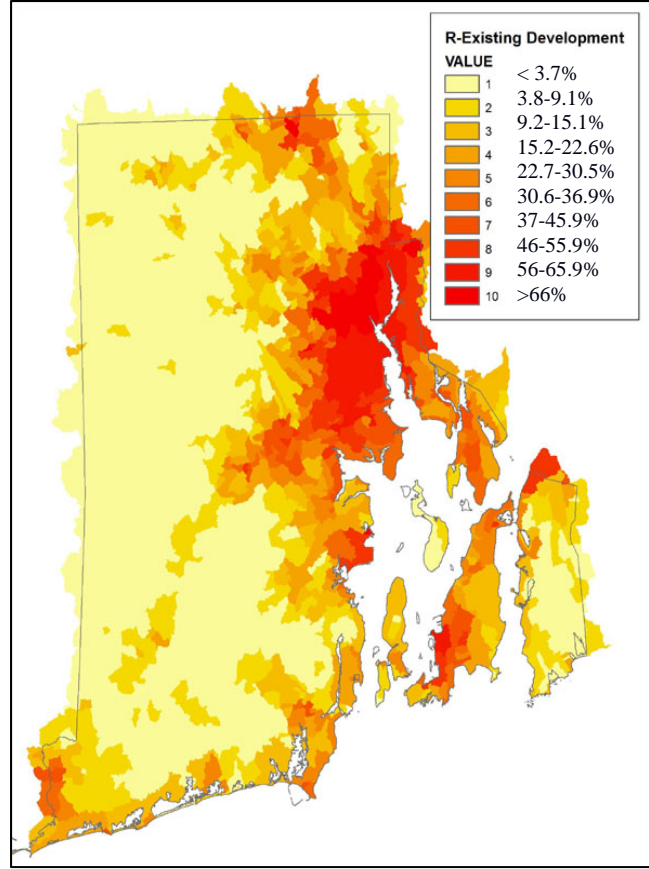
APPENDIX II

UNIT WATERSHED MAPS WITH THE RESULTING SCORES FOR EACH OF THE NINE METRICS USED TO DEFINE SDM WATERSHED CLASSIFICATIONS

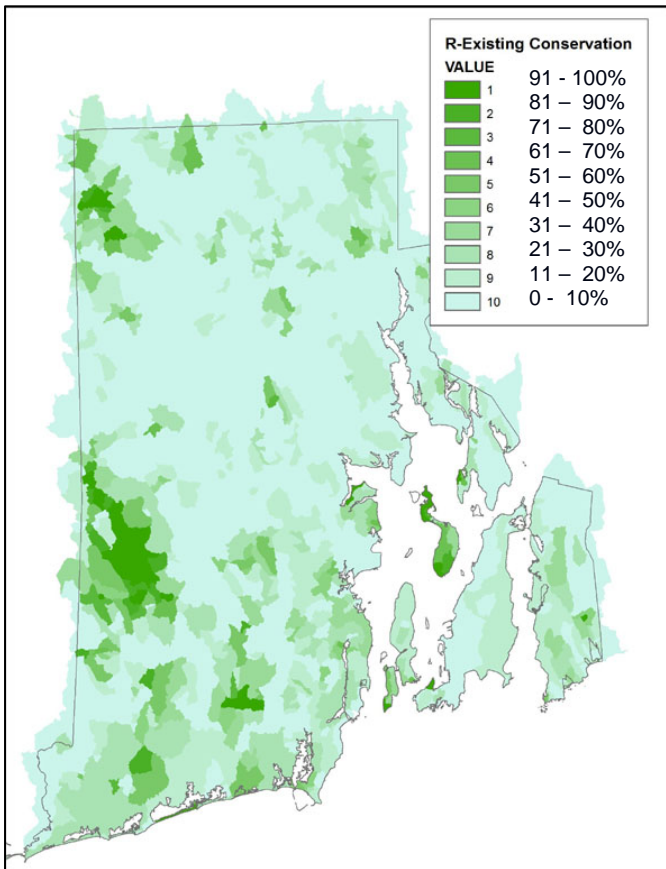
Diversions



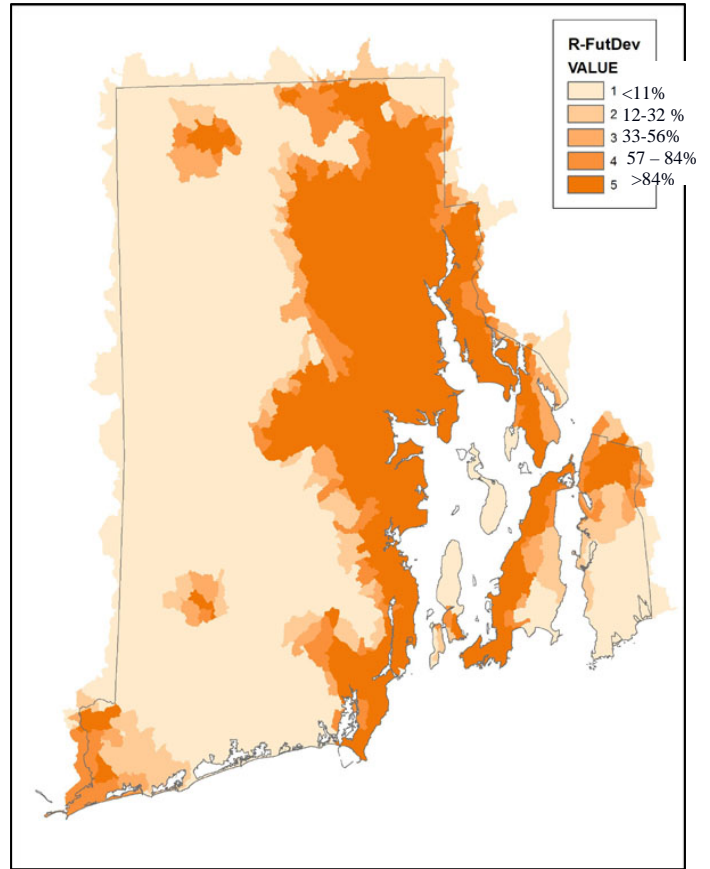
Impervious Cover

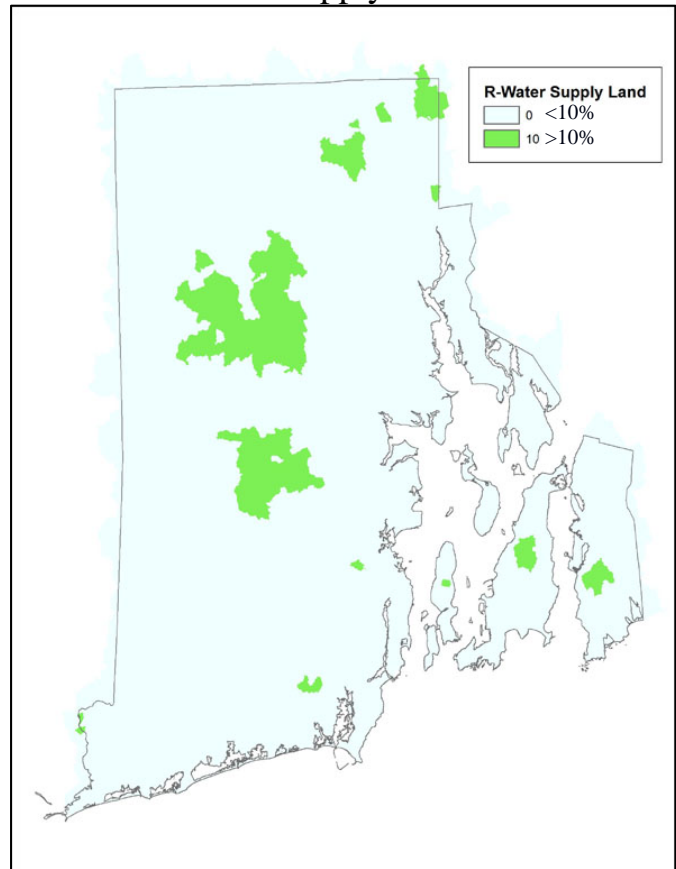
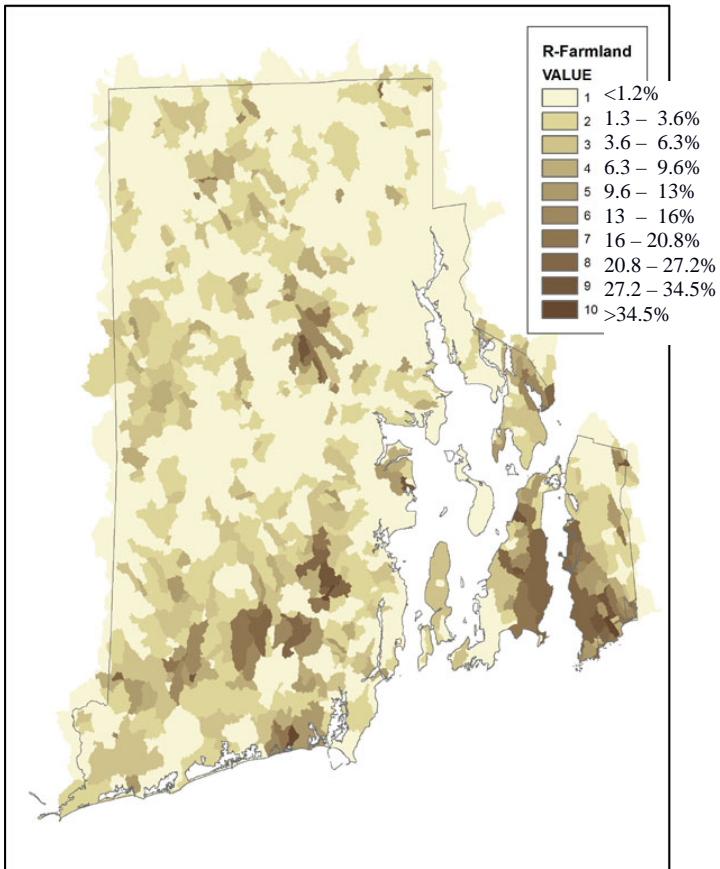
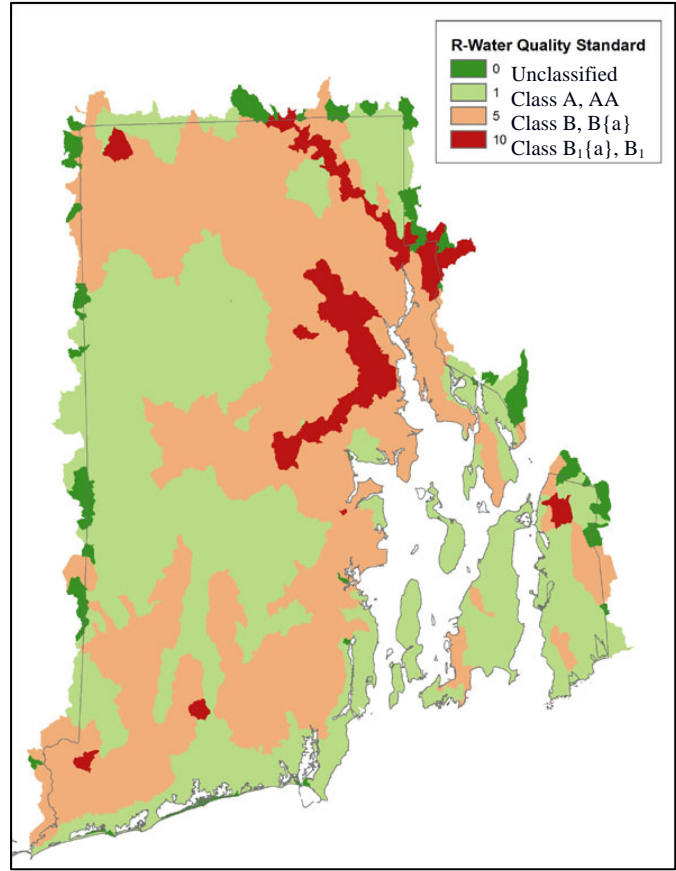
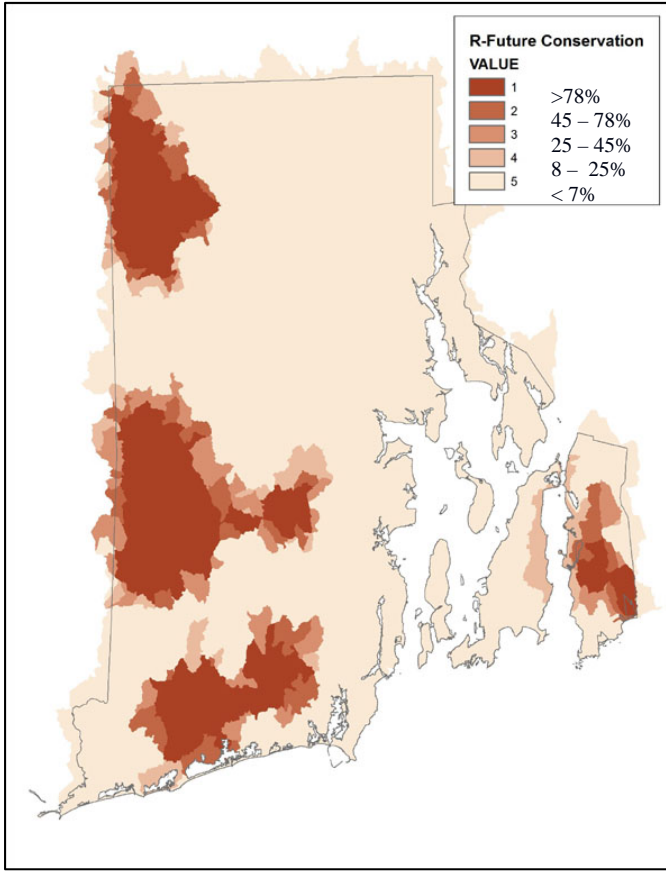


Existing Conservation

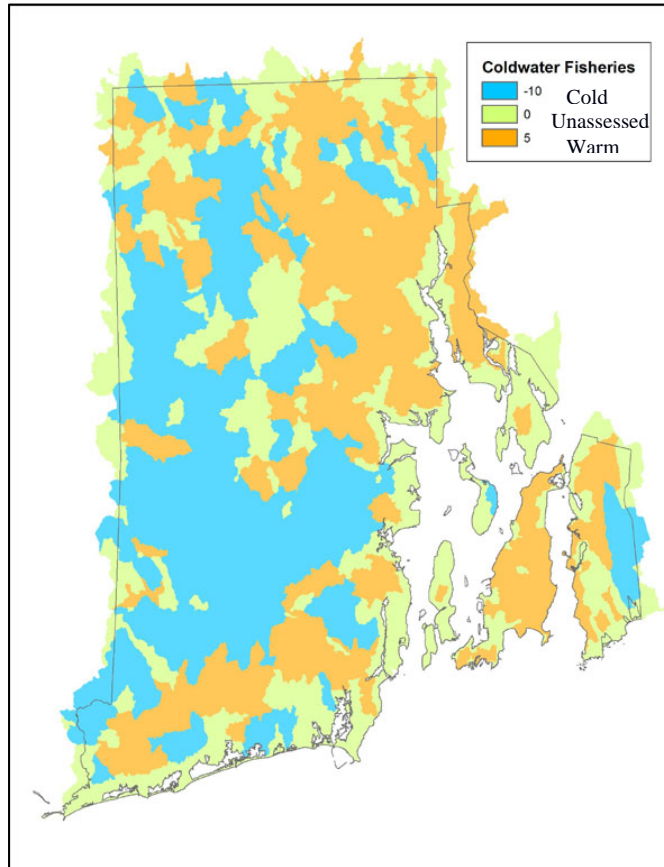


Future Development





Coldwater Fisheries



APPENDIX III

EXAMPLE STREAMFLOW DEPLETION CALCULATION

APPENDIX III- Example Streamflow Depletion Calculation

Below is an example of how an allowable depletion for a reach of river during the summer critical months would be calculated. In this scenario, the resulting streamflow depletion will be calculated from information in Table 5 and the natural 7Q10. Additionally, return flows will be considered in this example.

Well A is used seasonally for farming, Well B is used for a local private development on septic systems and Well C is transferred out of basin. The following example shows how the RIDEM would calculate the allowable depletion using the SDM.

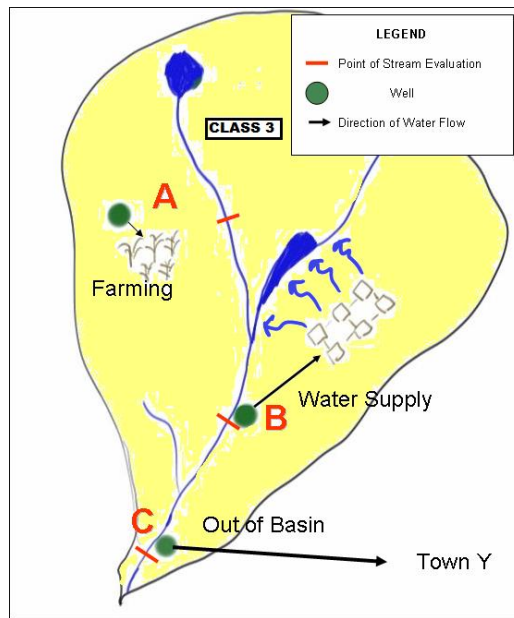


Figure 9 – Example Watershed Scenario

Reach A – An agricultural seasonal withdrawal from a well 500’ from the stream is located in this reach. Because the use of the water is agriculture the water is not returned to the system due to evaporation and uptake.

Natural 7Q10 (MGD)	Class	SDM Allowable Depletion (MGD) Class 3 = 30% of 7Q10	Upstream Depletions and Return Flows (MGD)	Well A Yield (MGD)	Calculated Depletion (MGD)
1.75	3	0.53	0	0.5	0.5*

*A depletion of 1:1 was assumed. Actual depletion may be less since the seasonality of the withdrawal and distance from the stream reduces depletion.

Reach A meets the allowable streamflow depletion because the calculated streamflow depletion is less than the 0.53 MGD of allowable streamflow depletion.

Reach B – A private development water supply is located in this reach. The well is in close proximity to the stream and 85% of the water is returned to the stream via septic systems. The basin here is Class 3. Reach B is affected by depletions in Reach A.

Natural 7Q10 (MGD)	Class	SDM Allowable Depletion (MGD) Class 3 = 30% of 7Q10	Upstream Depletions and Return Flows (MGD)	Well B Yield (MGD)	Calculated Depletion (MGD)
2.5	3	0.75	0.5 (depletion from Reach A) 0.25 (returns from private development B)	0.3	=0.5-0.25+0.3* = .55

*A depletion of 1:1 was assumed because the well was in close proximity to the stream.

Reach B meets the allowable streamflow depletion because the calculated depletion of 0.55 MGD is less than the 0.75 MGD of allowable streamflow depletion determined using SDM.

Reach C – A well located in this reach supplies another watershed. The well is in close proximity to the stream and no water is returned. The basin here is class 3. Reach C is affected by depletions in Reaches A and B.

Natural 7Q10 (MGD)	Class	SDM Allowable Depletion (MGD) Class 3 = 30% of 7Q10	Upstream Depletions and Return Flows (MGD)	Well B Yield (MGD)	Calculated Depletion (MGD)
4.0	3	1.2	0.5 (depletion from Reach A) 0.25 (returns from private development B) 0.3 (withdrawals from private development B)	1.0	=0.5-0.25+0.3+1 = 1.55

*A depletion of 1:1 was assumed because the well was in close proximity to the stream.

Reach C does NOT meet the SDM Allowable Depletion because the calculated depletion of 1.55 MGD of calculated depletion exceeds the allowable streamflow depletion as calculated using SDM.

APPENDIX IV

**CALCULATED ALLOWABLE STREAMFLOW DEPLETION
AT SELECTED LOCATIONS STATEWIDE**

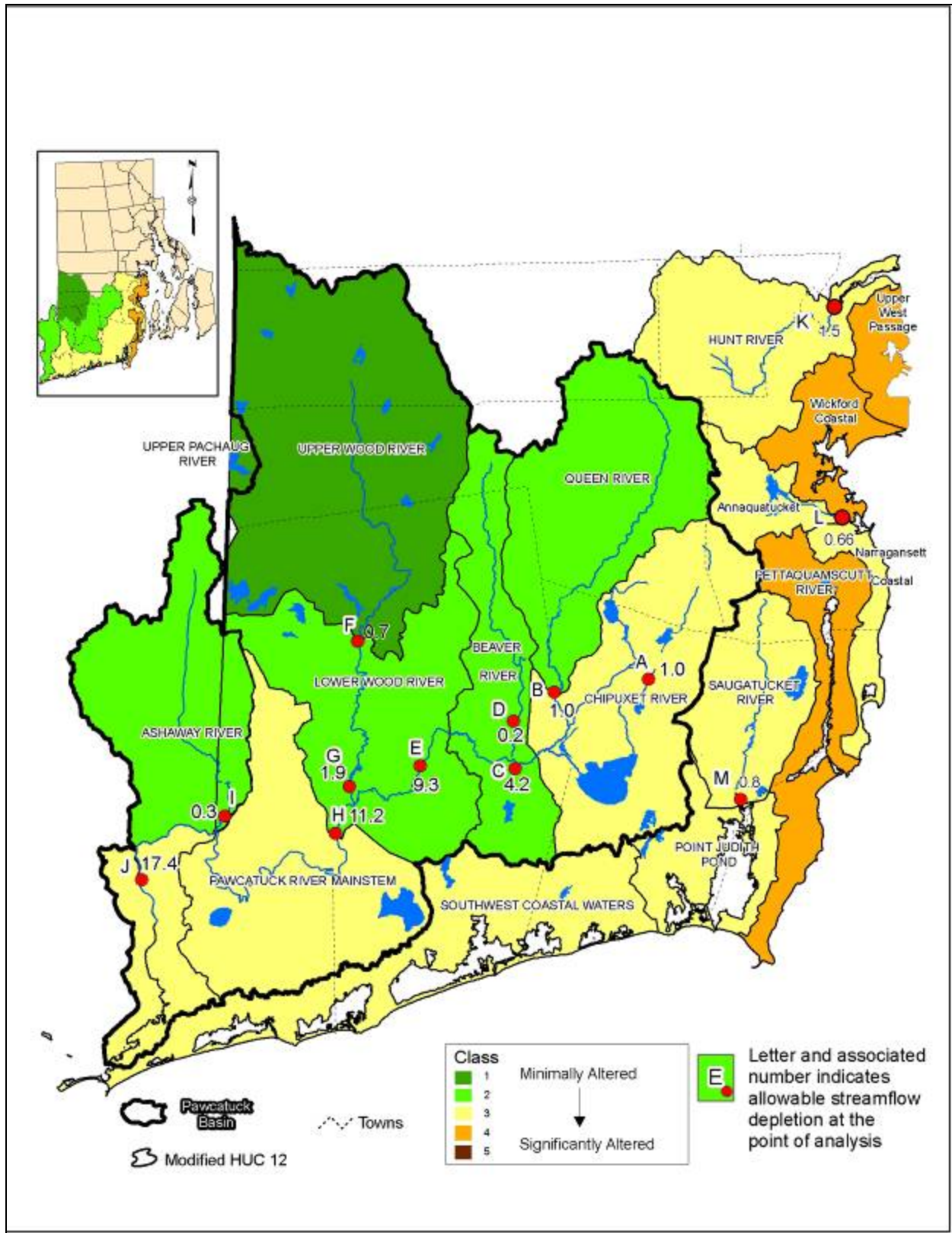


FIGURE IV-1 STREAMFLOW DEPLETION METHOD APPLIED TO SELECTED STREAMS IN SOUTHERN RHODE ISLAND

TABLE IV -1 SDM ANALYSIS AT SELECTED LOCATIONS IN SOUTHERN RHODE ISLAND

LOCATION	NAME	DRAINAGE AREA (SQ.MI)	NATURAL 7Q10 (MGD)	CLASS	ALLOWABLE DEPLETION July-Sept. (MGD)	*REFERENCE
	PAWCATUCK BASIN					
A	Chipuxet at Rt. 138	10.0	3.1	3	1.0	1. Low-Flow Report
B	Queen River	36.1	5.1	2	1.0	1. Low-Flow Report
C	Pawcatuck at Kenyon	79.5	14.0	3	4.2	1. Low-Flow Report
D	Beaver River	11.2	1.0	2	0.2	1. Low-Flow Report
E	Pawcatuck at Wood River Junction	100.0	31.0	3	9.3	1. Low-Flow Report
F	Wood River at Arcadia	35.2	6.6	1	0.7	5. Gaged Data
G	Wood River at Alton	85.7	9.7	2	1.9	5. Gaged Data
H	Pawcatuck at Burdickville	205.0	32.0	3	9.5	1. Low-Flow Report
I	Ashaway River	28.6	1.6	2	0.3	1. Low-Flow Report
J	Pawcatuck at Westerly	295.0	58.0	3	17.4	7. HSPF-Draft Report
K	HUNT RIVER	24.5	5.0	3	1.5	6. Modflow
L	ANNAQUATUCKET	7.3	2.2	3	0.66	1. Low-Flow Report
M	SAUGATUCKET RIVER	17.1	2.7	3	0.8	1. Low-Flow Report
*Key to Determining 7Q10						

Using the best available tools, there are a number of ways that natural 7Q10 can be determined. RIDEM chose the most accurate method available for each of the locations identified above. Available methods are listed in order of increasing accuracy:

1. USGS LOW FLOW REPORT (USGS REPORT 93-4046)

In this report, 7Q10s in Washington County were estimated to be correlated to the distribution of the percentage of stratified drift and till in the upstream watershed.

2. USGS LOW FLOW REPORT (USGS REPORT 95-4299)

In this report, 7Q10s in Northern Rhode Island were estimated to be correlated to the best fit of five long-term gaging stations within Rhode Island. Estimated 7Q10s are reported within the document for 18 partial record stations. This method is similar to method 3 however, the work has been documented.

3. CORRELATE THE LOCATION TO A GAGE IN ANOTHER WATERSHED WHICH IS NATURAL

If the basin characteristics are similar, one watershed can be correlated with another watershed and the 7Q10s can be calculated by multiplying by the ratio of the watersheds. If the percent stratified drift within the watershed is known, then the correlation will include an adjustment for stratified drift and till.

4. WATER AVAILABILITY STUDIES (BASIN SPECIFIC USGS REPORTS)

The Water Use and Availability studies calculated the Estimated Gross Yield from the drift and till in each basin. The 7Q10 was extracted from this analysis by subtracting the Estimated Gross Yield for 7Q10 scenario for July (in MGD) from the Estimated Gross Yield for July (in MGD)

5. CORRELATE A GAGED NATURAL RIVER TO A POINT WITHIN ITS WATERSHED

The natural 7Q10 of a point within a gaged watershed is calculated by multiplying by the ratio of drainage area to the point of analysis to drainage area to the gauged location.

6. MODFLOW MODEL

To date, MODFLOW reports are available for the Hunt-Annaquatucket-Pettaquamscutt (HAP) Basin. The depletion from wells was added to the calculated 7Q10 to determine the natural 7Q10. Gages at the bottom of the Annaquatucket and Pettaquamscutt sub-basins were not available, so the 7Q10 values reported in the Low Flow Report were used.

7. HSPF MODEL

To date, HSPF models have been developed for the Pawcatuck River and Blackstone River Basins. An HSPF model generates natural flow-duration curves as well as existing flow duration curves. The flow duration for the existing 7Q10 is calculated at the gage and then projected to the existing withdrawals flow duration curve. This determines the percent duration of 7Q10 under existing conditions. The percent duration is then projected upwards to determine the natural flow or natural 7Q10.

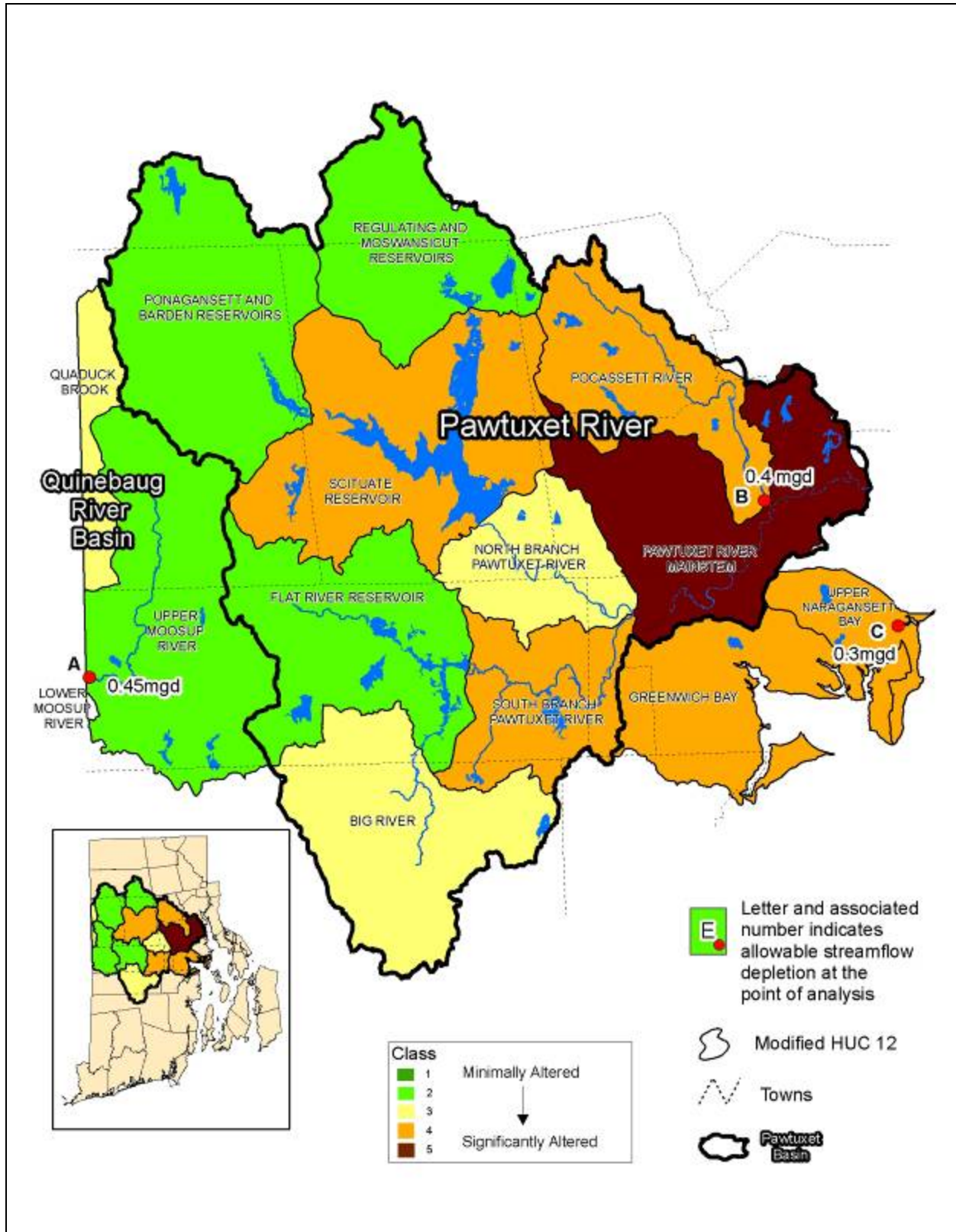


FIGURE IV-2 STREAMFLOW DEPLETION METHOD APPLIED TO SELECTED STREAMS IN CENTRAL RHODE ISLAND

TABLE IV -2 SDM ANALYSIS AT SELECTED LOCATIONS IN CENTRAL RHODE ISLAND

LOCATION	NAME	DRAINAGE AREA (SQ.MI)	NATURAL 7Q10 (MGD)	CLASS	ALLOWABLE DEPLETION (MGD)	*REFERENCE
	QUINNEBAUG RIVER BASIN					
A	Upper Moosup River	24.9	2.2	2	.45	3. correlated to Branch R.
	PAWCATUCK RIVER BASIN					
	Regulating and Mosquamucut Reservoirs					Managed Impoundment
	Scituate Reservoir					Managed Impoundment
	Big River					Managed Impoundment
	Flat River Reservoir					Managed Impoundment
	North Branch Pawtuxet River					Managed Impoundment
	South Branch Pawtuxet River					Managed Impoundment
	Pawtuxet River Mainstem					Managed Impoundment
B	Pocassett River	20.6	0.9	4	0.4	3. Woonasquatucket
C	Upper Narragansett Bay - Buckey Brook Outlet	9.6	.76	4	0.3	3. Moshassuck
* Key to Determining 7Q10						

Using the best available tools, there are a number of ways that natural 7Q10 can be determined. RIDEM chose the most accurate method available for each of the locations identified above. Available methods are listed in order of increasing accuracy:

1. USGS LOW FLOW REPORT (USGS REPORT 93-4046)

In this report, 7Q10s in Washington County were estimated to be correlated to the distribution of the percentage of stratified drift and till in the upstream watershed.

2. USGS LOW FLOW REPORT (USGS REPORT 95-4299)

In this report, 7Q10s in Northern Rhode Island were estimated to be correlated to the best fit of five long-term gaging stations within Rhode Island. Estimated 7Q10s are reported within the document for 18 partial record stations. This method is similar to method 3 however, the work has been documented.

3. CORRELATE THE LOCATION TO A GAGE IN ANOTHER WATERSHED WHICH IS NATURAL

If the basin characteristics are similar, one watershed can be correlated with another watershed and the 7Q10s can be calculated by multiplying by the ratio of the watersheds. If the percent stratified drift within the watershed is known, then the correlation will include an adjustment for stratified drift and till.

4. WATER AVAILABILITY STUDIES (BASIN SPECIFIC USGS REPORTS)

The Water Use and Availability studies calculated the Estimated Gross Yield from the drift and till in each basin. The 7Q10 was extracted from this analysis by subtracting the Estimated Gross Yield for 7Q10 scenario for July (in MGD) from the Estimated Gross Yield for July (in MGD)

5. CORRELATE A GAGED NATURAL RIVER TO A POINT WITHIN ITS WATERSHED

The natural 7Q10 of a point within a gaged watershed is calculated by multiplying by the ratio of drainage area to the point of analysis to drainage area to the gauged location.

6. MODFLOW MODEL

To date, MODFLOW reports are available for the Hunt-Annaquatucket-Pettaquamscutt (HAP) Basin. The depletion from wells was added to the calculated 7Q10 to determine the natural 7Q10. Gages at the bottom of the Annaquatucket and Pettaquamscutt sub-basins were not available, so the 7Q10 values reported in the Low Flow Report were used.

7. HSPF MODEL

To date, HSPF models have been developed for the Pawcatuck River and Blackstone River Basins. An HSPF model generates natural flow-duration curves as well as existing flow duration curves. The flow duration for the existing 7Q10 is calculated at the gage and then projected to the existing withdrawals flow duration curve. This determines the percent duration of 7Q10 under existing conditions. The percent duration is then projected upwards to determine the natural flow or natural 7Q10.

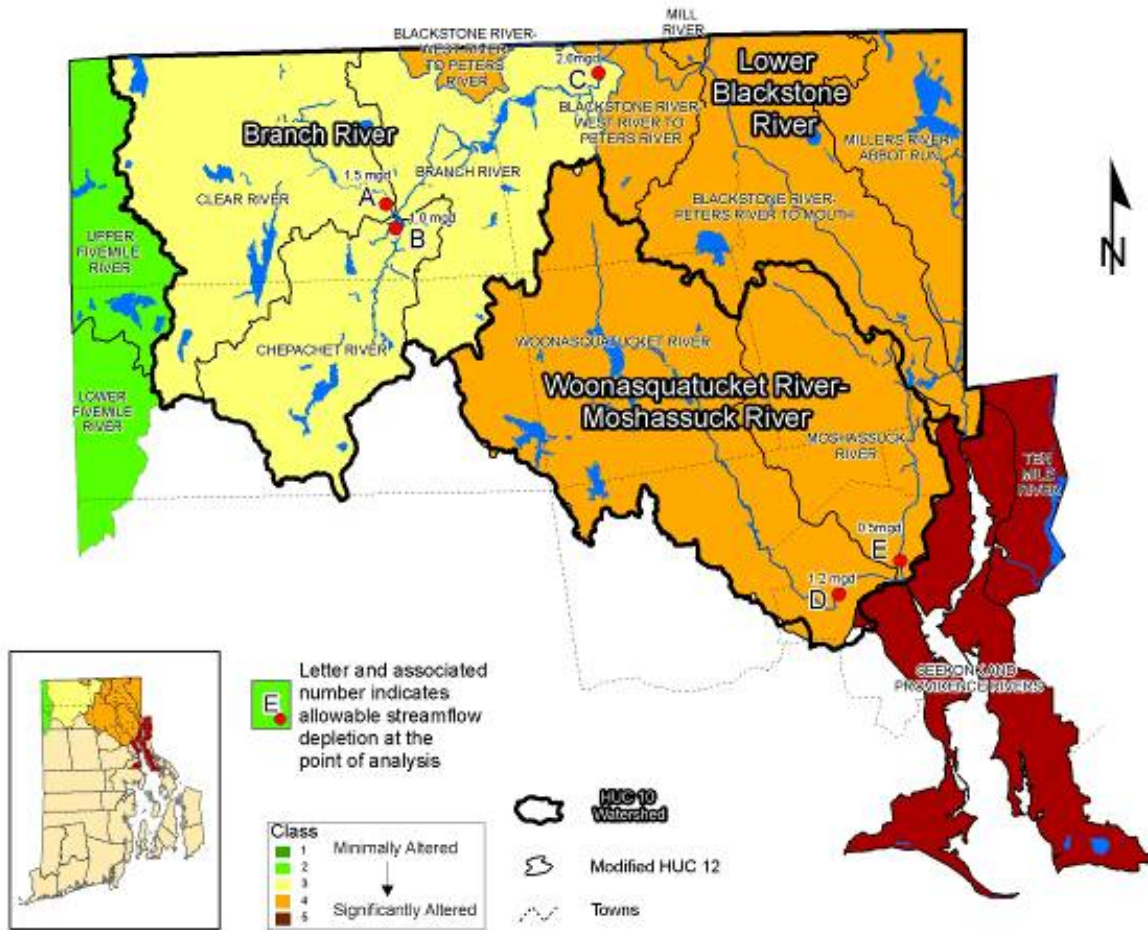


FIGURE IV-3 STREAMFLOW DEPLETION METHOD APPLIED TO SELECTED STREAMS IN NORTHERN RHODE ISLAND

TABLE IV -3 SDM ANALYSIS AT SELECTED LOCATIONS IN NORTHERN RHODE ISLAND

LOCATION	**RIVER BASIN NAME	DRAINAGE AREA (SQ.MI)	NATURAL 7Q10 (MGD)	CLASS	ALLOWABLE DEPLETION (MGD)	*REFERENCE
	BLACKSTONE RIVER BASIN					
A	Clear River	45.5	5.1	3	1.5	4.Water Availability Study
B	Chepachet River	21.3	3.1	3	1.0	4.Water Availability Study
C	Branch River	93.1	8.5	3	2.6	5. Branch River at Forestdale
	Millers River to Abbott Run					Managed Impoundment
	Blackstone R. - to Mouth					**NPDES Discharges and Hydropower
	WOONASQUATUCKET RIVER BASIN					
D	Woonasquatucket River	50.7	4.5	4	1.2	4.Water Availability Study
	MOSHASSUCK RIVER BASIN					
E	Moshassuck River	23.7	1.3	4	.5	4.Water Availability Study
*Key to Determining 7Q10						
**River Basins with NPDES Discharges and/or Managed Impoundments require site-specific analysis						

Using the best available tools, there are a number of ways that natural 7Q10 can be determined. RIDEM chose the most accurate method available for each of the locations identified above. Available methods are listed in order of increasing accuracy:

1. USGS LOW FLOW REPORT (USGS REPORT 93-4046)

In this report, 7Q10s in Washington County were estimated to be correlated to the distribution of the percentage of stratified drift and till in the upstream watershed.

2. USGS LOW FLOW REPORT (USGS REPORT 95-4299)

In this report, 7Q10s in Northern Rhode Island were estimated to be correlated to the best fit of five long-term gaging stations within Rhode Island. Estimated 7Q10s are reported within the document for 18 partial record stations. This method is similar to method 3 however, the work has been documented.

3. CORRELATE THE LOCATION TO A GAGE IN ANOTHER WATERSHED WHICH IS NATURAL

If the basin characteristics are similar, one watershed can be correlated with another watershed and the 7Q10s can be calculated by multiplying by the ratio of the watersheds. If the percent stratified drift within the watershed is known, then the correlation will include an adjustment for stratified drift and till.

4. WATER AVAILABILITY STUDIES (BASIN SPECIFIC USGS REPORTS)

The Water Use and Availability studies calculated the Estimated Gross Yield from the drift and till in each basin. The 7Q10 was extracted from this analysis by subtracting the Estimated Gross Yield for 7Q10 scenario for July (in MGD) from the Estimated Gross Yield for July (in MGD)

5. CORRELATE A GAGED NATURAL RIVER TO A POINT WITHIN ITS WATERSHED

The natural 7Q10 of a point within a gaged watershed is calculated by multiplying by the ratio of drainage area to the point of analysis to drainage area to the gauged location.

6. MODFLOW MODEL

To date, MODFLOW reports are available for the Hunt-Annaquatucket-Pettaquamscutt (HAP) Basin. The depletion from wells was added to the calculated 7Q10 to determine the natural 7Q10. Gages at the bottom of the Annaquatucket and Pettaquamscutt sub-basins were not available, so the 7Q10 values reported in the Low Flow Report were used.

7. HSPF MODEL

To date, HSPF models have been developed for the Pawcatuck River and Blackstone River Basins. An HSPF model generates natural flow-duration curves as well as existing flow duration curves. The flow duration for the existing 7Q10 is calculated at the gage and then projected to the existing withdrawals flow duration curve. This determines the percent duration of 7Q10 under existing conditions. The percent duration is then projected upwards to determine the natural flow or natural 7Q10.

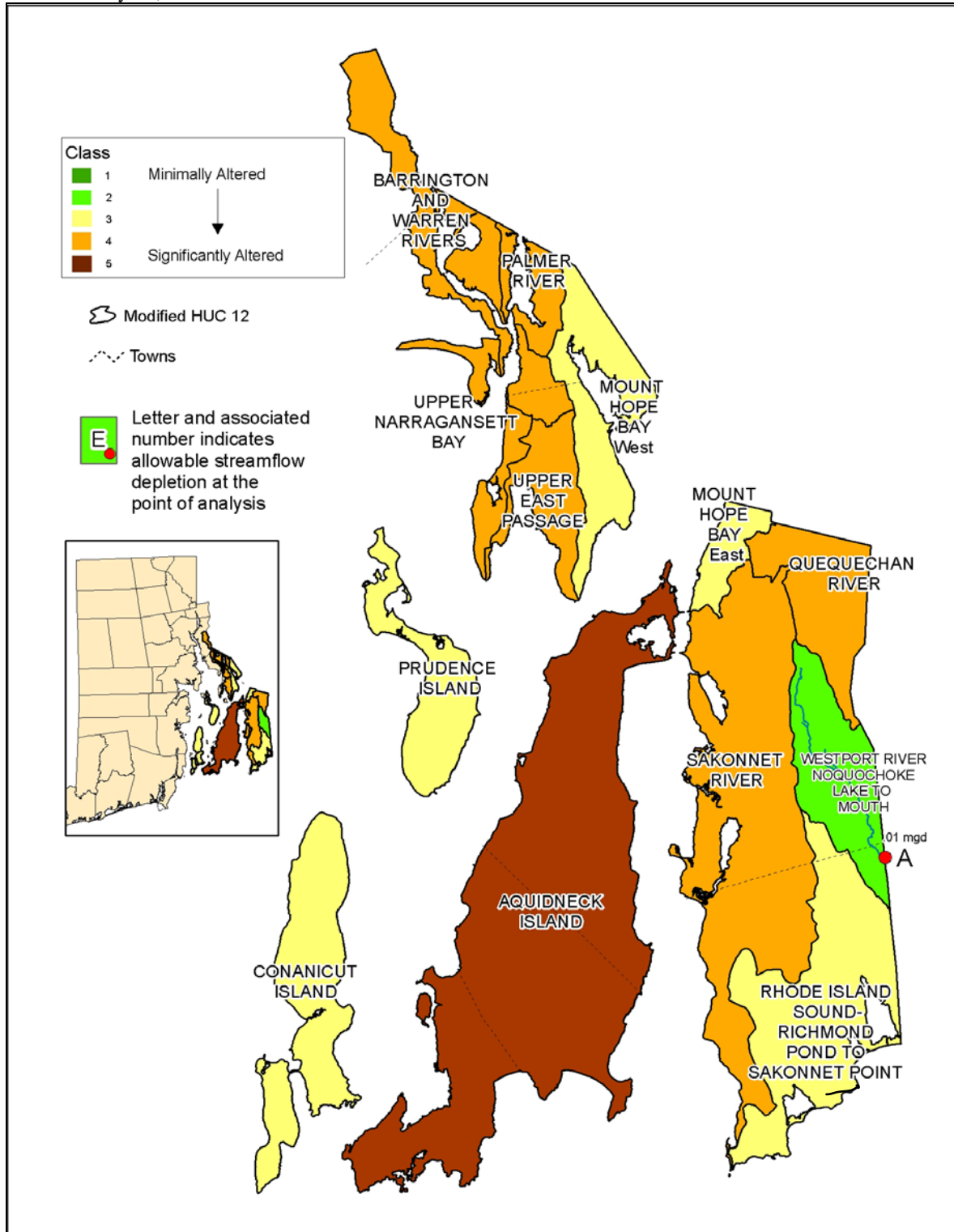


FIGURE IV-4 STREAMFLOW DEPLETION METHOD APPLIED TO SELECTED STREAMS IN EASTERN RHODE ISLAND

TABLE IV - 4 SDM ANALYSIS AT SELECTED LOCATIONS IN EASTERN RHODE ISLAND

LOCATION	NAME	DRAINAGE AREA (SQ.MI)	NATURAL 7Q10 (MGD)	CLASS	ALLOWABLE DEPLETION (MGD)	*REFERENCE
A	Westport River-Noquichoke Lake	6.8	.03	2	.01	5. Adamsville
	Conanicut Island					Managed Impoundment
	Aquidneck Island					Managed Impoundment
*Key to Determining 7Q10						

1. USGS LOW FLOW REPORT (USGS REPORT 93-4046)

In this report, 7Q10s in Washington County were estimated to be correlated to the distribution of the percentage of stratified drift and till in the upstream watershed.

2. USGS LOW FLOW REPORT (USGS REPORT 95-4299)

In this report, 7Q10s in Northern Rhode Island were estimated to be correlated to the best fit of five long-term gaging stations within Rhode Island. Estimated 7Q10s are reported within the document for 18 partial record stations. This method is similar to method 3 however, the work has been documented.

3. CORRELATE THE LOCATION TO A GAGE IN ANOTHER WATERSHED WHICH IS NATURAL

If the basin characteristics are similar, one watershed can be correlated with another watershed and the 7Q10s can be calculated by multiplying by the ratio of the watersheds. If the percent stratified drift within the watershed is known, then the correlation will include an adjustment for stratified drift and till.

4. WATER AVAILABILITY STUDIES (BASIN SPECIFIC USGS REPORTS)

The Water Use and Availability studies calculated the Estimated Gross Yield from the drift and till in each basin. The 7Q10 was extracted from this analysis by subtracting the Estimated Gross Yield for 7Q10 scenario for July (in MGD) from the Estimated Gross Yield for July (in MGD)

5. CORRELATE A GAGED NATURAL RIVER TO A POINT WITHIN ITS WATERSHED

The natural 7Q10 of a point within a gaged watershed is calculated by multiplying by the ratio of drainage area to the point of analysis to drainage area to the gauged location.

6. MODFLOW MODEL

To date, MODFLOW reports are available for the Hunt-Annaquatucket-Pettaquamscutt (HAP) Basin. The depletion from wells was added to the calculated 7Q10 to determine the natural 7Q10. Gages at the bottom of the Annaquatucket and Pettaquamscutt sub-basins were not available, so the 7Q10 values reported in the Low Flow Report were used.

7. HSPF MODEL

To date, HSPF models have been developed for the Pawcatuck River and Blackstone River Basins. An HSPF model generates natural flow-duration curves as well as existing flow duration curves. The flow duration for the existing 7Q10 is calculated at the gage and then projected to the existing withdrawals flow duration curve. This determines the percent duration of 7Q10 under existing conditions. The percent duration is then projected upwards to determine the natural flow or natural 7Q10.

APPENDIX V

STREAMFLOW DEPLETION METHOD WORKSHEET

**DEPARTMENT OF ENVIRONMENTAL MANAGEMENT
OFFICE OF WATER RESOURCES
STREAMFLOW DEPLETION METHOD WORKSHEET**

Evaluator: _____

Date: _____

Location to Determine Streamflow Depletion

River Reach Location: _____ 7Q10: _____ MGD River Reach Class: _____

TABLE 1 - ALLOWABLE STREAMFLOW DEPLETION AT THE RIVER REACH

(A) Month	(B) Flow Regime	(C) 7Q10 (MGD)	(D) %7Q10 from Table 5 in SDM document	=(C) * (D) Allowable Depletion (MGD)
October	Medium-Low			
November	Medium			
December	Medium			
January	High			
February	High			
March	High			
April	High			
May	Medium			
June	Medium-Low			
July	Low			
August	Low			
September	Low			

TABLE 2 – NET STREAMFLOW DEPLETION AT THE RIVER REACH ACCOUNTING FOR **EXISTING USERS
(ALL UNITS IN MGD)**

Month	Withdrawal #1		Withdrawal #2		**Net Streamflow Depletion
	(A) *W/d	(B) *Return	(C) W/d	(D) Return	=(A)-(B)+(C)-(D) etc. if there are more withdrawals and returns
Oct					
Nov					
Dec					
Jan					
Feb					
Mar					
April					
May					
June					
July					
Aug					
Sept					

* Water Availability Studies – or other information

** Depletion from withdrawals and returns may be counted as 1:1 or the depletion effect may be determined from modeling efforts

**TABLE 3 – NET STREAMFLOW DEPLETION AT THE RIVER REACH ACCOUNTING FOR NEW USER
(ALL UNITS IN MGD)**

Month	Requested Withdrawal	Returns to Reach from Requested Withdrawal	**Depletion Effect of Requested Withdrawal
Oct			
Nov			
Dec			
Jan			
Feb			
March			
April			
May			
June			
July			
August			
Sept			

* Depletion from withdrawals and returns may be counted as 1:1 or the depletion effect may be determined from modeling efforts

Evaluation of the Remaining Allowable Streamflow Depletion at the River Reach

TABLE 4 - ALLOWABLE WITHDRAWAL WITHIN THE SUB-WATERSHED (ALL UNITS IN MGD)

Month	(A) Allowable Depletion (Table 1)	(B) Net Stream Depletion (Table 2)	(C) Depletion effect of new user (Table 3)	(D) Total Stream Depletion =(B)+(C)	(E) *Remaining Allowable Depletion =(A)-(D)
Oct					
Nov					
Dec					
Jan					
Feb					
Mar					
April					
May					
June					
July					
Aug					
Sept					

* Negative numbers indicate that the total existing and proposed depletion exceeds the allowable depletion. Positive numbers indicate that the existing and proposed depletion does not exceed the allowable depletion as determined by SDM.