Draft Storm Water Pollutant Total Maximum Daily Load for Headwaters of the Shawsheen River

DEP, DWM TMDL Report MA83-08-2003-01   June 9, 2003
DWM Control Number CN:168.00

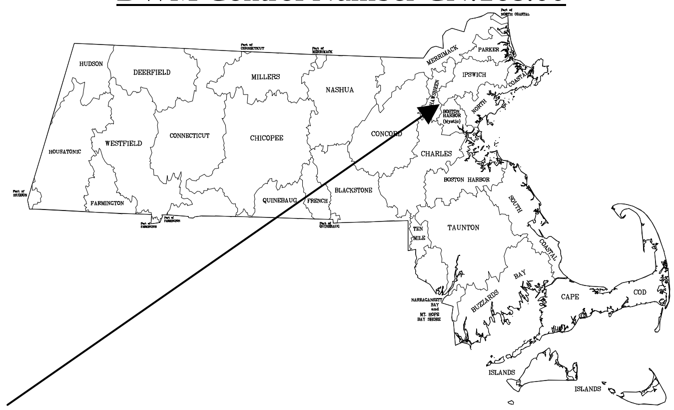
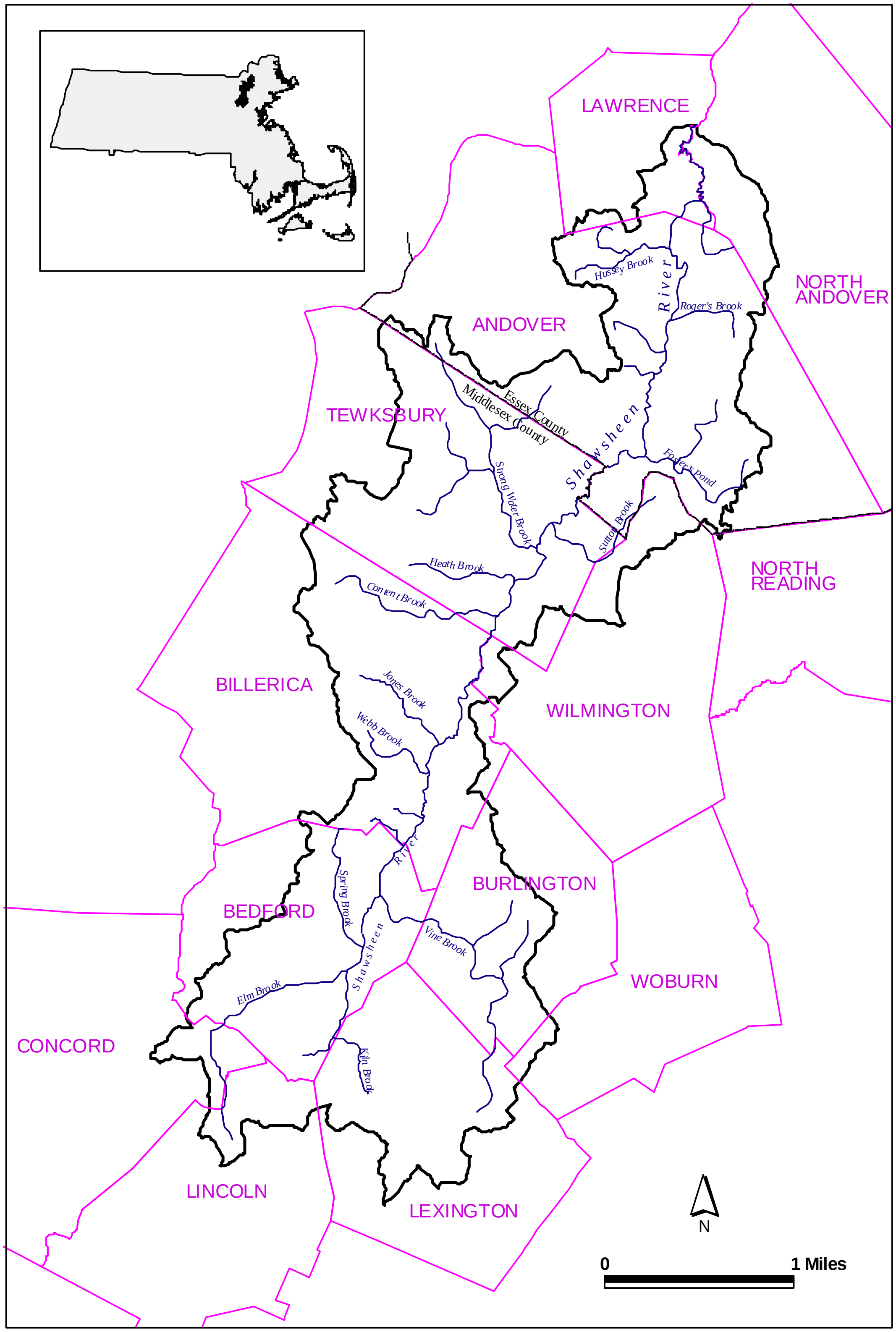


Figure 1: Location of the Shawsheen Basin in Massachusetts.

Key Feature: Storm water Pollutant TMDL for Headwaters of the Shawsheen River.
Location: EPA Region 1.
Land Type: New England Upland
303d Listings: Other Habitat Alterations (MA83-08) (Storm water pollutants).
Data Sources: Merrimack River Watershed Council, Massachusetts Department of Environmental Protection, and Land Use information.
Data Mechanism: Massachusetts Surface Water Quality Standards for Aquatic Life, Ambient Data, and Best Professional Judgment
Monitoring Plan: Merrimack River Watershed Council (MRWC)
Control Measures: Watershed Management, Storm Water Management.


LAWRENCE
NORTH ANDOVER
ANDOVER
TEWKSBURY
Essex County
Middlesex County
Shawsheen River
Hussey Brook
Roger's Brook
Foster's Pond
Strong Water Brook
Sutton Brook
Heath Brook
Content Brook
NORTH READING
BILLERICA
WILMINGTON
Jones Brook
Webb Brook
BURLINGTON
BEDFORD
Spring Brook
Vine Brook
WOBURN
Elm Brook
CONCORD
Kiln Brook
LINCOLN
LEXINGTON
N
0
1 Miles

Storm Water Pollutant TMDL for the Shawsheen River Headwaters
Executive Summary

The Department of Environmental Protection (DEP) is announcing that the Draft Total Maximum Daily Load (TMDL) for Stormwater in the Shawsheen River Headwaters Report number MA 83-08-2003-01 (CN: 168.0), is available for public comment. This Draft TMDL Report is required by the Federal Clean Water Act section 303d.

A TMDL is essentially a "pollution budget" and a cleanup plan designed to restore the health of an impaired waterbody. DEP has prepared a TMDL for controlling stormwater runoff and its associated pollutants in the Shawsheen River Headwaters (mile points 27.0 through 25.0) (Report number MA 83-08-2003-01). During rain events, stormwater pollutants (e.g., sediment as reflected in suspended solids, metals, etc.) are entering the headwaters of the Shawsheen River and impairing aquatic life uses and impacting river habitat.

A copy of this Draft TMDL Report, a complete listing of all lakes, rivers and coastal waters on the Massachusetts 303d impaired list and further explanation of the TMDL Program is available on DEP's website at http://www.state.ma.us/dep/brp/wm/tmdls.htm

This Stormwater TMDL (cleanup plan) covers the headwaters of the Shawsheen River mile points 27.0 through 25.0 (MA-83-08). The sub-watersheds included are: Hanscom Air Force Base and Hanscom Air Field, which drain portions of the following towns:

Bedford and Lincoln

The headwaters of the Shawsheen River are affected by the dramatic change in land use occasioned by the replacement of wetlands with the airport and airfield dating from the early years of World War II. As such, the drainage from the area has been greatly affected both in quality and quantity. With the substantial increase of impervious surface accompanying the development of the air base, runoff from storm water increased in volume and rapidity. As such, sediment and other pollutants from impervious surfaces as well as in-stream erosion adversely impact aquatic life. At the same time, reduction of infiltration to the ground water system diminishes in-stream flow during dry periods, thus stressing aquatic life. To address the impacts from storm water pollutants, a total maximum daily load (TMDL) has been developed for generalized storm water pollutants. The goal is based on the protection of aquatic life as required by Massachusetts Water Quality Standards and the vehicle for regaining this use is to match the hydrology of a nearby reference stream, which has been judged to have a balanced indigenous biota. A side benefit from reducing the impact of storm water runoff is the augmenting of stream flow during dry periods, which lessens the stress on the aquatic life community.

The TMDL calls for storm water and watershed controls, which will mitigate the peaks in runoff from storms through promotion of infiltration of storm water into the ground. This has the dual benefit of reducing peak flows, which contribute to erosion and increasing groundwater recharge which helps maintain in-stream flows during dry periods thus helping maintain aquatic life.

The US Air Force has taken steps already to ameliorate the situation by instituting some control measures to reduce peak flows from storm water runoff. Both the Air Force and Mass Port have indicated a willingness to pursue other measures to help achieve the goals set forth in the TMDL.

DEP Overall Summary of the Main Points of the Shawsheen River Headwaters Storm water Pollutant TMDL

1. Description of Waterbody, Pollutant of Concern, Pollutant Sources and Priority Ranking

The description of the Shawsheen River and pollutant of concern (storm water runoff and its associated pollutants) are presented in the introduction of the accompanying technical report titled: Storm Water Pollutant TMDL for the Shawsheen River Headwaters authored by Tham Savrarvanapana of the Merrimack River Watershed Council, Lawrence, MA. The TMDL covers the headwaters of the Shawsheen River mile points 27.0 through 25.0 (MA-83-08). Pollutant sources are summarized in the section 2 titled Problem Assessment. Priority rankings are based on the Watershed Cycle established by the Massachusetts Secretariat of Environmental Affairs.

A description of the location of sampling stations and data collected also is presented in Section 2 of the document that follows and the report titled Shawsheen River Watershed 1996-1998 Volunteer Monitoring Report by L. Mattei et al., Merrimack River Watershed Council, Lawrence, MA.

2. Description of the Applicable Water Quality Standards and Numeric Water Quality Criteria

The Massachusetts Water Quality Standards call for all water classes to be good or excellent "… habitat for fish, other aquatic life…" The upper portion of the Shawsheen River does not meet the goal for aquatic life. This conclusion is based on biological assessments of fish and macroinvertebrate communities as well as observed habitat alterations. For this type of impairment, only the narrative criterion applies and is based on the afore mentioned comparison using biological measures.

In the case of the unnamed brook originating and passing through the Hanscom Air Force Base and the MassPort Airport, reference conditions have been established using the nearby Elm Brook as the goal. To determine if the goal of the TMDL is met, rapid bio-assessment sampling techniques will be used. The goals will be considered to be achieved when the Division of Watershed Management's multi-metric index values for the stream through Hanscom is not different from that of Elm Brook at the 90% confidence level based on three 100 organism samples.

3. Loading Capacity - Linking Water Quality and Pollutant Sources

The loading capacity of storm water and its pollutants is determined by the comparison of the current hydrograph for the Hanscom tributary to that of Elm Brook. A combination of best management practices (BMPs) for storm water control and pollution prevention measures is expected to achieve the water quality goal of this TMDL. This topic is examined in detail in Section 2.5 and Sections 4 and 5 of the technical report by the Merrimack River Watershed Council.

4. Load Allocations (LAs)

Storm water flow from the Hanscom Air Force Base and the MassPort Airport are subject to NPDES storm water permits. As such, flow entering from these areas is considered to be from point sources so the Load Allocation is set to zero. This is discussed in detail in Sections 5 and 6 of the accompanying technical report.

5. Wasteload Allocations (WLAs)

The waste load allocation for storm water pollutants is conveyed through the surrogate measure of the target hydrograph supplemented by pollution prevention efforts and installation of storm water BMPs. This is discussed in detail in Sections 5 and 7 of the accompanying technical report.

6. Margin of Safety (MOS)

This TMDL is based on a reference site, specifically, Elm Brook. As such, it is believed that controls for storm water pollutants for the Hanscom site will achieve the water quality goals once the hydrograph of the Hanscom stream approximates that of Elm Brook. Meeting the hydrograph objective may be a sufficient but not a necessary condition in order to achieve the biological and water quality goals. Thus, the Margin of Safety is incorporated into the hydrograph objective through conservative assumptions. In addition, pollution prevention measures should help ensure water quality objectives are met.

7. Seasonal Variation

Variation in flow is being used as the surrogate for seasonal variation. The target hydrograph is a reflection of this goal.

8. Monitoring Plan for TMDLs Developed Under the Phased Approach

Monitoring to assess the success of the efforts to control the impacts from storm water pollutants will be conducted on the watershed cycle. It is anticipated that monitoring especially of macroinvertebrates will be a key aspect of the overall assessment effort.

While monitoring by the Massachusetts Department of Environmental Protection will follow the watershed cycle, this does not preclude efforts by other groups to monitor on a more frequent basis. DEP will work with any and all such groups to ensure all data are compatible and comparable. The next regularly scheduled monitoring of the Shawsheen River by MA DEP is in 2007. While resources and priorities will determine the systems actually monitored, this upper portion of the Shawsheen River should rank high—especially if substantial control efforts have been implemented.

9. Implementation Plans

The objective of this TMDL is to specify reductions in storm water pollutant loads and other associated stressors so that aquatic life uses can eventually be met. The detailed discussion of this topic is presented in Section 10 of the accompanying report. Existing and any increase in impervious areas will be targeted for runoff controls so that wet weather loads do not exceed current contributions from this source.

10. Reasonable Assurances

Many pollution prevention measures have already been undertaken by Hanscom Air Force Base. The United States Air Force has contracted with the Merrimack River Watershed Council to identify, screen, select and size BMPs to be installed on the USAF premises to meet the TMDL surrogate target.

MassPort Authority is working on identifying solutions to reduce runoff from the runways (Personal communication with Keith Beasley, PE, Pollution Prevention Manager, MassPort Authority)

11. Public Participation

To be Completed.

Some public involvement has been accomplished through Shawsheen Watershed Team meetings. Publication of this document on the web and a public meeting will further public participation. Response to comments received will be included in the final version of this document.

TMDL: Storm water Pollutants Shawsheen River Headwaters (MA-83-08), between river miles 27.0 and 25.0.

Author: Tham Saravanapavan, Merrimack River Watershed Council

1. Introduction

1.1 Background

Section 303(d) of the Clean Water Act requires States to report all impaired or threatened water bodies that are not meeting water quality goals, despite the application of required technology based control measures, to the EPA. Furthermore, Section 303(d) requires States to develop Total Maximum Daily Loads (TMDLs) for each 303(d) impaired water body. The Upper Shawsheen River headwaters is listed on the 1998 Massachusetts Department of Environmental Protection (MADEP) 303(d) list, which was approved by the Environmental Protection Agency (EPA).[1]

The Upper Shawsheen River (MA-83-08) is listed for "Other Habitat Alterations" between river miles 27.0 and 25.0, roughly from north of Folly Pond and North Great Road, Lincoln to Summer Street, Bedford[2]. This reach of river flows partially through the Hanscom Air Force Base, receiving storm water runoff from areas draining base housing, facilities, and airfields. The river is enclosed in storm drains for approximately 500 feet, running south to north along the east edge of Hanscom Airfield. The natural stream has been channeled to facilitate storm water conveyance.

The purpose of this report is to establish a TMDL to address the aquatic life impairments associated with stormwater in the headwater segment of the Shawsheen River. The goal of this TMDL is to provide the basis for improving the river ecosystem by reducing pollutant loading associated with stormwater runoff, such that the beneficial uses of the segment is restored.

1 Massachusetts Department of Environmental Protection, Division of Watershed Management, Final Massachusetts Section 303(d) List of Waters -1998, February 1999.
2 Same as Note 1.

1.2 Shawsheen Headwaters and Watershed

The Shawsheen headwaters and watershed (Figure 1) includes drainage from the Hanscom Air Force Base (HAFB), with the exception of the research and development area located in the eastern part of the base that drains into the Kiln Brook sub watershed, and the southeastern part of the Hanscom Air Field (HAF). The Shawsheen River originates in a swamp area north of Folly Pond and North Great Road and flows north through an open channel to the culvert near the intersection of Marrett Street and Bedford Road. Two unnamed tributaries, one originating at the Lincoln Housing Scheme that flows through an open channel and the other originating near Liberty Lane, meet and combine near the parking lot on the right side of Langley Road; the combined stream flow is then routed through concrete pipes and joins the Shawsheen River near Lincoln School. At the intersection of Marrett Street and Bedford Road, the Shawsheen enters enclosed conduits, resurfacing as an open channel again along the taxiways of HAF (approximately 2800 feet to the north). The Shawsheen receives stormwater runoff from HAF through eight concrete pipes and flows northeast to the boundary of the base through a wide and deep open channel. A USGS continuous flow gage, installed by HAFB and USGS in 1995, is located about 1500 feet downstream from the pipe outfalls.

Native soils have been drastically modified by construction and earthworks associated with the installation of the HAFB. Because of the generally low degree of relief and glacial effects, there were numerous wetlands and swamps on the base and in surrounding areas. While adjoining sub-watersheds, like Kiln Brook and Elm Brook, still have significant amounts of wetlands and swamps, much of the original wetlands and swamps in the Hanscom sub watershed have been filled to accommodate the construction. The Natural Resources Conservation Services (previously known as Soil Conservation Services) has classified most of the soils on the base as “made land”-which is land that has been altered or disturbed by buildings, industrial areas, paved parking lots, and yards. In general, most of the soils at HAFB and HAF, especially in the areas with low degree of relief fall into Hydrologic Soils Group C, indicating a slow rate of water infiltration when soils are thoroughly wetted. However, areas with a high degree of relief fall into Hydrologic Soil Groups B and A, soils with a fast rate of water infiltration.

The watershed is highly developed, including substantial infrastructure, residential housing, runways, and other support facilities (e.g., school, hospital, office complexes, etc.) and the river is significantly altered by channelization, culvertization, riparian encroachment, road crossings, and hydromodification.

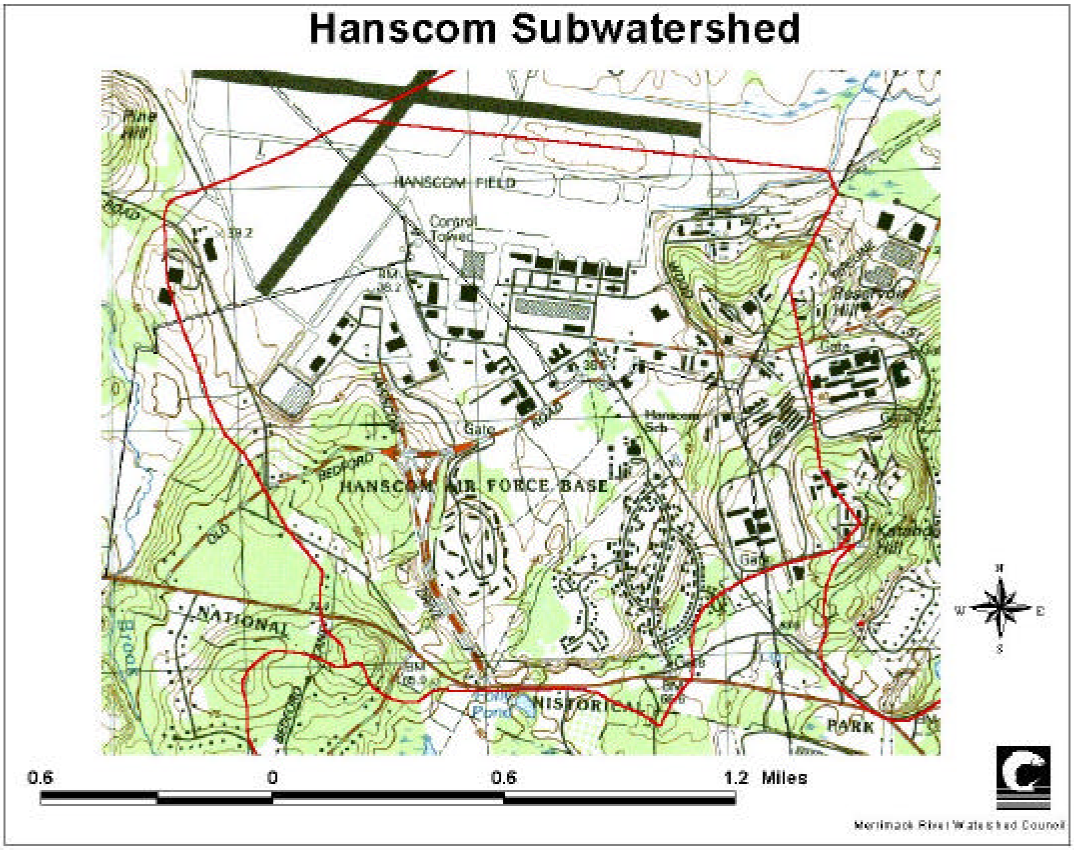


Figure 1. Drainage area of impaired segment. It includes Hanscom Air Force Base and supporting facilities (housing, research facilities, laboratories, etc.) and portion of Hanscom Air Port, owned by Massport Authority.

2. Problem Assessment

The headwater of the Shawsheen River is a Class B freshwater, as identified under Massachusetts Water Quality Standards and has a designated use of Aquatic Life.[3] However, the headwater of the Shawsheen River has been assessed by MADEP as not fully supporting a healthy aquatic life community that is consistent with the narrative criteria in Massachusetts Water Quality Standards. Based on extensive data and modeling analyses, and an inventory of potential pollution sources, a combination of several factors have been identified as potentially causing non-attaining aquatic life uses. These factors include contaminants associated with storm water runoff (e.g., sediments, metals, etc.), excessive storm water flow rates, and insufficient stream flow rates.

2.1 Land Use Changes

The installation of the Hanscom Air Force Base (HAFB) in 1942 was one of the most striking changes to the nature of the upper Shawsheen watershed. Figure 2 compares recent topography with a background one. Significant amount of pervious land has been converted to impervious land as a result of the construction of runways, office buildings, parking lots, roads, residences, etc (Figure 3). Major alteration to the natural hydrology at HAFB and the surrounding communities greatly contributed to the water quality and flow problems in this watershed.

[3] Commonwealth of Massachusetts, Department of Environmental Protection, 314 CMR 4.00: Massachusetts Surface Water Quality Standards, 2001.

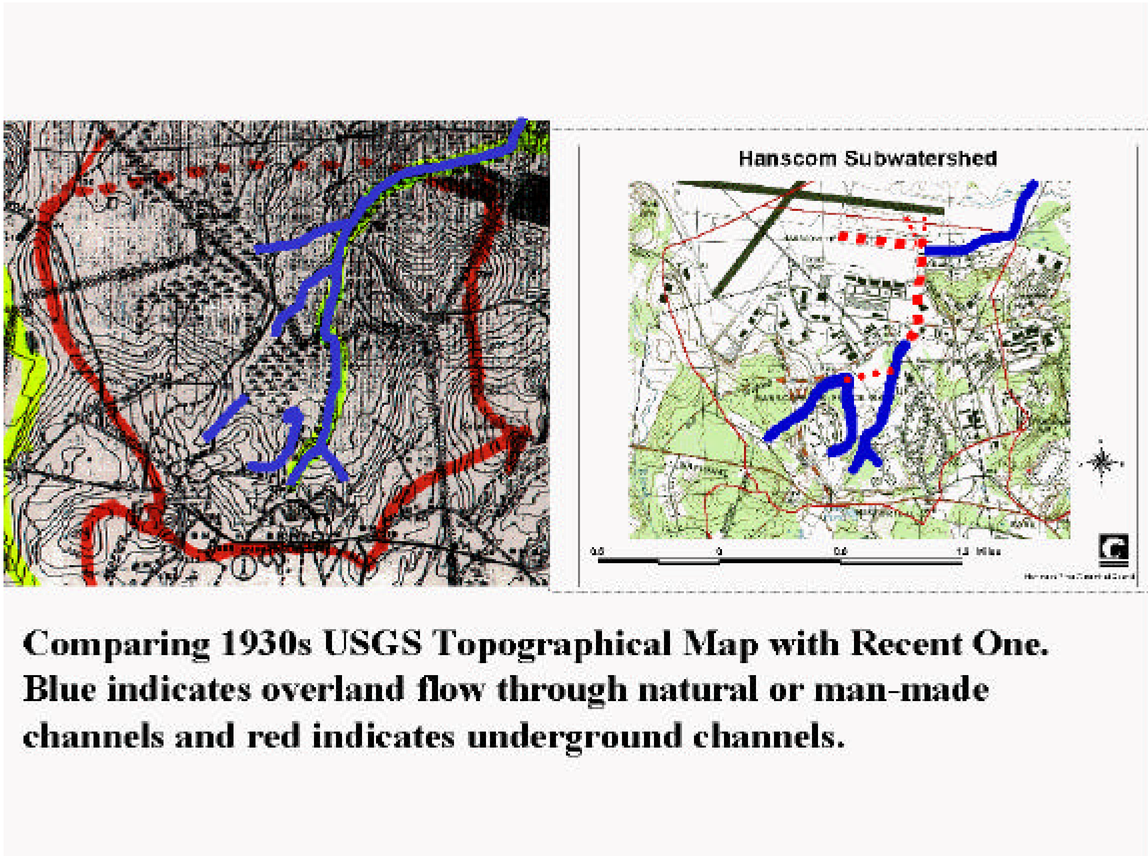


Figure 2. Comparing current topography with background one.

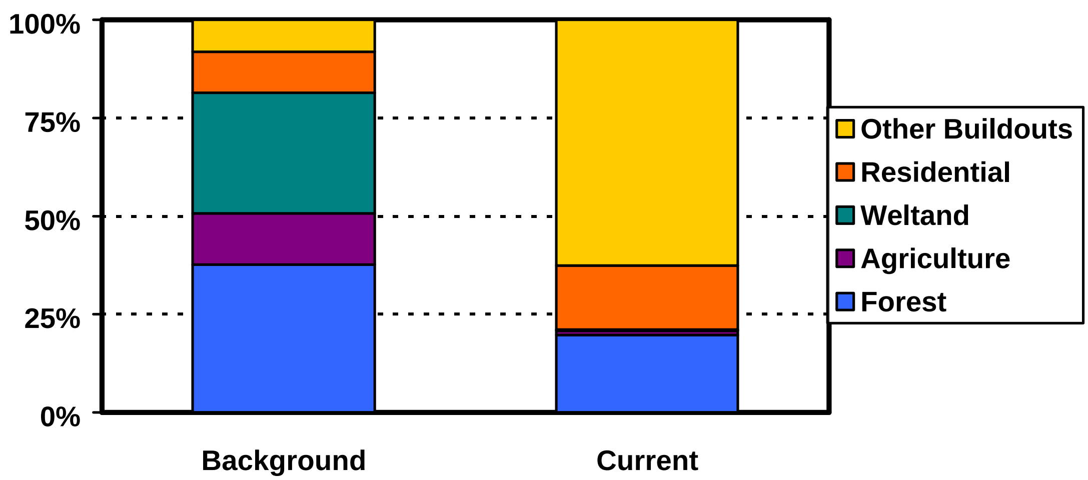


Figure 3. Major land uses in the Hanscom subwatershed

2.2 Hydrology and Aquatic Life impairments

USGS Gauge Flow Data

Flow data was analyzed for biological suitability, and determined an important habitat variable. Flow is important because it forms habitat via sediment distribution (e.g., channel formation), transports energy (e.g., food transport), and defines habitat niches for various species and life stages of aquatic organisms. Based on land use analysis, significant impacts to the Upper Shawsheen River hydrology are expected. This expectation is confirmed by flow data analyses. Flow data, from the USGS for the 1995, 1996, and 1997 water years (October 1, 1995 to September 30, 1998), was analyzed.

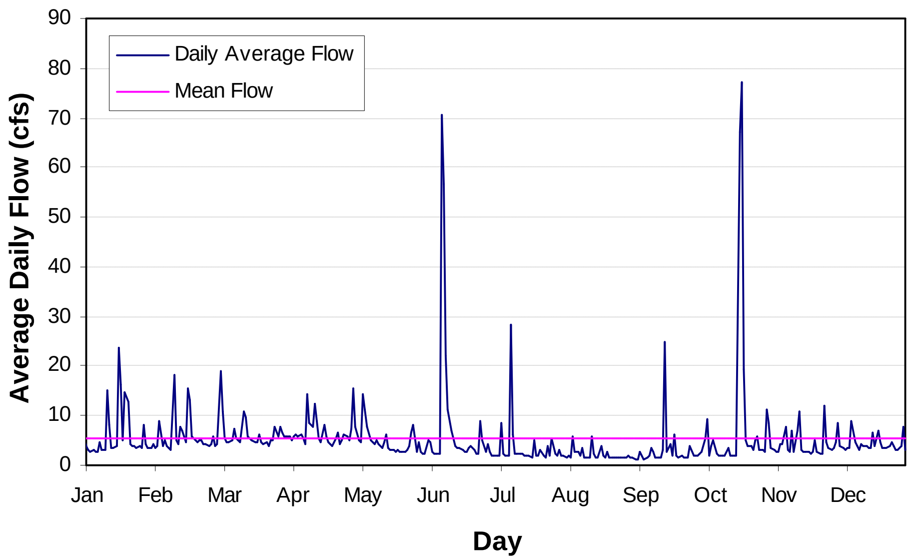


Figure 4. Average daily flow and mean flow of record (10/01/1995 – 09/31/1998) for discharge data obtained at the USGS Hanscom gauging station.

Substantial reductions in stream base flows reduce habitat abundance and increase the concentration of pollutants. Elevated water temperatures are often associated with decreased flows because of shallower flow depths in the stream channel and the reduction of cooler groundwater entering the channel which typically comprises most of the stream's base flow. Conversely frequently occurring high flows resulting from high runoff rates from impervious areas, adversely impacts aquatic organism survival and reproduction due to the poor quality of the runoff and by decreasing channel stability and destroying useful habitat through scouring or excessive sediment deposition. While infrequent flood flows are a healthy component of stream hydrology, abnormally frequent high-flow events cause long-term instability and biological degradation. To illustrate the "flashiness" of flow in the Shawsheen Rive the daily average flows compared to the mean flow is plotted in Figure 4.

GWLF Model Development and Application

A screening-level analytical tool, Generalized Watershed Loading Function (GWLF) model, was developed and applied as to assess the watershed hydrology. GWLF was applied for a ten-year period (April 1989 - March 1999) to obtain the long-term water balance presented in Table 2. The calibration and validation of the model is documented by Merrimack River Watershed Council in its report entitled Water Flow Analysis – Shawsheen River Basin[4] and the details are also well documented in the EPA approved Quality Assurance Project Plan (QAPP) (Attachment 1) for this project.

Table 1. Ten-year (4/89–3/99) water balance[1] results from application of GWLF v2.0 for the Shawsheen River headwater sub-basins.

Sub-watershed	**Basin Area** (mi^2)	**Precipitation** (inches)	**Ground Water** (inches)	**Surface Runoff** (inches)	**Stream Flow** (inches)	**% Ground Water**
Hanscom[2]	2.03	53.7	9.4	18.7	28.3	33%
Kiln Brook	4.66	53.7	13.8	10.7	24.4	57%
Elm Brook	5.84	53.7	15.0	9.0	24.0	63%
Spring/Beaver/Upper Shawsheen	5.33	53.7	14.8	9.3	24.1	61%
Vine Brook	9.94	54.0	17.6	11.7	29.4	60%

Table 1 presents the water balance and the estimated relative contribution of groundwater baseflow for the Hanscom sub-watershed (impaired site) and surrounding sub-watersheds. The percentage of groundwater baseflow to stream flow ranged from a low of 33% in the Hanscom sub-watershed to a maximum of 63% in the Elm Brook among sub-watersheds in the upper Shawsheen. The average condition for the entire Shawsheen River watershed is 57%. In general, the ground water contribution is reduced from natural conditions throughout the watershed due to urbanization.

4 Merrimack River Watershed Council, Water Flow Analysis-Shawsheen River Basin, Report –I, October 2000.

Urbanization contributes to unstable flow conditions, (highly variable flow rates over short periods of time) with large volume of surface runoff and reduced groundwater recharge and stream baseflow, leading to degradation of habitat and aquatic life.

GWLF was also applied with the land use data from the aerial photos of 1938 to evaluate differences in hydrology between current and pre-development conditions in these watersheds. Figure 5 compares the current baseflow condition with the pre-development state. Based on the land use data derived from aerial photograph of 1938 (before the Air Force Base was built), the percentage of base flow was 71% in the Hanscom sub basin and decreased to 33% due to the significant land use changes. One can infer that increased impervious cover of the watershed results in reduced groundwater recharge and stream baseflow due to increased surface runoff. Increased surface runoff and associated pollutants washed from impervious surfaces are believed to be the primary causes contributing to the aquatic life impairments.

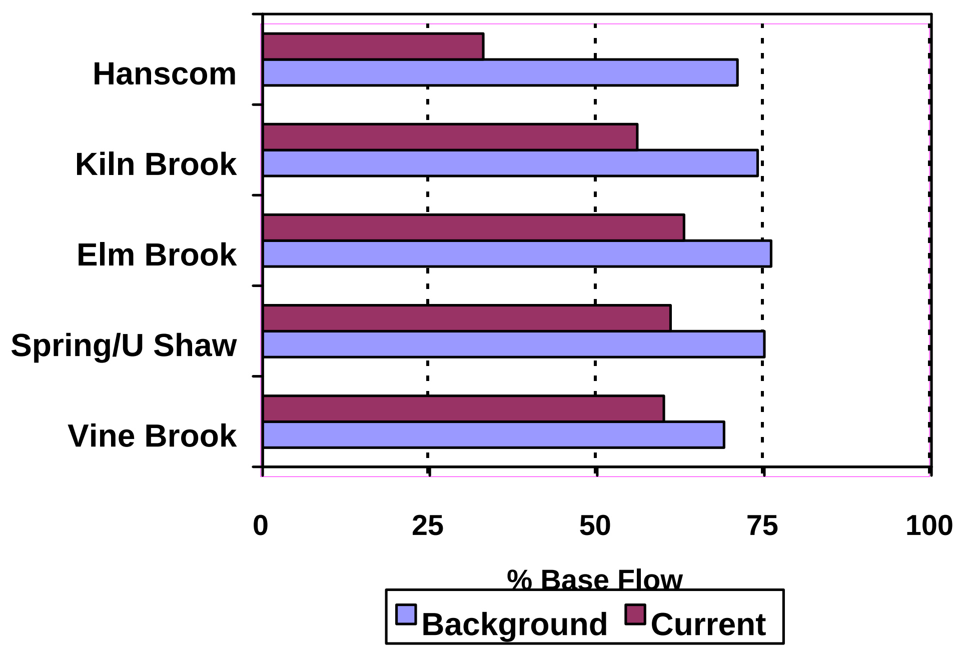


Figure 5. Background and current baseflow contribution in the streamflow

Flow Duration Curve

One way to analyze the system hydrology is through a flow-duration curve. Flow duration curves show the percentage of days during a period of record that flow exceeds a certain flow value. Because actual flow rates can vary considerably between sites, they are normalized by the median flow (i.e., normalized flow = observed flow/median flow of record) to facilitate cross-comparison from one watershed to another or between separately gauged sites. The median flow is exceeded 50% of the time. The two extremes can be represented by the ninety-five percent (low flow) and five-percent (high flow) exceedance flows, expressed as a percent of the median flow.

The flow duration curve for the Hanscom sub-watershed (Figure 6) was developed using the daily output of flow over a 10 year period (1990-1999) using the GWLF model. The ninety-five percent exceedance flow is equal to 33% of the median and the five-percent exceedance flow is equal to 571% of the median. Based on these results, we expect habitat and, consequently, biological communities of the Upper Shawsheen River to be impaired due to hydromodification and the increased pollutant load associated with land use changes.

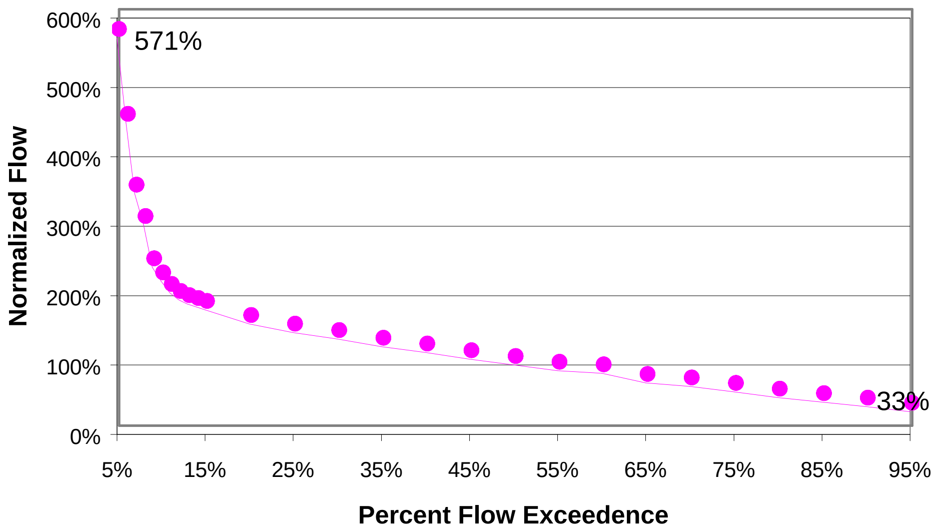


Figure 6. Flow duration curve for the Shawsheen River headwaters using GWLF simulated flow from (04/01/1989 –03/31/1999).

2.3 Water Quality and Aquatic Life Impairment

Stormwater quality testing and biological assessment was carried out by Rizzo Associates[5]. Merrimack River Watershed Council (MRWC) carried out habitat assessments[6] and macroinvertebrate surveys[7]. These studies provide insight into the

sources of pollutants associated with habitat impairment in the Shawsheen. Rizzo Associates' water quality assessment program was specifically designed to evaluate the overall ecological

5 Rizzo Associates, Inc., Hanscom Air Force Base Stormwater Quality Testing Program, January 1996.
6 Merrimack River Watershed Council, 1997 Habitat Assessment Report, 1998.
7 Merrimack River Watershed Council, Benthic Macroinvertibrates Survey Report, 1999.

condition at the headwaters of the river by including the three elements of ecological integrity: chemical, physical, and biological as defined by the Environmental Protection Agency (EPA-440/5-90-004). Figure 7 shows the locations of sample sites. An extended list of parameters[8], including Total Suspended Solids, Fecal Coliform, Nutrients, Hydrocarbons, Metals, etc., were chosen to provide a wide range of screening for potential contamination. Whole Effluent Toxicity (WET) tests were also carried out at all three stormwater sampling sites.

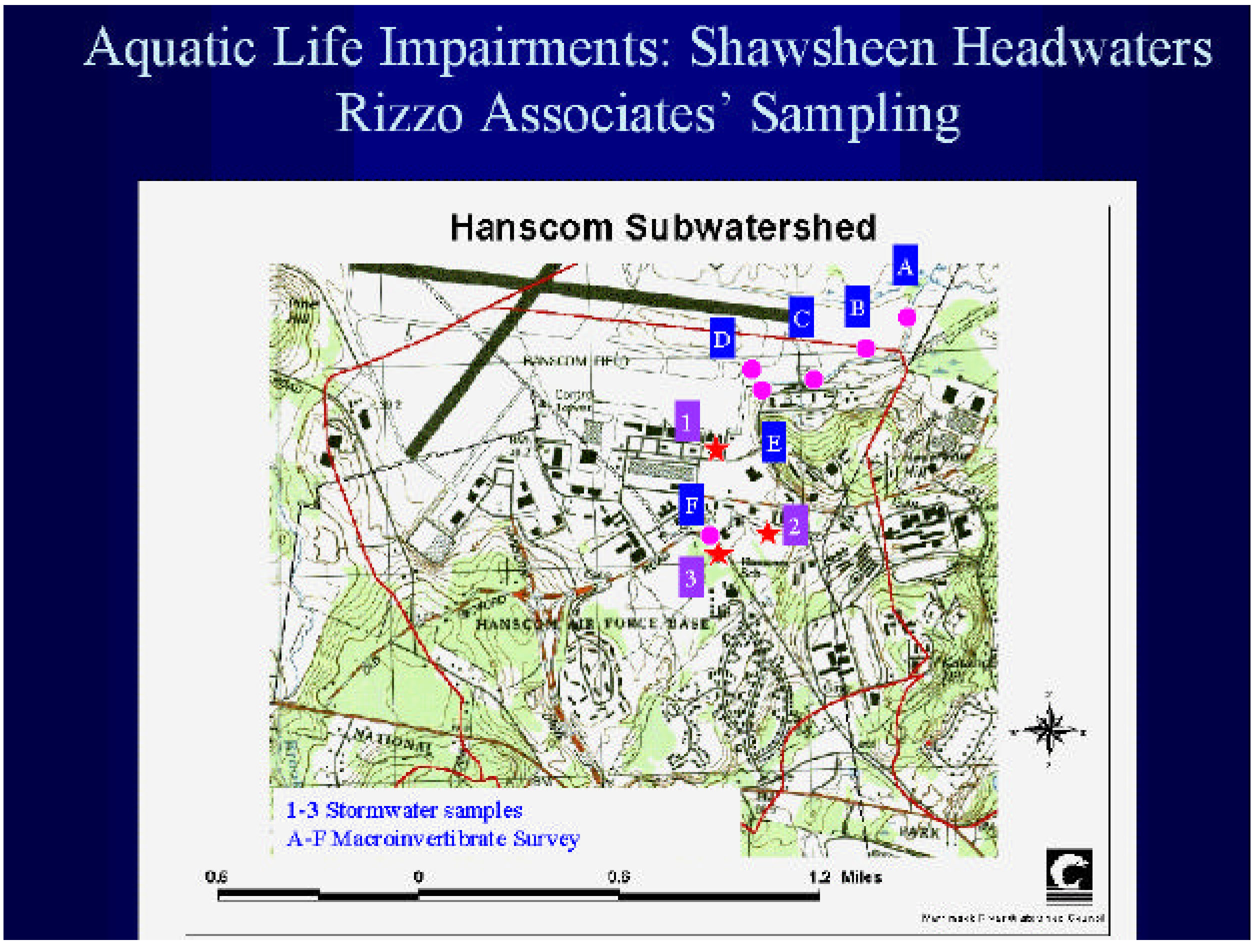


Figure 7. Sampling sites in purple and star are wet weather water quality assessment locations and sites in blue are macroinvertebrate and habitat survey locations.

Storm water sampling did not detect the presence of volatile organic compounds

(VOCs), polynuclear aromatic hydrocarbons (PAHs), or petroleum hydrocarbons and the WET tests revealed that the samples were not acutely toxic. However, concentrations of copper at sites 1 and 3, zinc at site 1, and silver at all locations are excessive, especially with a very diluted

8 Same as 5

situation with a high velocity runoff from Hanscom. Although Rizzo Associates concludes that except for silver, stormwater samples were typical of Urban Runoff (Using NURP values), elevated levels of metals are believed to partially contribute to the aquatic life impairments in this segment.

Rizzo's biological assessment was conducted in the upper one-half mile of the Shawsheen River. River substrate and bank materials, aquatic and terrestrial vegetation, water quality, aquatic macroinvertebrate populations, and habitat characteristics were investigated. Sampling locations are noted as A-F in Figure 7. In general, species diversity decreased in the upstream direction (A (fair) > B > C > D > E > F (the poorest)). Excessive sediment deposition was identified at C, D, E, and F. The sediment deposits at site F are of the highest because of the presence of fine silts and reduced species diversity.

MRWC's aquatic assessments (Employed the procedures and methodology of River Watch Network's Benthic Macroinvertebrate Monitoring Manual [9, 10]) included four sites of habitat survey (UH1-UH4) and one site of macroinvertebrate survey (UB1) in 1997 and two sites of both macroinvertebrate and habitat surveys (SH0.0 & SH0.3) in 1998 (Figure 8) within the segment of this TMDL development.

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[9] Dates, Geoff, and Jack Byrne, Benthic Macroinvertebrate Monitoring Manual, River Watch Network, Montpelier, VT, 1995.
[10] Klem, Donald J., et al., Macroinvertebrate Field and laboratory Methods for Evaluating the Biological Integrity of Surface Waters, Report # EPA/600/4-90-030. U.S. EPA, Environmental Monitoring Systems Laboratory, Cincinnati, OH, November 1990

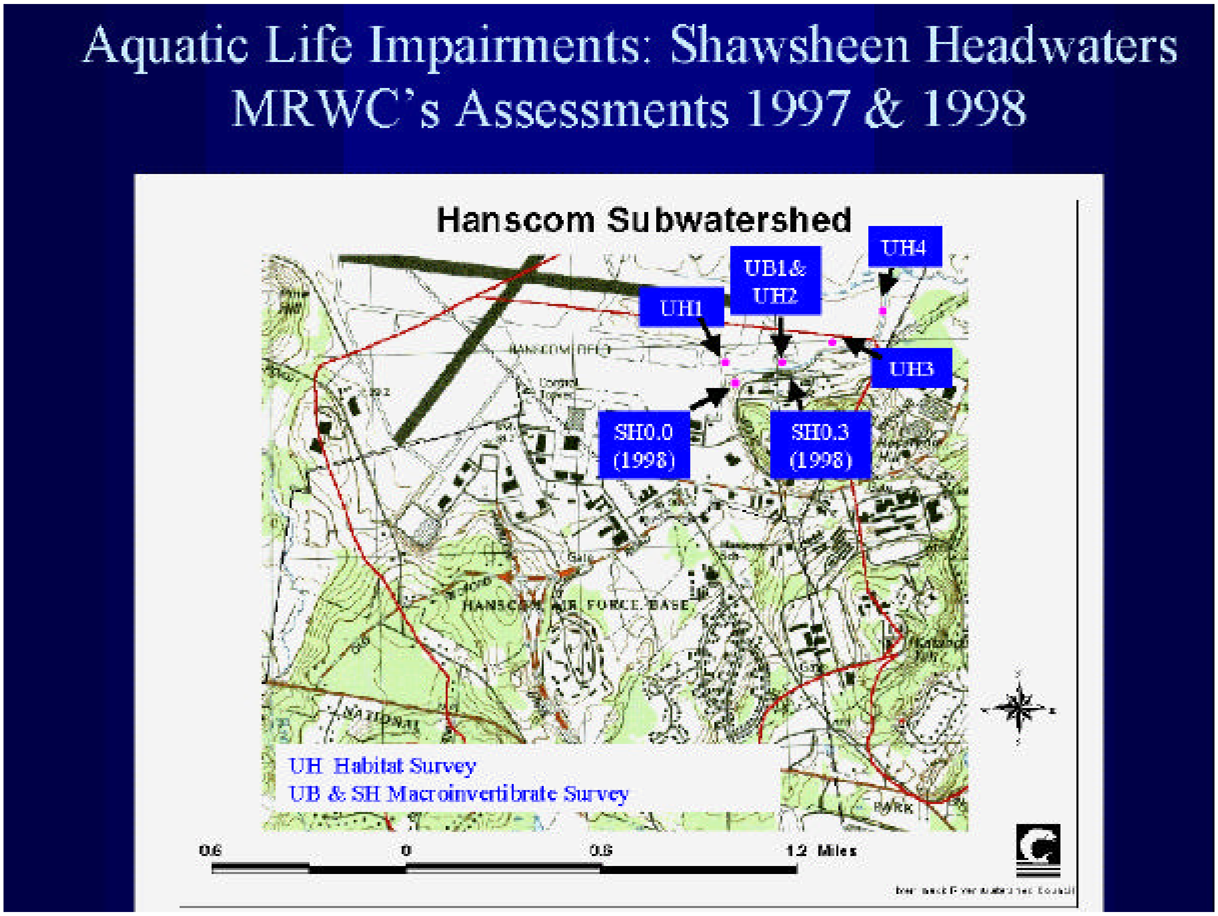

Figure 8. Locations of MRWC survey sites. UH1, UH2, UH3, and UH4 are habitat survey sites and UB1 is macroinvertebrate survey site in 1997. SH0.0 and SH0.3 are both habitat and macroinvertebrate sites in 1998.

Habitat conditions were "poor" at all sites except "fair" condition at UH4, the downstream site. Poor habitat conditions were generally associated with poor pool substrate characterization, poor pool variability, excess sediment deposition, lack of channel sinuosity, and poor channel flow status. The macroinvertebrate survey in 1997 concluded that site UB1 was seriously impaired due to an abundant presence of pollutant tolerant species (Midges, Craneflies, Scuds, etc) and lack of presence of pollutant intolerant species (Mayflies, Stoneflies, etc.). In the 1998 survey, both sites (SH0.0 & SH0.3) were found seriously impaired and benthic communities at these sites were composed of more pollutant tolerant families and generally associated with water polluted with organic matter or material. All these observations confirm that the habitat impairment is partially associated with the pollutants transported in the stream.

2.4 Uncertainty Associated with Multiple Stressors and TMDL

Based on previously mentioned data collection and analyses, the stressors believed to be impacting aquatic life/habitat in the headwaters of the Shawsheen include contaminants associated with storm water runoff (e.g., sediments, metals, etc.), hydrologic modifications (excessive and insufficient stream flow rates), riparian corridor encroachment (the area and landscaping adjacent to the stream), and channel alteration.

There are many stressors that may be acting either in an individual or cumulative manner to cause the impairment. However, it is very difficult to determine the exact role and significance that each pollutant/stressor plays in contributing to the impairment to aquatic life. However, based on available information it can be safely inferred that the impairments are related to extensive development of the watershed. In cases where there are multiple stressors contributing to aquatic life impairments, it is very difficult to meaningfully identify appropriate loading capacities for each individual stressor within the TMDL process. Therefore, this TMDL proposes to use pollutant loading from storm water runoff as a surrogate for all stressors. Using storm water pollutant loading as an umbrella surrogate for all stressors contributing to the aquatic life impairment is particularly appropriate for this TMDL since all stressors (pollutant loading, habitat destruction and hydrologic alteration) are related to storm water runoff. Furthermore, the key stakeholders (MA EOEA Watershed Team, MA DEP, US Air Force, Massport Authority, US EPA, Merrimack River Watershed Council, etc) agree that the major cause of aquatic life impairment is storm water runoff from the Hanscom AFB and Massport's Air Field. In addition to addressing the aquatic life impairment, stormwater controls are necessary to reduce flooding problems in the watershed. Considerable efforts are presently underway by stakeholders to address the problem.

This approach is based on extensive information/data, modeling analyses, and sound professional judgment and will allow for the implementation of controls, believed to be necessary, to proceed. The stakeholders agree that expending significant amounts of additional resources and time to further study the problem and attempt to better define the role of each stressor is unnecessary because of the dominant role that storm water runoff has in the impairment.

2.5 TMDL Targets and Assumptions

The objective of developing a TMDL is to determine/estimate using best available information pollutant load reductions that are needed to meet water quality standards. However, TMDLs that address aquatic life/habitat impairments are not always straightforward. This is because water quality impacts occurring as a result of urbanization and storm water runoff are usually quite complex and are typically the result of numerous stressors that may be acting either in an individual or cumulative manner. Typically, there is insufficient data/information to isolate the relative strength of each stressor and to link each stressor independently to the impairment. As a result, innovative approaches are required to develop a TMDL that will address such impairments and also be the basis for implementing control actions.

In this case, the challenge is to develop a TMDL, which by definition must address pollutant loading, that effectively addresses, either directly or indirectly, all stressors believed to be contributing to the impairment. The use of surrogate indicators expressed as quantitative targets is an important tool for developing such TMDLs. The major cause of the impairment in this segment is stormwater runoff because of its associated pollutants and the effects on the systems hydrology. Therefore, for this TMDL hydrologic targets were selected as an appropriate surrogate to estimate storm water pollutant load reductions needed to meet water quality standards.

In developed landscapes, where water quality data is limited, hydrology can be used as a surrogate indicator of storm water pollutant loading. Regulating and managing storm water not only reduces the loading of related pollutants but also may restore the hydrologic balance that is so important to aquatic life. Some of the major advantages of using hydrology as a surrogate indicator to estimate pollutant load reductions are as follows:

(1) Hydrologic targets expected to support aquatic life uses can be selected with reasonable confidence using reference sites within the Shawsheen watershed and literature information;

(2) Hydrologic targets are directly related to storm water runoff and, therefore, are also indicators of storm water pollutant loading originating from impervious areas in the watershed;

(3) Storm water runoff is responsible for both the hydrologic impacts and excessive pollutant loading (addressing one stressor will result in addressing the other); and

(4) Availability of high quality flow data from USGS gages in the watershed, and calibrated modeling tools[11,12] are key in selecting appropriate quantitative targets (using reference sites) and predict with reasonable accuracy the hydrologic response, as well as, relative pollutant load reductions resulting from BMP implementation.

3. Applicable Water Quality Standards and Numeric Water Quality Target

11 Same as Note 4.
12 Merrimack River Watershed Council, Hanscom Stormwater System Computer Model – Model Development and Calibration, June 2001.

This is discussed in the overall summary authored by the Department of Environmental Protection and which precedes this document.

4. Linking Impairment and Surrogate Target

Selecting Reference Site

Every TMDL's goal is to achieve water quality standards for the impaired segment. Therefore, it is important to identify the target so that the water body will meet the water quality standard or designated use. If the water quality standard is a narrative one like in the Shawsheen headwaters, the target needs to be developed by describing the desired level of water quality or aquatic life community.

For this TMDL, the surrogate target is developed by making comparison to a reference site–Elm Brook. Elm Brook is one of the headwater tributaries of the Shawsheen. Both the Shawsheen Headwaters and Elm Brook have similarities in land cover, topography and geology. Elm Brook is characterized by wetlands, heavy vegetation and slow moving water in the upper basin whereas the lower reaches have increasing levels of residential and commercial development as the brook flows through Bedford and into the Shawsheen River. Hanscom AFB's topography is very similar to Elm Brook, except considerable amount of wetlands were filled for airport construction and the natural channel was replaced by man-made channels and pipes to accommodate the excess runoff resulting from increased imperviousness.

Based on biological monitoring, Elm Brook meets the aquatic life use consistent with Massachusetts Water Quality Standards and is not listed on the 1998 - 303 (d) list of impaired waterbodies. In addition, a recent survey by MA DEP[13] evaluated the habitat and fish population at two sites, one from Elm Brook and the other from the Shawsheen headwaters and found that scores of 145 and 91 out of 200 in the habitat survey at Elm Brook and the Shawsheen headwaters respectively. The fish survey identified 45 numbers of 9 species and 36 numbers of 4 species at Elm Brook and the Shawsheen headwaters respectively. Model[14] results indicate that the watershed hydrology in Hanscom has been changed significantly compared to Elm Brook (Tables 2 and 3). Like

Hanscom, Elm Brook has also gone through channel alteration in several segments of the brook and flows through extensively development activities. However, Elm Brook's baseflow contribution to streamflow is still significantly higher than that of Hanscom. Therefore, it is appropriate to select the hydrologic conditions in the Elm Brook as a surrogate target to develop the phased TMDL plan for the Shawsheen headwaters.

13 A Memorandum on 2000 Shawsheen River and Elm Brook Fish Survey, May 29, 2001 by Robert J. Maietta, Aquatic Biologist, MA DEP.
14 Same as Note 4.

Selecting Surrogate Hydrology Target

Aquatic life impairment or habitat impairment cannot be defined by a single event. Typically, aquatic life impairments are a function of conditions that occur over an extended period of time (i.e., seasonally or annually). Aquatic life impairments in the headwaters of the Shawsheen are believed to be due to recurring storm water discharges and inadequate base flows. Addressing the hydrologic imbalances through the application of appropriate storm water best management practices will address excessive storm water pollutant loading, as well as excessive flood flows that occur too frequently, and inadequate base flow. Therefore, it is important to establish the appropriate hydrologic domain throughout the year to provide for a suitable ecosystem that is needed for healthy aquatic life. Flow duration statistics has been successfully employed to develop ecological targets for rehabilitation of rivers[15]. As previously mentioned, a flow duration curve shows the percentage of days during a period of record that flow exceeds a certain value. Because actual flow rates can vary considerably between sites, they are normalized by the median flow (i.e., normalized flow = observed flow/median flow of record) to facilitate cross-comparison from one watershed to another or between separately gauged sites.

Flow duration curves for Shawsheen headwaters (Hanscom) and Elm Brook are plotted in Figure 10 and the values are tabulated in Table 2.

15 Wiley, M. J., P.W. Seelbach, and S. P. Bowler, Ecological Targets for Rehabilitation of the Rough River, Final Report, *University of Michigan, Ann Arbor*, April 1998.

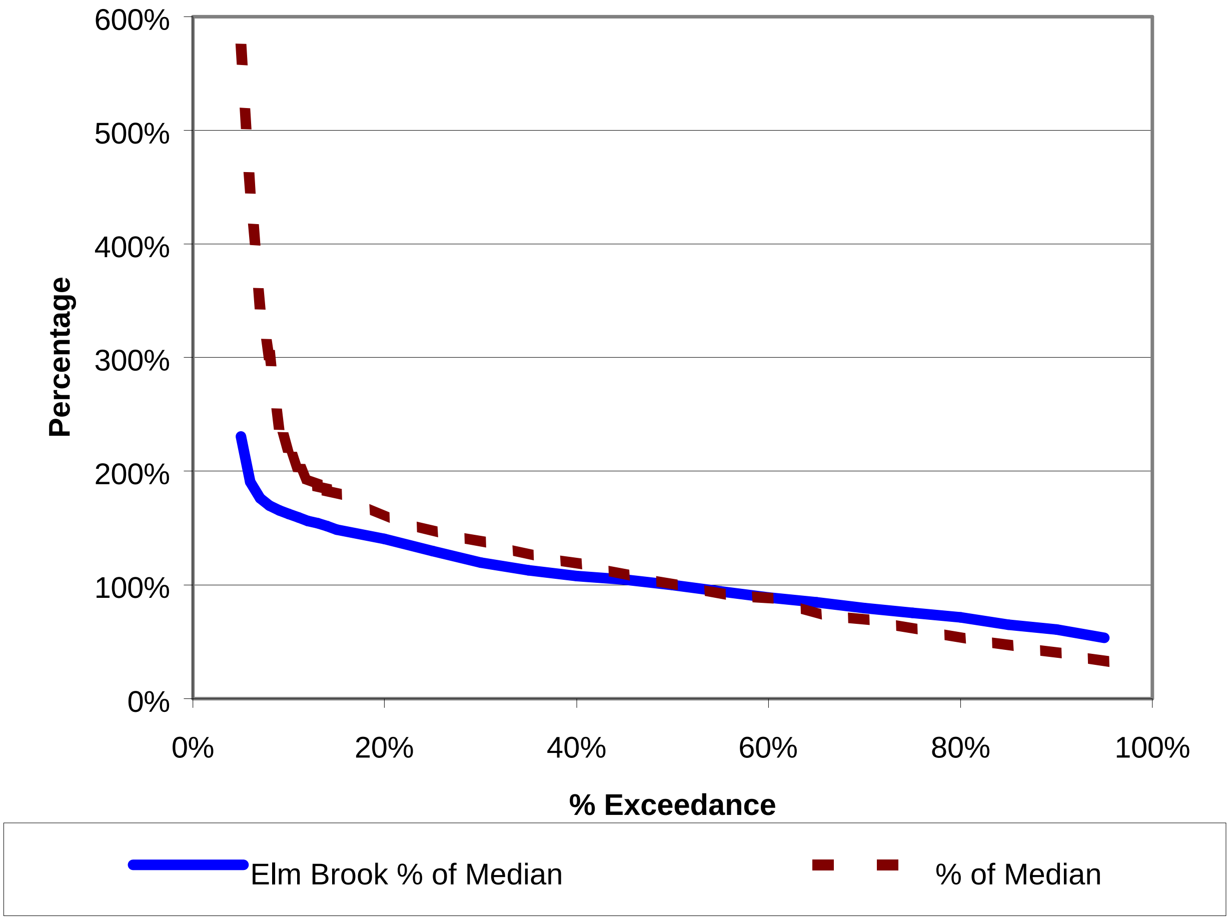

Figure 10. Flow Duration Curves of Elm Brook and Hanscom derived by simulated stream flow. Percent exceedance flow values are normalized by median flow.

Table 2. Flow duration statistics using model simulated daily flows for of 10-year period (1990-1999) for the Elm Brook and Shawsheen River at Hanscom.

%time exceedance	Elm Brook				Hanscom			
	Flow (cfs)	Flow Yield (cfs/sq. mile)	% of Mean	% of Median	Flow (cfs)	Flow Yield (cfs/sq. mile)	% of Mean	% of Median
95%	5.1	0.87	40.67%	53.46%	0.8	0.39	18.26%	32.65%
90%	5.8	0.99	46.25%	60.80%	0.98	0.48	22.37%	40.00%
85%	6.2	1.06	49.44%	64.99%	1.14	0.56	26.03%	46.53%
80%	6.8	1.16	54.23%	71.28%	1.3	0.64	29.68%	53.06%
75%	7.2	1.23	57.42%	75.47%	1.5	0.74	34.25%	61.22%
70%	7.6	1.30	60.61%	79.66%	1.7	0.84	38.81%	69.39%
65%	8.1	1.39	64.59%	84.91%	1.82	0.90	41.55%	74.29%
60%	8.5	1.46	67.78%	89.10%	2.16	1.06	49.32%	88.16%
55%	9	1.54	71.77%	94.34%	2.25	1.11	51.37%	91.84%
50%	9.54	1.63	76.08%	100.00%	2.45	1.21	55.94%	100.00%
45%	10	1.71	79.74%	104.82%	2.66	1.31	60.73%	108.57%
40%	10.3	1.76	82.14%	107.97%	2.9	1.43	66.21%	118.37%
35%	10.8	1.85	86.12%	113.21%	3.1	1.53	70.78%	126.53%
30%	11.4	1.95	90.91%	119.50%	3.37	1.66	76.94%	137.55%
25%	12.4	2.12	98.88%	129.98%	3.6	1.77	82.19%	146.94%
20%	13.4	2.29	106.86%	140.46%	3.9	1.92	89.04%	159.18%
15%	14.2	2.43	113.24%	148.85%	4.4	2.17	100.46%	179.59%
14%	14.5	2.48	115.63%	151.99%	4.5	2.22	102.74%	183.67%
13%	14.7	2.52	117.22%	154.09%	4.6	2.27	105.02%	187.76%
12%	14.9	2.55	118.82%	156.18%	4.75	2.34	108.45%	193.88%
11%	15.2	2.60	121.21%	159.33%	5	2.46	114.16%	204.08%
10%	15.5	2.65	123.60%	162.47%	5.4	2.66	123.29%	220.41%
9%	15.8	2.71	126.00%	165.62%	5.9	2.91	134.70%	240.82%
8%	16.2	2.77	129.19%	169.81%	7.4	3.65	168.95%	302.04%
7%	16.8	2.88	133.97%	176.10%	8.5	4.19	194.06%	346.94%
6%	18.2	3.12	145.14%	190.78%	11	5.42	251.14%	448.98%
5%	22	3.77	175.44%	230.61%	14	6.90	319.63%	571.43%

Although a suitable hydrologic domain for healthy aquatic life cannot be defined by a single critical condition, one can use two hydrologic conditions, representing high flow and low flow conditions, to select appropriate hydrologic targets to estimate acceptable storm water pollutant loading that will restore habitat and aquatic life uses. For this TMDL, the five-percent exceedance flow (high flow) and ninety-five percent exceedance flow (baseflow or low flow) were chosen. The ninety-five percent exceedance flow (low flow) to median flow percentages for the Hanscom (impaired) and Elm Brook (reference) sites are 33% and 53%, respectively, while the five-percent exceedance flow (high flow) to median flow percentages are 571% and 231% for the Hanscom and Elm Brook sites, respectively. It is important to notice that the impaired site has significantly higher "high" flow and lower base flows relative to median flows than the reference site. Increased runoff causes more frequent high flow conditions, increasing scouring, streambed instability, and washes off and transports pollutants from the watershed into the river.

Conversely, the increased runoff reduces ground water recharge that supplies stream base flow during dry periods that reduce the stream pollutant assimilation capacity and habitat abundance. Also, elevated water temperatures are often associated with decreased flows.

In this TMDL, the surrogate hydrologic targets are set to meet the normalized flow duration statistics of the reference site and are used to estimate acceptable pollutant load allocations from the watershed. The reference site represents pollutant loading and hydrologic conditions that supports a healthy aquatic life community. Table 3 provides current and target hydrologic conditions.

Table 3. Critical conditions at impaired and reference sites and surrogate target for impaired sites at a glance.

Hydrology Indicator	Hanscom (Impaired Site)	Current Flow (Impaired Site) (cfs)	Elm Brook (Reference)	Surrogate Target (Impaired Site) (cfs)
5% flow	6.90 cfs/mi^2	14.0	3.77 cfs/mi^2	7.6
95% flow	0.39 cfs/mi^2	0.8	0.87 cfs/mi^2	1.3
50% flow (Median)	1.21 cfs/mi^2	2.5	1.63 cfs/mi^2	3.3
Annual Runoff	18.7 inch	2.8	9.0 inch	1.4
Annual Baseflow	9.4 inch	1.4	15.0 inch	2.2

The impacts of selected surrogate targets on pollutant load reduction and developing implementation strategy will be discussed in the following sections, "Waste Load Allocation" and "Implementation Plan" respectively.

5. Loading Capacity

Pollutants are transported from the watershed to the river by surface runoff. Therefore, pollutant loads were estimated using ten-year average annual surface runoff. In order to quantify the pollutant load reduction associated with meeting the surrogate hydrologic target, one should follow the following steps:

Pollutant load = Flow x Concentration of Pollutant

As the pollutants are transported to the river by surface runoff during the storm events, Pollutant Load = Surface Runoff * EMC (Event Mean Concentration) of Pollutant from the watershed

EMC values for urban pollutants can be found in literatures[16,17].

Sediment, Copper, Silver, and Zinc were found elevating the water quality standards in past stormwater sampling and biological surveys. If sediment, in this case total suspended solids (TSS), is considered,

Sediment Load for an average urban stream = Runoff * 78.4 [18] (mg/l)
Current Load at impaired watershed = 2.8 (cfs) * 78.4 (mg/l)
= 196 Mg/year
Target Load at impaired watershed = 1.4 (cfs) * 78.4 (mg/l)
= 98 Mg/year

Similarly one can estimate the other pollutant loads (Table 4).

Table 4. Estimated load reduction on selected pollutants.

Pollutant	Current Load	Target Load
TSS	196 Mg/year	98 Mg/year
Copper	33.8 Kg/year	16.9 Kg/year
Zinc	405 Kg/year	203 Kg/year

6. Load Allocations (LAs)

Storm water runoff that enters into the streams through pipes is considered as a point source.

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16 Smullen, J. T., A. L. Shallcross, and K. A. Cave, Updating the U.S. Nationwide Urban Runoff Quality Data Base, Water Science and Technology, Vol. 39, No. 12, pp 12-16, 1999.
17 U.S. Environmental Protection Agency, Results of the Nationwide Urban Runoff Program, Volume1, Final Report. 1983.

Therefore, this TMDL concludes that there are no non-point sources and recommends a zero load allocation. However, the non-point sources associated with the impairment are lumped together with Waste Load Allocation (WLA) in the following section.

7. Waste Load Allocations (WLAs)

WLAs identify the portions of loading capacity allocated to point sources. The impairment in this TMDL results from multiple stressors associated with storm water runoff. In this specific situation, hydrologic targets are employed as surrogate measure to estimate storm water pollutant load reductions needed to support aquatic life uses and to be expressed as wasteload allocations in the TMDL. In other words, the WLAs are equal percent removal of known and unknown pollutants associated with storm water runoff that is 50% pollutant reduction.

8. Margin of Safety (MOS)

This is discussed in the overall summary authored by the Department of Environmental Protection and which introduces this report.

9. Monitoring Plan

This is discussed in the overall summary authored by the Department of Environmental Protection and which introduces this report.

10. Implementation Plans

The objective of this TMDL is to specify reductions in storm water pollutant loads and other associated stressors so that aquatic life uses can eventually be met. To estimate necessary reductions hydrologic targets were selected. Best management Practices (BMPs) designed to enhance ground water recharge and reduce high storm water flows and pollutant loads will be necessary.

The weighted average runoff curve number[18] for the watershed of an impaired stream is 84 and it must be brought to approximately 71 by installing BMPs in this watershed. Figure 11 demonstrates how flow duration statistics would be, if the surrogate hydrology target were met. This TMDL is being implemented through the commitment of both the Hanscom Air Force Base and MassPort as part of their corporate efforts to protect and enhance the environment. These

18 United States Department of Agriculture Soil Conservation Service, Technical Release 55, June 1986.

efforts are a voluntary extension of what is required under the NPDES storm water permits issued to each of these operations.

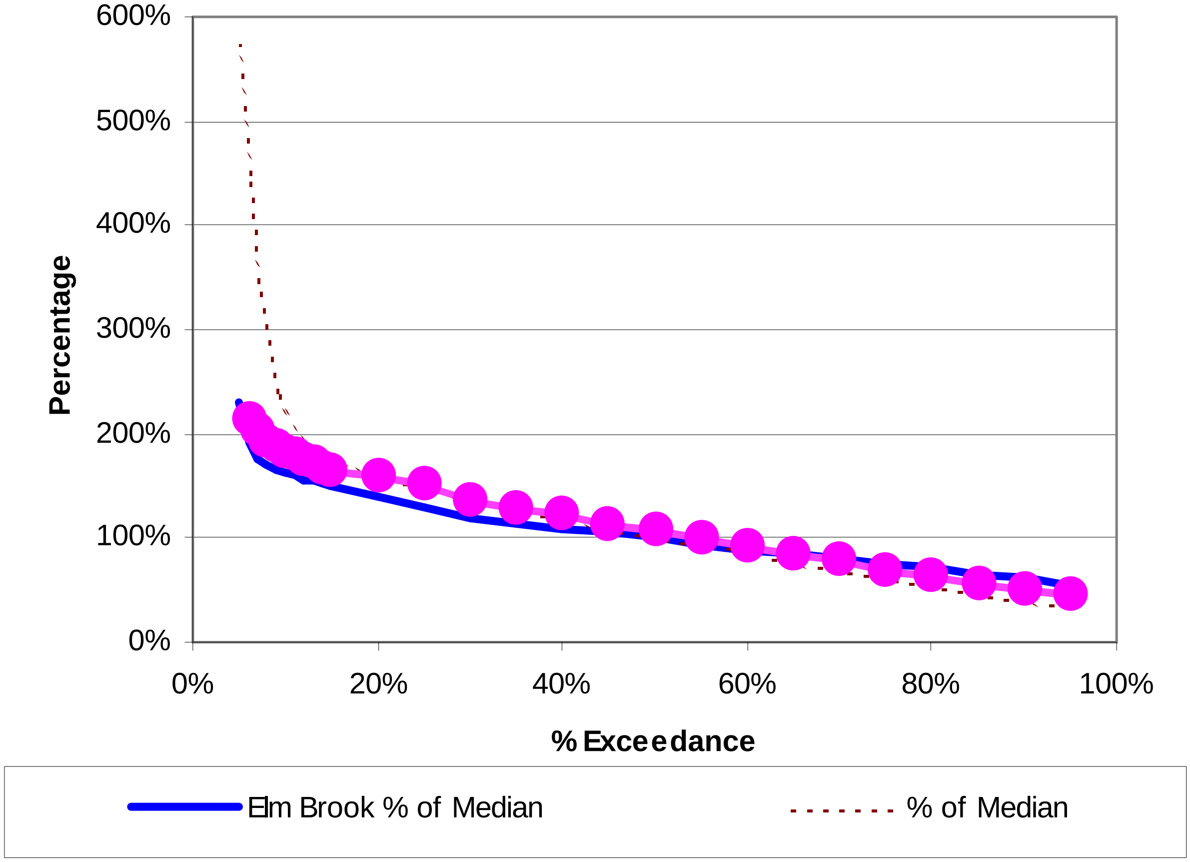

Figure 10. Flow duration statistics for impaired (brown dot line) and targeted (pink dot) conditions for impaired watershed and reference (blue line) watershed.

In this impaired segment, the land in the watershed mainly is owned by United States Air Force (USAF) and Massport Authority. Both USAF and Massport Authority closely work with stakeholders and state and federal agencies to restore this impaired segment.

The following actions are already underway:

- USAF contracted Merrimack River Watershed Council to identify, screen, select and size BMPs to be installed on the USAF premises to meet the TMDL surrogate target. The recommendations of BMPs are scheduled to be presented to USAF during spring of 2003.
- MassPort Authority is working on identifying solutions to reduce runoff from the runways (Personal communication with Keith Beasley, PE, Pollution Prevention Manager, Massport Authority)

All the implementation activities will be coordinated by the Massachusetts Department of Environmental Protection, the Merrimack River Watershed Council, the Hanscom Air Force Base and MassPort Authority.