2.0 REVIEW OF PREVIOUS STUDIES ON THE ASSABET RIVER

A review of previous studies on the Assabet River system was performed to enhance understanding of the hydrology, water quality, and ecology of the Assabet River. A review of previous studies also serves to identify gaps in our understanding of the river system and to provide context for present and future assessments of the Assabet River.

A physical description is provided below including a description of watershed size and Assabet River tributaries. A hydrologic data review, focused on evaluation of previously collected streamflow and time of travel measurements, is then presented. Previously collected hydrologic measurements are evaluated for their applicability in estimating streamflow variations throughout the river and for estimating nutrient loadings.

A water quality and biological data review is also provided with focus on evaluation of previously collected data related to eutrophication conditions. The water quality review includes previously collected nutrient-related parameter measurements and dissolved oxygen concentration measurements. The biological data review includes an evaluation of the types and relative abundance of species observed during previous surveys.

The review of previous studies is organized by physical, hydrological, water quality, and biological components of the Assabet River. In each component, the characteristics of the Assabet River are described. A summary, provided at the end of the section, provides a compilation of key findings of the previous studies and a contains a discussion of the status of the Assabet River.

2.1 Sources of Existing Data

The following organizations were consulted during the process of collecting information on the Assabet River:

- United States Environmental Protection Agency, Region I, Boston, MA (US EPA)
- United States Geological Survey, Northborough, MA (USGS)
- United States Army Corps of Engineers, New England District, Concord, MA (COE)
- Massachusetts Department of Environmental Protection, Worcester, MA (DEP)
- Massachusetts Department of Environmental Management, Boston, MA (DEM)
- Massachusetts Executive Office of Environmental Affairs, Div. of Watersheds, W. Boylston, MA (EOEA)
- Massachusetts Division of Fisheries and Wildlife (MDFW)

- Organization for the Assabet River, Concord, MA (OAR)

The search for existing data included visits by ENSR personnel to libraries at DEP and the USGS. Support and guidance in obtaining documents and information on the Assabet River was provided by Art Screpetis (DEP), Sue Beede (OAR), Barbara Offenhartz (OAR), and Tom Sheppard (USGS).

Thirty-seven documents were evaluated in performing the review of previous studies. Table 2-1 contains a compilation of documents reviewed and includes document name, source, topics, and types of measurements reported.

2.2 Physical Description of the Assabet River

The Assabet River is situated in eastern Massachusetts, approximately 20 miles west of Boston (Figure 2-1). The Assabet begins at a swamp-like impoundment in Westborough, Massachusetts and flows in a generally northeasterly direction for a distance of 31 miles to the confluence of the Concord River in Concord, Massachusetts. The Concord River begins at the confluence of the Assabet and Sudbury Rivers and flows in a generally northerly direction to the Merrimack River in Lowell, Massachusetts.

The Assabet River is relatively narrow and shallow, typically 30 to 60 feet wide and 2 to 4 feet deep. The Assabet River is a gently sloped river, typical of low-lying coastal streams in eastern Massachusetts (USGS, 1994) and has six impoundments. The river impoundments were created by dams originally constructed prior to the 20th century (MWRC, 1975). Long, narrow river impoundments are found upstream of Assabet River dams. Typically, Assabet River impoundments are shallow (5 to 10 feet deep) and narrow (100 to 300 feet wide). Several Assabet River impoundments extend for several miles.

Figure 2-2 contains a schematic cross-sectional view of the Assabet River with rivermile (RM) on the x-axis and elevation (in feet above mean sea level) on the y-axis. Figure 2-2 shows that the Assabet River drops 170 feet in elevation over its 31 mile length for an average slope of 5.5 feet per mile. The Assabet River's slope, however, is approximately 2 feet per mile throughout 27 of its 31 mile length. Several steeper reaches, with slopes as great as 25 feet per mile, are found immediately below impoundment dams and account for the majority of the vertical gradient of the River. Thus, the Assabet River’s effective slope is gradual resulting in relatively slow moving water in most reaches.

Fourteen tributaries to the Assabet River have been identified (Blanc and O’Shaughnessy, 1974) and are presented in Table 2-2 along with estimated sub-watershed areas. Data on the physical configuration, hydrology, and water quality of the Assabet River tributaries is sparse.

The Assabet River drains a watershed of approximately 177 square miles of land (USGS, 1974). The watershed is populated by approximately 177,000 people. Thus, the population density in the watershed is approximately 1,000 people per square mile. The Assabet River flows through several highly populated areas including Westborough, Northborough, Hudson, Maynard, and Concord, Massachusetts (MADEQE, 1988).

Wastewater dischargers have released effluent to the Assabet River for many years. Four major publicly-owned sewage treatment works (POTWs), located in Westborough, Marlborough West, Hudson, and Maynard, discharge to the Assabet River. In all four cases, wastewater discharge locations are either within or immediately above river impoundments. Historic POTW discharge effluent characteristics are well documented and are presented later in this section. Several minor dischargers also contribute wastewater to the Assabet River including MCI Concord, Acton Powdermill Plaza, and the Middlesex School (via Spencer Brook).

2.3 Hydrology

An understanding of the quantity and variability of water movement throughout the Assabet River is critical to assessing water quality problems in the Assabet River for several reasons. Ambient surface waters provide dilution for point and non-point source nutrient loads to the river. Also, the quantity of surface water, along with physical configuration, determines the rate of travel (i.e., mean water velocity) of water and nutrient-related chemical constituents through the river system. The rate of travel is important because, in general, slower water movement provides extended exposure of nutrients within the system. This results in increased nutrient cycling by biota in the water column and sediments, that could potentially lead to adverse impacts to water quality. In terms of variability, significant precipitation events tend to result in rapid changes in streamflows. These relatively short duration, high flow events can carry large nutrient loads associated with land surface run-off. Stormwater runoff events and associated high river flowrates can have major impacts on water quality through increased nutrient loading and scouring of riverbed sediments. Thus, the quantity and variability of water movement is a critical component of the Assabet River water quality assessment.

Two sets of streamflow measurements were found in the review of previous studies; continuous measurements at one location and sporadic streamflow measurements throughout the river system. Also, several time of travel studies have been performed on the Assabet River.

2.3.1 Continuous Streamflow Measurement at the USGS Maynard Gauge

Streamflow has been measured consistently at only one location on the Assabet River. In 1941, the United States Geological Survey established a stream gauge in Maynard at rivermile 7.4. Continuous streamflow measurement at RM 7.4 is very useful for quantifying temporal streamflow variations at one location. Approximately one-third of the watershed (61 of 177 square miles) drains below the Maynard gauge and is not captured by the gauge (USGS, 1984). The Maynard gauging station alone cannot assess spatial streamflow variations along the river. Thus, Maynard gauge data, while useful, cannot solely support hydrologic assessments throughout the watershed.

Monthly average streamflows at the USGS Maynard gauge for the period of 1941 to 1997 are presented in Figure 2-3. Average monthly flows at the Maynard gauge range from 60 to 75 cfs during low flow summer-time conditions (July, August, and September). Low flow conditions are of particular interest in this investigation because they are commonly associated with unfavorable water quality conditions (see Section 3.1). The annual minimum seven-day mean discharge for a ten year recurrence interval ($7Q_{10}$) is a low flow metric frequently applied as a reasonable "worst-case" condition. The $7Q_{10}$ value is a statistical representation of the lowest flow conditions that may be expected to occur consistently for a one week period every 10 years.

An appropriate estimate of the $7Q_{10}$ flow at the Maynard gauge has been the subject of much discussion in recent years. A $7Q_{10}$ estimate of 15.1 cfs was provided in a 1983 USGS hydrologic report (USGS, 1984). This estimate was calculated based on a ten year period of record that contained unusually high flows. Because of errors implied by the relatively short period record used in the calculation, the estimate was recently revisited by MADEP (1999) and a $7Q_{10}$ estimate of 4.5 cfs was obtained for the entire period of record. The MADEP also calculated a "rolling 10-year" $7Q_{10}$ calculation that resulted in a $7Q_{10}$ estimate in recent years of approximately 13.5 cfs.

The $7Q_{10}$ low flow statistic is complicated in the Assabet River by the presence of POTW discharge flows that comprise the majority of river streamflows under low flow conditions. Total POTW flowrate measurements, collected during 11 surveys performed between 1969 and 1990, ranged from 7.8 to 13.0 cfs (5.0 to 8.4 MGD). It appears unlikely that low flows in the Assabet River can be lower than the total of the POTW discharge flows, excluding Maynard and Concord MCI effluents, that are downstream of the Maynard gauge. In summary, there is some uncertainty regarding the $7Q_{10}$ flow at the Maynard gauge and estimates range from 4.5 cfs to 15.1 cfs.

2.3.2 Streamflow measurements collected throughout the Assabet River

Table 2-3 contains a summary of the most extensive sets of historic streamflow measurements collected throughout the Assabet River. Streamflow measurements were collected during six surveys performed from 1969 to 1995 and including over 30 total survey days. All measurements were collected during summer-time conditions (June 4 through September 21). Concurrent streamflow measurements collected at the USGS Maynard gauge are included (in bold) in Table 2-3 to provide flow regime context. The most extensive streamflow survey was performed by Blanc and O'Shaughnessy (1974) in September 1973. In general, the historic streamflow data set is considered sparse because there are few surveys and typically few streamflow measurements per survey. A compilation of all streamflow survey measurements collected during the period of record is provided in Appendix A (Table A-1).

Ideally, previously collected streamflow measurements could be applied to develop streamflow vs. rivermile relationships, whereby streamflows associated with a specific flow regime (e.g., at one point in time) could be plotted verses rivermile. A streamflow vs. rivermile relationship could be established to estimate flows throughout the system under different flow regimes. Streamflow vs. rivermile curves would be useful in evaluating critical time-varying parameters such as nutrient loadings and average water velocity throughout the river system.

The historical streamflow data record is not sufficiently robust to support an accurate set of streamflow vs. rivermile curves. Figure 2-4 provides a crude estimate of the streamflow vs. rivermile obtained by plotting measurements from the four largest historical streamflow measurement data sets. Collection of future streamflow measurements throughout the river system will support development of a more accurate set of streamflow vs. rivermile relationships.

In summary, available streamflow data for the Assabet River is sparse. Accurate estimates of nutrient loadings and nutrient flux in river impoundments are dependent upon accurate hydrological characterizations. Thus, a substantial set of streamflow measurement must be collected to support the TMDL allocation for the Assabet River.

2.3.3 Time of travel measurements

Time of travel studies are useful for measuring the rate of movement of water and chemical constituents through the river system. Time of travel measurements are typically collected by releasing a detectable conservative substance (e.g., Rhodamine dye) into the river and tracking its movement downstream.

Table 2-4 contains a summary of measurements collected during four time of travel studies. All of the studies were performed by the Massachusetts Department of Environmental Protection. The studies were performed in December 1968, August 1969, October 1969, and March 1980. A complete compilation of time of travel study measurements in provided in Appendix A (Table A-2). Concurrent streamflows at the Maynard gauge ranged from 54 cfs to 452 cfs. A total of 6 dye release events were performed, 2 in the Upper Assabet, 3 in the Lower Assabet, and one through the entire Assabet River. Dye was observed to take 7.8 days (188 hours) to travel the full length of the Assabet River in October of 1969, concurrent with a Maynard gauge flowrate of 54 cfs.

In August 1969, however, dye released from RM 29.8 in Westborough took 11 days to move roughly one-half the length of the Assabet River to RM 13.9 miles, below the Gleasondale Dam. The August 1969 survey was performed concurrent with a USGS Maynard gauge flowrate of 23 cfs. A third dye release event (October 9-15, 1969) was performed from RM 13.9 to RM 0.5 and took 6.4 days. If considered together with the August 1969 survey a total travel time of 17.5 days is obtained. Based on these limited results, it appears likely that travel times are significantly longer during low flow conditions than during average conditions. Time of travel estimates on the order of one to three weeks were observed to occur at USGS Maynard gauge flowrates of 23 to 69 cfs.

2.4 Water Quality

Water quality measurements collected during eleven surveys from 1969 to 1990 were reviewed. Surveys were performed during summer-time and fall conditions with sampling dates ranging from June 4 to October 23. All of the surveys were performed by the State of Massachusetts. Water sampling locations are compiled in Table 2-5, along with location identifications and rivermiles. Figure 2-5 contains a map indicating sampling locations. In the MADEP water quality studies, the Assabet River is described in two sections, the Upper Assabet River and the Lower Assabet River. The Upper Assabet River begins at the headwaters (RM 31.8) and extends to rivermile 23.9. The Lower Assabet River extends from RM 23.9 to the mouth (RM 0.0).

A summary of historical water sampling for nutrient-related and biological constituents and in-situ measurement of dissolved oxygen concentration measurements collected between 1969 and 1990 is provided in Section 2.4.1 – 2.4.3 below. A summary of measurements collected from 1993 through 1997 by the Organization for the Assabet River is provided in Section 2.4.4. Nutrient budgets are critical to understanding the ecological balance in the Assabet River system. Water quality measurements of nutrient concentrations combined with concurrent streamflow measurements are applied to determine nutrient loadings to and within the Assabet River system.

2.4.1 Water Sampling for Chemical Constituent Concentrations

Water samples were collected in the Assabet River for analysis of nutrient-related and bacterial constituents during eleven previous studies from 1969 through 1990, referred to herein as the period of record. Specifically, total phosphorus, nitrate, ammonia, and BOD_5 concentrations, and fecal coliform counts were measured and are summarized below.

In summary, total phosphorus and nitrate concentration measurements in the Assabet River were each typically greater than 0.5 mg/l during the period of record. Biochemical oxygen demand (BOD_5) concentrations measurements in the Assabet River were typically greater than 2.5 mg/l. Fecal coliform counts varied dramatically, typically on the order of hundreds of colonies per 100 ml and were measured as high as 500,000 colonies/100ml. Since elevated fecal coliform counts are typically associated with wet-weather events, precipitiation records prior to fecal coliform sampling events were obtained and are included in the data summary. In general, the historic in-stream water quality measurements are consistent with nutrient-rich waters with a strong component of human sewage.

Prior to 1987, the most severe water quality problems in the Assabet River were observed between the headwaters and Boundary Street at rivermile 23.9 (Upper Assabet River). Boundary Street is located on town line between Northborough and Marlborough. This reach of the river had the most severe water quality problems, as measured by nutrient concentrations, minimum DO concentrations, and biochemical oxygen demands. According to previous reports (e.g., MADEQE, 1988), extreme water quality problems in the Upper Assabet were due to the presence of the Westborough and Shrewsbury wastewater plant effluent discharges. These two discharges were particularly problematic since they provided relatively large nutrient loadings into the relatively small baseflow of the Upper Assabet River.

In August of 1987, the Westborough and Shrewsbury wastewater plants were combined (Shrewsbury was taken off-line) and upgraded to reduce loadings. Reductions in loadings focused on oxygen demand, ammonia, and solids, and only to a limited degree on phosphorus. Water quality conditions in the Upper Assabet River are reported to have improved significantly since the 1987 Westborough upgrade (MADEQE, 1988).

Figure 2-6 contains total phosphorus concentration measurements vs. rivermile from three previous surveys, Sept. '87, July '85, and Aug. '79, and is typical of the elevated levels of nutrient-related constituents found in the Upper Assabet River in the 1970s and 1980s (prior to 1987). Total phosphorus concentration measurements were observed to range from 0.3 mg/l to 3.2 mg/l throughout the river with the highest concentration in the Upper Assabet. Measurements from the two reaches of the river, Upper and Lower, are presented separately herein since water quality conditions between the two reaches were distinctly different during the period of record.

Tables 2-6 and 2-7 contain summaries of nutrient-related water quality measurements collected in the Upper Assabet and Lower Assabet, respectively, during eleven previous surveys. Results from each survey are represented as typical, high, and low concentration measurements. Data are presented in this manner to provide a concise summary of the data suitable for observing values and temporal trends in values. An awareness of key contextual information is critically important when evaluating in-stream water quality information. Table 2-8 contains key contextual information including streamflow at the USGS Maynard gauge and POTW flow and nutrient loadings collected concurrently during each of the 11 surveys. Streamflows, as measured at the USGS Maynard gauge, concurrent with the water quality surveys were relatively low. During 9 of 11 surveys, streamflows were below 100 cfs. Antecedent rainfall records provide important contextual information and are discussed as part of the data summary.

2.4.1.1 Upper Assabet River Measurements Collected Between 1969 – 1989

POTW nutrient loadings in the Upper Assabet River (31.8 to 23.9) consisted of Shrewsbury and Westborough prior to the summer of 1987 and Westborough alone since 1987. Upper Assabet River POTW nutrient loadings maintained similar levels of phosphorus loadings and nitrate loadings, while nearly doubling in effluent flowrate over a 20 year period between 1969 and 1989 (Table 2-8). The Westborough POTW also reduced its BOD loading by a factor of 3 over the same period. This represents a significant accomplishment in terms of improved effluent treatment.

Upper Assabet River phosphorus concentrations ranged from typical values of 0.7 to 3.0 mg/l over the same period (Table 2-6). Nitrate concentrations were typically approximately 0.6 and 1.0 mg/l. Ammonia concentrations were typically between 1.0 mg/l and 2.5 mg/l prior to the 1987 Westborough

POTW upgrade and were dramatically lower in one survey after the upgrade (i.e. September 1987; typical value 0.1 mg/l). Typical river BOD concentrations ranged from 4.0 mg/l to 11.0 mg/l prior to August 1987 and were measured to be typically 1.8 mg/l in September 1987.

Fecal coliform counts are known to be highly variable and the uncertainty associated with any one fecal coliform measurement is large. As a result, US EPA has developed standards for fecal coliform counts based on statistical populations of measurements rather than a single measurement. For example, the Class B fecal coliform standard is a geometric mean of 200 col./100 ml. Fecal coliform measurements observed in the Assabet River were highly variable during the period of record, ranging from 5 to 460,000 col/100ml in the Upper Assabet River. Historic rainfall records from the Bedford, MA gauge were obtained and reviewed to support the evaluation. Review of the rainfall record indicates that all fecal coliform measurements collected during the 1970's (first 5 surveys listed in Table 2-6) were associated with greater than 0.1 inches of rainfall during the period 3-days prior to and during the surveys. Thus, fecal coliform measurements collected within 3-day of rainfall ranged from 500 to 460,000 col/100 ml and dry-weather fecal coliform measurements ranged from 200 to 440 col/100 ml. Historical values are very high and are indicative a large proportion of flow consisting of sewage.

2.4.1.2 Lower Assabet River Measurements Collected Between 1969 – 1989

POTW nutrient loadings in the Lower Assabet River (RM 23.9 to 0.0) consisted of Marlborough West, Hudson, Maynard, and Concord MCI discharges. Lower Assabet River POTW nutrient and BOD loadings maintained similar levels, while nearly doubling in effluent flowrate during the 20 year period from 1969 to 1989 (Table 2-8). This represents a significant accomplishment in terms of improved effluent treatment.

Ambient concentrations of nutrients and other constituents in the Lower Assabet River were influenced by all loadings upstream of the sampling locations, including, at some locations, POTW loadings from both the Upper and Lower Assabet River. Also, three sets of in-stream nutrient measurements were collected in 1989 and 1990 in Lower Assabet River that were not collected in the Upper Assabet River. These measurements are beneficial in that they extend the period of record and support assessment of the Assabet River after the 1987 upgrade of the Westborough POTW.

Lower Assabet River phosphorus concentrations ranged from typical values of 0.35 to 3.0 mg/l during surveys performed between 1969 and July 1987 and were typically 0.45 mg/l in 1989 and 1990 surveys (Table 2-7). Nitrate concentrations were typically 0.6 and 3.0 mg/l throughout the period of record. Ammonia concentrations were typically between 0.0 mg/l and 0.07 mg/l throughout the period of record.

Lower Assabet River BOD concentrations ranged from 2.0 mg/l to 5.0 mg/l during the period of record. Fecal coliform measurements observed in the Assabet River were highly variable, ranging from 5 to 500,000 col/100ml in the Lower Assabet River. Review of rainfall records, described above, showed that elevated fecal coliform measurements were associated with rainfall events (e.g., September 17-19, 1974). Historical values are very high and reflect a large proportion of flow as human sewage.

2.4.1.3 Comparison Between Upper and Lower Reaches (1969 – 1989)

In general, water quality conditions measured in the Upper Assabet River were worse than those measured in the Lower Assabet River. Total phosphorus and nitrate concentration measurements collected in the Upper Assabet River were higher than those collected in the Lower Assabet River during the period of record. Ammonia and BOD concentration measurements were typically dramatically higher in the Upper Assabet than in the Lower Assabet, by factors of approximately 10 and 2.5, respectively. Fecal coliform counts were found to be highly variable and at levels of concern throughout the river during the period of record.

2.4.1.4 Assabet River Measurements Collected between 1993 and 1999

The Organization for the Assabet River (OAR) collected Assabet River water samples for laboratory analysis of water quality parameters between 1993 and 1999. OAR did not have an approved QAPP during this time period. OAR received an approved QAPP in February 2000. Thus, formal use of the OAR 1993 through 1999 data will require a quality assurance analysis with regulatory approval. Since virtually no other measurements were collected on the Assabet River during the 1990's, water quality measurements collected by OAR represent a valuable resource in assessing water quality in the Assabet River. OAR collected water quality measurements throughout the Assabet River on a monthly basis between May and October of each year from 1993 through 1999. During each survey, samples were typically collected at approximately 20 locations along the Assabet River. These measurements were reviewed and are summarized below.

<u>Phosphorus</u>

During 27 surveys over 300 samples were collected and analyzed for total phosphorus by OAR. Total phosphorus measurements ranged from 0 mg/l to 2.8 mg/l with an average value of 0.4 mg/l. Ortho-phosphorus measurements collected by OAR during 4 surveys and values ranged from 0.01 to 1.36 mg/L with average value of 0.30 mg/l.

<u>Nitrogen</u>

Nitrate-Nitrogen measurements collected by OAR during 20 surveys. Nitrate values ranged from 0.01 to 8.5 mg/L with an average value of 1.7 mg/L. Ammonia-nitrogen measurements were collected by OAR during 14 surveys. Ammonia concentration measurements ranged from 0.04 to 0.54 mg/L with average value of 0.15 mg/L.

Other

Fecal coliform measurements were collected by OAR during 24 surveys ranged from 0 to 7400 col./100ml with an average value of 575 col./100 ml. Lastly, biological oxygen demand (BOD) measurements collected by OAR during 5 surveys. BOD_5 concentration measurements ranged from 0.5 to 20 mg/L with an average value of 2.4 mg/L.

2.4.2 In-situ Dissolved Oxygen Concentration Measurements

In-situ dissolved oxygen measurements were collected in support of most of the water quality surveys discussed above. Prior to 1987, minimum DO concentrations of near-zero in the Upper Assabet River, resulting directly from impacts of the Shrewsbury and Westborough POTWs, were commonly reported (MWRC 1969, 1974, and MADEQE, 1979). Since the 1987 POTW upgrade at Westborough minimum DO concentrations increased significantly. In September 1987, after the POTW upgrade, several minimum DO concentrations below 3.0 mg/l and numerous measurements below the water quality standard of 5.0 mg/l were collected. During the period of record, the water quality standard for dissolved oxygen of 5.0 mg/l has frequently not been met.

In August 1996, EPA personnel collected one set of DO concentration measurements in the early morning at 19 locations. Early morning DO concentration measurements were below 5.0 mg/l at 5 of 19 sampling locations (MADEP 1999). One of the DO concentration measurements (3.1 mg/l) was collected 8 ft deep in the Powdermill Impoundment. Table 2-9 contains a compilation of dissolved oxygen concentration measurements collected by EPA in August 1996. Also, dissolved oxygen concentrated measurements collected by the Organization for the Assabet River (OAR) during the 1990s were reviewed and found to contain frequent summer-time DO concentration measurements below 5.0 mg/l.

2.5 Biology

The purpose of this section is to review and analyze scientific literature and existing data on the aquatic plants in the Assabet River. This analysis will provide a preliminary evaluation of the status of aquatic plant communities in selected reaches and impoundments of the Assabet River, with emphasis on the conditions and ecology of duckweed species (e.g., *Lemna* spp.), a predominant plant in the river.

In-stream vegetation is an important natural component of the river ecosystem. Evaluation of the distribution and abundance of aquatic macrophyte communities can be a useful diagnostic tool in assessing potential impacts to that ecosystem. The term macrophyte is used to distinguish large aquatic plants from unicellular algae (i.e., attached periphyton, floating phytoplankton), but large algal mats are considered macrophytes (“large plants”) in addition to vascular species.

Evaluation of aquatic macrophytes provide insights into the trophic condition of a waterbody since macrophytes usually acquire nutrients accumulated in bottom sediments rather than directly from the water column. It is also important to consider macrophyte growth since an overabundance of macrophytes can threaten water quality due to diurnal oxygen oversaturation/depletion, impact to fishery habitat, and impact to aesthetics and recreational opportunities. Due to this importance, the available information on macrophyte communities in the Assabet River was reviewed and the information compared to existing trends of macrophyte distribution and abundance (Section 3). The ecology of the major class of macrophytes in the Assabet River (i.e., duckweeds) was also considered.

Macrophyte surveys of the Assabet River are very scarce in the watershed water quality literature of the past 30 years. No organized macrophyte surveys were conducted of the river and impoundments from the headwaters to the confluence with the Concord River, but observations and field notes attached to some of the survey documents provide descriptions of conditions historically observed. Due to the level of development in the SuAsCo watershed, it is assumed that observable blooms of duckweed have been present on the Assabet River since at least the 1940's (see Eaton, 1947).

A 1969 survey of the Assabet River noted heavy growth of aquatic weeds impeding collection of secchi disk measurements at or just below the A-1 Impoundment near River Mile (RM) 31.8 (MWRC, 1969). *Lemna* blooms were reported in the Assabet at the Route 20 dam in Northborough (RM 27.7) as well as at the Ben Smith Impoundment in Maynard (RM 9.2) on August 27, 1969. The Maynard impoundment exhibited a supersaturated dissolved oxygen (DO) content of 13 mg/l at 23^oC (149% of saturation). While this indicates intense photosynthetic activity, it does not identify whether macrophytes or phytoplankton (or a combination of both) were responsible. At both impoundments, observers noted very little water going over the dam indicating very limited flushing during late summer (MWRC, 1969).

Oxygen supersaturation in a marshy area upstream of the Ben Smith Impoundment and at the Powder Mill Impoundment was noted in a 1973 summer (late July) survey (Blanc and O'Shaughnessy, 1974). These stations were among those where the Assabet River was noted to "be in a eutrophic condition when compared to other sampling stations."

Observations of macrophytes were not included in the 1974 and 1979 Assabet River Surveys (MWRC, 1974; MA DEQE, 1979). Both surveys indicate consistent patterns and abundance of the supply of nitrogen and phosphorus to the River from the contributing POTWs. The Assabet River Basin survey of the Flow Augmentation Pond in Westborough indicated that this reservoir was also a rich supply of nutrients. Researchers believe that this may be due to the breakdown of the extensive terrestrial vegetation that had been left in place when the George H. Nichols Dam had been constructed and the basin filled (MA DEQE, 1974).

The 1989 Assabet River Basin Water Quality Management Plan (WQMP) summarized data from summer 1987 and 1988 surveys (MA DEQE, 1989). The WQMP noted that "significant portions of the river still support dense populations of algae and macrophytes during the summer months. Decay of excess vegetation and sediments in many slow moving parts of the Assabet River can cause local odor problems."

The WQMP also compared historical trends in phosphorus concentrations in the Assabet River that suggest that in-stream phosphorus concentrations were increasing with time. One potential reason for this increase would be the recycling of accumulated phosphorus in the sediments to the water column (MA DEQE, 1989). This translocation of phosphorus from the sediments to the water column by macrophytes ("phosphorus pumping") has been demonstrated elsewhere (Horne and Goldman, 1992).

More recent information about the Assabet River macrophytes comes from related biological surveys. A summer 1989 benthic macroinvertebrate survey found that thick growths of vegetation impeded standard Macroinvertebrate Rapid Bioassessment (MRB) protocols (Nuzzo, 1989). Vegetation presence and proliferation were reported at all stations. Sampling downstream of the Marlborough POTW (RM 22), the survey team found the river bottom covered by thick clumps of common waterweed (*Elodea*) with some pondweed (*Potamogeton* sp.) and milfoil (*Myriophyllum* sp.) while dense beds of arrow arum (*Peltandra*) and pickerelweed (*Pontederia*) were growing along the stream margins (Nuzzo, 1989). The team reported "a steady density of *Lemna* floated by on the current and coated the water's surface in the backwater area." Further downstream, the heavily vegetated character of the river was considered symptomatic of extreme nutrient enrichment conditions. The deeper, slow-moving sections were heavily coated with duckweed species (*Lemna, Wolffia*) with dense beds of macrophytes across the stream bottom, even in shallow riffle areas. Periphyton, moss, and rooted macrophytes (*Elodea, Potamogeton, Callitriche*) were abundant.

Observations from a fish collection effort on the Assabet River in the Ben Smith Impoundment noted that "submerged aquatic macrophytes were abundant and the water surface was covered entirely by floating duckweed." (MA DEP, 1997). The pond appeared to be choked by aquatic macrophytes in late summer and early fall, although it was considered to provide excellent habitat for waterfowl and other wildlife. A 1998 fishery survey found "heavy duckweed" in the Assabet River off Summer Hill Road in Maynard (MDFW, 1998).

2.5.1 Ecology of Duckweeds

Duckweed species (*Lemna, Wolffia*) have been historically abundant and are highly significant to the visual aesthetic appearance of the River. Duckweed species are one of the most noticeable species to the lay public. Based on its importance in the Assabet River, the ecology of duckweed was further investigated to identify key factors.

Plants in the duckweed group (*Lemna, Wolffia, and Spirodela*) constitute part of the "free-floating" macrophyte community. Although often visually confused with surface mats of unicellular algae, these plants are actually monocotyledonous angiosperms (flowering plants). These plants do not form true leaves or stems, but are comprised of a floating green plant body, with photosynthetically-active tissue on the dorsal surface and tiny roots on the ventral surface that hang down into the water column. Unlike the more common rooted aquatic macrophytes, these plants move freely in waterbodies due to wind, waves, and currents. Due to their small size, these plants are readily transported between waterbodies by both natural (e.g., waterfowl) and man-made (e.g., boats) factors. Duckweeds derive their nutritional needs by direct uptake from the water column via the suspended roots and/or thin cuticle ventral membrane. Thus, these plants are not dependent on the accumulated nutrients in the bottom sediments. There is evidence that, in some instances, nitrogen-fixing bacteria cover the roots of *Lemna* and presumably provide additional nitrogen inputs to the host plant (Horne and Goldman, 1994).

The historic onset of proliferation of large surface blooms of duckweed in the SuAsCo watershed has been previously described (Eaton, 1947). In the paper "*Lemna minor* as an aggressive weed in the Sudbury River," Eaton noted that, starting in the 1930's, massive blooms of *Lemna* had been observed on that river, while it had been hitherto a minor component of the river flora. Similar observations had been made for the Charles River during the same time period. Eaton concluded that pollution from sewage was the principal factor for *Lemna's* success (Eaton, 1947). While a similar set of historic observations is not documented for the Assabet River, it seems reasonable that the rise of *Lemna* from a ubiquitous, but minor member of the river flora to its predominant role in the River is linked to urbanization and/or effluent discharges of multiple publicly-owned sewage treatment works (POTWs) in the watershed.

In summary, the ecology of duckweeds indicates that these species are favored by eutrophication, particularly the conditions of slow water movement and high nutrient enrichment. In addition, the turbid conditions that limit light for many macrophytes in some eutrophic waterbodies are not relevant to this floating species. Until environmental conditions are shifted towards lower nutrients or fast water movement (i.e., faster flushing rate), the duckweed species are likely to be highly successful and an important component of macrophyte communities in the Assabet River impoundments.

2.6 Summary of the Review of Previous Studies

The review of previous studies provided strong evidence that eutrophic conditions have been present in the Assabet River for at least the past 30 years. Results from all previous water quality surveys consistently indicate that nutrient concentrations in the Assabet River are sufficient to promote to eutrophic conditions. Other indicators of eutrophic conditions, such as large diurnal DO concentration variations and extensive biomass production, were also consistently observed in previous studies.

Results of all previous biological surveys provide good circumstantial evidence to indicate that macrophyte communities in the Assabet River have been well established throughout the period of record. Limited historic observations suggest that duckweed and pondweed have been important components of the macrophyte community for many years. Review of the ecology of duckweeds supports the contention that such forms are favored in slow-moving waters with high nutrient enrichment. Reduction of duckweed populations may require alterations in present nutrient or hydrologic regime.

In summary, the primary factors contributing to the eutrophic status of the impoundments on the Assabet River, namely availability of excess nutrients in slow-moving, impounded waterbodies, with organically rich sediments in the presence of optimum growth conditions (summer-time) appear to have long been in place and supporting eutrophic conditions in the Assabet River.

Table 2-1 A Compilation of Previous Studies of the Assabet River

Document Number	Study Name (Date & Color Key)	Source	Sampling Date(s)	Number of Stations	In-situ Water Quality	Grab Water Quality	Wastewater	Streamflow	Biological	Physical Characterization	Interesting Findings
82-A-1**	SUASCO River Study- Background Data on Water Quality	MWRC	Assabet (June 22 & 24, 1965)	12 (on Assabet)	X	X			X		
82-A-2	The Assabet River Report- Part A, Data Record on Water Quality	MWRC	August 18-29, 1969 & October 9-13, 1969	17	X	X		X	X		Time of Travel measurements
82-A-4	The Assabet River-1974 Water Quality Survey Data	MWRC	June 3-7, 1974 & September 16-20, 1974	20 & 22	X	X		X	X	X	
82-A-5	The Assabet River-1979 Water Quality Data. Massachusetts Department of Water Quality	MADEQE	June 4-8, 1979 & August 6-10, 1979	26	X	X	X	X	X	X	
82-A-7	Upper Assabet River-1988 Dissolved Oxygen Data	MADEQE	July 8, 14, 15, 21, 28, 1988, August 4, 11, and 15, 1988, & September 8, 1988	12	X[b]		X	X[a]			
82-AB-2	Assabet River Basin- 1989 Water Quality Data and Wastewater Discharge Data	MADEP	August 9, 1989	13	X	X	X		X	X	
82-AB-3	Lower Assabet River and Powdermill Impoundent- 1990 Water Quality Data and Wastewater Discharge Data	MADEP	July 10, 1990 & August 9 and 21, 1990	10	X	X	X	X	X	X	
82-ABC-3	Assabet River- 1986-1987 Water Quality SurveyData, Wastewater Discharge Data, and Analysis	MADEQE	November 1986 - May 1987 (monthly), June - September 1987 (twice per month), July 22-23, 1987, and September 1-2, 1987	23	X	X					Non-summer sampling
82-B-1*	The Assabet River Report- Part B, Wastewater Discharge Data	MWRC	1965, 1968, 1969, and 1970	6			X				
82-B-2*	SUASCO River Basin- 1976 Wastewater Discharge Data	MADEQE	1976	18			X				
82-B-3*	SUASCO River Basin- 1977 Wastewater Discharge Data	MADEQE	1977	11			X				
82-B-4	Concord (Suasco) River Basin- Part B, 1981-1982 Wastewater Discharge Data	MADEQE	1981-1982	21			X				
82-B-5	Suasco River Basin- Part B, 1983-1985 Wastewater Discharge Data	MADEQE	1983-1985	17			X				
82-B-6	1992 Wastewater Discharge Data	MADEP	1992	7			X				
82-C-3	The Assabet River-1974 Water Quality Analysis	MWRC	1965, 1969, & 1974	~24	X[c]	X[c]	X[c]	X[ac]		X	
82-D-2*	The SUASCO River Basin-1981 Water Quality Management Plan	MADEQE	1981 (report date)	NA	NA	NA	NA	NA	NA	NA	
82-D-4	Assabet River-1989 Water Quality Management Plan	MADEQE	1989 (report date)	23	X[c]	X[c]	X[c]	X[c]	X[c]	X	

Document Number	Study Name (Date & Color Key)	Source	Sampling Date(s)	Number of Stations	In-situ Water Quality	Grab Water Quality	Wastewater	Streamflow	Biological	Physical Characterization	Interesting Findings
82-E-1	Baseline Water Quality Studies of Selected Lakes and Ponds- 1974 Assabet River Basin	MADEQE	June - July, 1974		X				X		
N/A	Gazetteer of Hydrologic Characteristics for Streams in Massachusetts—Merrimack River Basin	USGS	Previously existing data through 1981	12 gaging sites & 79 partial-record sites				X			
N/A	Hydrologic Budget Analysis, A-1 Impoundment on the Assabet River, Westborough, MA	GSC	Previously existing data September 1, 1997-August 31, 1998 and New data June 24, 1997-September 30, 1998	6 gaging stations & 5 monitoring wells				X		X	Bathymetric Map
N/A	Draft 1996 SuAsCo River Basin Assessment Report for Review	MADEP	June-August, 1996 (additional fish surveys in September 1997)	9 water quality, 13 benthic invertebrate, and ~1 lakes	X (Dissolved Oxygen only)	X (Total Phosphorous only)	X		X		Benthic assessment, fish toxics monitoring
N/A	Flood Plain Information, Assabet River, Westborough to West Concord, MA, (Summary Report)	USACE	1966	N/A						X	
N/A	1997 Fish Toxics Monitoring Public Request Surveys	MADEP	September 16-18, 1997	4 (Assabet)					X		Fish toxics survey
N/A	Concord River Basin, Inventory and Analysis of Current and Projected Water Use, Vol. 1	MADEM	1984-1986?	N/A							Water use
N/A	Water Quality of Selected Wetland Streams in Central and Eastern Massachusetts, 1988-1989	USGS	1994	2	X	X		X		X	
N/A	Characteristics of Low-Slope Streams that Affect O2 Transfer Rates	USGS	May 1985-October 1988	2	X			X		X	
N/A	Lemna Minor as an Aggressive Weed in the Sudbury River	Eaton							X		
N/A	The Biokinetics of the Assabet River	Blanc, F.C. and O'Shaughnessy, J.C	July-September 1973	29	X	X	X	X	X		Travel times
N/A	A Procedure for Estimating Reaeration Coefficients for Massachusetts Streams	USGS	1983-1984	2 (Assabet)				X			Travel times, non-summer measurements included
N/A	Water-Quality Data for Selected Wetland Streams in Central and Eastern Massachusetts	USGS	June and September 1974, August 1989	4 (Assabet)	X	X					

Document Number	Study Name (Date & Color Key)	Source	Sampling Date(s)	Number of Stations	In-situ Water Quality	Grab Water Quality	Wastewater	Streamflow	Biological	Physical Characterization	Interesting Findings
N/A	Estimation of Low-Flow Duration Discharges in Massachusetts	USGS	1993	N/A							Model to determine basin yield during periods of low-flow
N/A	Technical Memorandum on the Assabet River: Flow at the Maynard Gauge and Nutrients	MADEP	USGS gage data for all years on record	N/A		X (based on 1979 data)	X	X			
N/A	Fish Survey Electro-Shock Log Sheets	MDFW	1979, 1983, 1997 and 1998	N/A					X		
N/A	Effluent and Influent Data for Hudson, Westborough, Maynard, and Marlborough WWTPs for May, June and July 1999	MADEP	1999	N/A			X				
N/A	1999 SOD Sampling	USEPA	July 1999	24							Sediment Oxygen Demand
N/A	Modeling Design Concepts for the Assabet River Using GIS	WPI								X	
N/A	Mill Pond 2005, A Shoreline Survey of the Mill Ponds and Canal, Maynard, MA	OAR									

[*] = Only partial copy
[b] = Dissolved Oxygen only
[**] = Request complete copy of report from MADEP
[c] = analysis of data
[a] = Flow measurement taken from USGS gage only
N/A = Not applicable

Table 2-2 Assabet River Tributaries with Approximate Drainage Areas and Rivermiles

Tributary Name	River Mile	Area (miles^2)	% of Total Area
Nashoba Brook	3.0	47.6	26.9
Elizabeth Brook	10.0	20.0	11.3
North Brook	23.0	18.0	10.2
Cold Harbor Brook	26.8	11.5	6.5
Hop Brook	29.5	9.3	5.3
Fort Meadow Brook	13.4	8.9	5.0
Spencer Brook	1.3	7.7	4.3
Mill Brook	18.4	6.6	3.7
Hog Brook	18.9	6.3	3.5
Stirrup Brook	25.2	4.9	2.8
Boon's Pond Outlet	12.5	3.7	2.1
Milham Reservoir	24.3	3.4	1.9
Second Division Brook	4.4	2.1	1.2
Taylor Brook	9.3	1.8	1.0
Unspecified Tributaries and Shoreline	--	25.3	14.3
Total Watershed Area	--	177	100
Ref: Blanc, F.C. and O'Shaughnessy, J.C. 1974			

Table 2-3 Summary of Streamflow Measurements Collected During Previous Studies

			Flow Rate (cfs)					
			10/21/69	**8/10/73**	**8/16/73**	**9/21/73**	**6/6/79**	**6/7/79**
Location	**Town**	**River Mile**	**MWRC 1970**	**B&O 1974**	**B&O 1974**	**B&O 1974**	**MADEQE 1979**	**MADEQE 1979**
Outfall of Mill Road	Westborough	31.8				24.7		
Maynard Street	Westborough	30.7	0.1	40.3		29.1	8.2	7.6
Route 9	Westborough	29.8	3.5	40.5		21.8		
Route 135	Westborough	28.9	8.0	54.3		43.9		
Brigham Street	Northborough	28.3				31.5		
Route 20	Northborough	27.1	13.0	49.8		23.6		
Hudson Street	Northborough	26.1	15.0	58.7		23.7		
Boundary Street	Marlborough	23.9			93.9	33.9	76.0	63.0
Robin Hill Road	Marlborough	23.4			94.9	29.3		
Bigelow Road	Berlin	21.5				35.6		
Route 495	Marlborough	20.8				59.3		
Chapin Road	Hudson	19.4	27.0			64.3		
Washington Street	Hudson	18.7		87.7		86.0		
Forest Avenue	Hudson	17.9	30.0				152.0	115.0
Cox Street	Hudson	15.9	34.0		111.9	54.3		
Gleasondale	Stow	13.9	40.0	90.5	147.0	73.7		181.0
Boon Road	Stow	11.4	45.0			114.5		
Route 62/117	Maynard	8.6	52.0		167.0			
Route 27/USGS	**Maynard**	**7.4**	**54.0**	**111.0**	**149.0**	**129.5**	**179.0**	**162.0**
Route 62	Acton	6.5						
Route 62	Concord	6.2				184.0	250.0	
Route 62	Concord	4.7				135.0		
Main Street	Concord	3.1	64.0			182.0		
Route 2A	Concord	2.4		112.0	218.0	228.0	292.0	326.0

MWRC. 1970. The Assabet River Report – Part A, Data Record on Water Quality. Massachusetts Water Resources Commission, Division of Water Pollution Control, Boston, MA. December 1969 and September 1970.

Blanc, F.C. and O'Shaughnessy, J.C. 1974. The Biokinetics of the Assabet River. Northeastern University, Department of Civil Engineering, Environmental Engineering Laboratories Report to the Commonwealth of Massachusetts Division of Water Pollution Control Research Project 73-05. Boston, Massachusetts. September 30, 1974.

MADEQE. 1979. The Assabet River – 1979 Water Quality Data. Massachusetts Department of Environmental Quality Engineering, Division of Water Pollution Control, Westborough, MA. November 1979.

Table 2-4 Summary of Time of Travel Measurements Collected During Previous Studies

		Survey Date					
		Dec 11, 1968	**Aug 18-29, 1969**	**Oct 9-15 1969**	**Oct 21-23,1969**	**Mar 20, 1980**	**Mar 20, 1980**
Data Source		**MWRC 1970**	**MWRC 1970**	**MWRC 1970**	**MWRC 1970**	**MADEP Unpublished Data, 1980**	**MADEP Unpublished Data, 1980**
Flow at USGS Maynard Gage (cfs)		126	23	69	54	452	452
From (river mile)		8.6	29.8	13.9	30.7	30.7	17.9
To (river mile)		3.1	13.9	0.7	0.7	21.5	15.9
Total Distance of Dye Travel (miles)		5.5	15.9	13.2	30	9.2	2
Total Elapsed Time (hours)		12.3	267.6	153.8	188	19	2.6
Average Velocity (ft/sec)		0.66	0.09	0.13	0.23	0.71	1.12
Range of Velocities	Maximum (ft/sec)	1.12	0.27	1.47	0.59	1.58	1.8
	Minimum (ft/sec)	0.44	0.05	0.07	0.15	0.43	0.93

MWRC. 1970. The Assabet River Report – Part A, Data Record on Water Quality. Massachusetts Water Resources Commission, Division of Water Pollution Control, Boston, MA. December 1969 and September 1970.

MADEP. 1980. Unpublished Dye Study Information For the Assabet River

Table 2-5 Summary of Sampling Locations of Previous Studies (MADEQE, 1988)

Station Number	Location	River Mile
AS01	Water Outlet, George H. Nichols Multi-Purpose Dam	31.8
AS02	Maynard Street, Westborough	30.7
AS03	Outlet of Hocomonco Pond, Otis Street, Westborough	30.5
AS04	Route 9, Westborough	39.8
AS05	Route 135, Westborough/Northborough line	28.9
AS06	School Street, Northborough	28.0
As07	Above Dam, Route 20, Northborough	26.5
AS09	Boundary Street, Northborough/Marlborough line	23.9
AS10	Robin Hill Road, Marlborough	23.4
AS11	Bigelow Road, Berlin	21.5
AS13	Chapin Road, Hudson	19.4
AS14	Below dam, Route 85, Hudson	17.9
AS16	Cox Street, Hudson	15.9
AS17	Below dam, Route 62, Stow	14.2
AS18	Boon Road, Stow	11.4
AS19	Route 62/117, above dam, Maynard	8.6
AS20	Route 27/62 at USGS gage, Maynard	7.4
AS21	Above Powdermill dam, Acton	6.5
AS22	Route 62, first bridge, Concord	6.1
AS24	Route 62, second bridge, Concord	3.1
AS25	Routes 2/2A, Concord	2.4
SU15	Sudbury River, Nashawtuc Hill Road, Concord	0.0, -0.5
C001	Concord River, Lowell Road, Concord	0.0, +0.1

Table 2-6 Upper Assabet River Water Quality Measurements Collected During Previous Studies

Location	DEP Document ID No.	Date	Maynard gage (cfs)	Assabet River Concentrations														
				Total Phosphorus (mg/L)			Nitrate (mg/L)			Ammonia (mg/L)			BOD_5 (mg/L)			Fecal Coliform (per 100 ml)		
				Typ.	High	Low	Typ.	High	Low	Typ.	High	Low	Typ.	High	Low	Typ.	High	Low
Headwaters to Boundary Street (RM 31.8 - 23.9)	82-A-2	Oct. 21-23, 1969	57	2.50	3.70	0.07	1.0	2.0	0.0	2.50	5.30	0.14	5.0	14.0	1.2	50,000	460,000	91
	82-A-4	Jun. 4-6, 1974	154	0.70	1.10	0.03	0.6	1.2	0.0	1.00	1.60	0.00	4.0	7.0	1.8	500	10,000	100
	82-A-4	Sep. 17-19, 1974	53	0.80	1.25	0.02	1.0	1.9	0.0	1.50	2.20	0.01	5.0	9.9	0.8	2,000	68,000	100
	82-A-5	Jun. 4-6, 1979	186	0.90	1.30	0.09	0.7	1.3	0.2	1.00	1.60	0.07	7.0	9.9	4.2	10,000	40,000	500
	82-A-5	Aug. 6-10, 1979	34	1.40	2.00	0.19	1.0	2.0	0.1	2.50	4.20	0.07	8.0	15.3	1.2	800	4,200	100
	82-D-4	Jul. 1985	49	0.90	1.00	0.7	---	---	---	---	---	---	11.0	19.0	5.0	300	2,000	50
	82-ABC-3	Jul. 22, 1987	28	3.00	3.80	0.04	1.0	1.2	0.2	1.50	2.10	0.06	6.5	6.9	4.8	200	440	5
	82-ABC-3	Sep. 2, 1987	26	1.60	2.10	0.07	7.0	9.6	0.5	0.10	0.14	0.02	1.8	2.1	1.5	200	400	100
	82-AB-2	Aug. 9, 1989	99	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	82-AB-3	Jul. 10, 1990	38	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	82-AB-3	Aug. 21, 1990	72	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

Notes:

Typ. - Typical concentration are approximate averages observed in Assabet River data.

POTW Loadings from headwaters to Boundary Street consist of the Shrewsbury and Westborough plants prior to 1987 and the combined Westborough plant after 1987. POTW Loadings consist of the Marlborough, Hudson, Maynard, and Concord MCI treatment facilities.

Table 2-7 Lower Assabet River Water Quality Measurements Collected During Previous Studies

Location	DEP Document ID No.	Date	Maynard gage (cfs)	Assabet River Concentrations														
				Total Phosphorus (mg/L)			Nitrate (mg/L)			Ammonia (mg/L)			BOD_5 (mg/L)			Fecal Coliform (per 100 ml)		
				Typ.	High	Low	Typ.	High	Low	Typ.	High	Low	Typ.	High	Low	Typ.	High	Low
Boundary Street to Concord River (RM 23.9 - 2.4)	82-A-2	Oct. 21-23, 1969	57	0.70	2.00	0.13	0.8	1.5	0.0	0.20	0.83	0.07	3.5	14.0	1.0	1,000	93,000	36
	82-A-4	Jun. 4-6, 1974	154	0.35	0.60	0.05	0.6	1.1	0.1	0.30	0.45	0.00	2.5	7.2	1.2	1,000	38,000	50
	82-A-4	Sep. 17-19, 1974	53	0.60	1.30	0.02	0.6	1.5	0.0	0.05	1.50	0.01	3.0	6.0	1.0	1,000	500,000	100
	82-A-5	Jun. 4-6, 1979	186	0.35	0.77	0.11	0.6	0.8	0.2	0.25	0.70	0.02	3.5	5.1	1.8	2,500	20,000	400
	82-A-5	Aug. 6-10, 1979	34	0.50	2.00	0.12	0.6	2.5	0.0	0.10	0.59	0.00	2.0	10.0	0.3	1,000	5,300	40
	82-D-4	Jul. 1985	49	3.00	3.10	2.7	---	---	---	---	---	---	3.5	6.5	2.0	2,000	2,000	2,000
	82-ABC-3	Jul. 22, 1987	28	0.75	2.20	0.08	2.0	6.2	0.1	0.15	1.60	0.03	5.0	9.3	4.5	100	1,000	5
	82-ABC-3	Sep. 2, 1987	26	1.00	2.30	0.14	3.0	5.2	0.1	0.25	1.20	0.02	2.5	17.0	0.9	200	1,100	20
	82-AB-2	Aug. 9, 1989	99	0.45	0.45	0.36	0.65	0.73	0.48	0.08	0.11	0.04	2.5	3.0	2.1	200	340	90
	82-AB-3	Jul. 10, 1990	38	0.40	0.47	0.04	0.80	1.30	0.30	0.04	0.08	0.02	---	---	---	---	---	---
	82-AB-3	Aug. 21, 1990	72	0.45	0.48	0.37	0.70	0.88	0.56	0.10	0.13	0.04	---	---	---	---	---	---

Notes:

Typ. - Typical concentrations are approximate averages observed in Assabet River data.

POTW Loadings from headwaters to Boundary Street consist of the Shrewsbury and Westborough plants prior to 1987 and the combined Westborough plant after 1987. POTW Loadings consist of the Marlborough, Hudson, Maynard, and Concord MCI treatment facilities.

Table 2-8 Summary of POTW Flows and Nutrient Loadings Measured During Previous Studies

Location	DEP Document ID No.	Date	POTW discharge (MGD)	POTW discharge (cfs)	POTW Loadings			
					Phos-phorus (lbs/day)	BOD_5 (lbs/day)	Nitrate (lbs/day)	Ammonia (lbs/day)
Headwaters to Boundary Street (RM 31.8 - 23.9)	82-A-2	Oct. 21-23, 1969	2.02	3.01	157	782	92	112
	82-A-4	Jun. 4-6, 1974	2.02	3.01	157	782	92	112
	82-A-4	Sep. 17-19, 1974	2.02	3.01	157	782	92	112
	82-A-5	Jun. 4-6, 1979	3.36	4.99	112	867	104	214
	82-A-5	Aug. 6-10, 1979	2.23	3.32	98	420	131	82
	82-D-4	Jul. 1985	---	---	---	---	---	---
	82-ABC-3	Jul. 22, 1987	3.11	4.63	143	338	617	3.38
	82-ABC-3	Sep. 2, 1987	3.07	4.57	141	115	384	3.08
	82-AB-2	Aug. 9, 1989	3.77	5.61	142	245	94	2.20
	82-AB-3	Jul. 10, 1990	---	---	---	---	---	---
	82-AB-3	Aug. 21, 1990	---	---	---	---	---	---
Boundary Street to Concord River (RM 23.9 - 2.4)	82-A-2	Oct. 21-23, 1969	3.25	4.83	243	845	---	340
	82-A-4	Jun. 4-6, 1974	3.25	4.83	243	845	---	340
	82-A-4	Sep. 17-19, 1974	3.25	4.83	243	845	---	340
	82-A-5	Jun. 4-6, 1979	4.53	6.74	268	846	232	345
	82-A-5	Aug. 6-10, 1979	3.35	4.98	179	775	157	291
	82-D-4	Jul. 1985	---	---	---	---	---	---
	82-ABC-3	Jul. 22, 1987	4.78	7.11	301	1138	139	394
	82-ABC-3	Sep. 2, 1987	4.93	7.33	317	1098	354	459
	82-AB-2	Aug. 9, 1989	4.98	7.41	192	928	289	248
	82-AB-3	Jul. 10, 1990	---	---	---	---	---	---
	82-AB-3	Aug. 21, 1990	---	---	---	---	---	---

Notes:

POTW Loadings from headwaters to Boundary Street consist of the Shrewsbury and Westborough plants prior to 1987 and the combined Westborough plant after 1987. POTW Loadings consist of the Marlborough, Hudson, Maynard, and Concord MCI treatment facilities.

Table 2-9 Dissolved Oxygen Concentration Measurements Collected by US EPA in August 1996

Sample Location		Location	Time	Temperature	DO
Rivermile	Description		(AM)	(•C)	(mg/l)
31.8	Mill Rd	Westborough	5:10	23.5	4.5
29.5	Hop Brook	Northborough	5:20	24.2	8.2
29.2	South St	Northborough	5:30	22.6	3.1
	Rte 20 Dam	Northborough	5:40	23.1	4.3
	Howard Brook	Northborough	5:55	22.5	8
25.6	Allen St	Northborough	6:05	23.5	6.5
25.6	Allen St - 3 ft depth		6:05	23.5	6.5
23.4	Robin Hill Rd	Marlborough	6:15	22	5.2
	North Brook	Berlin	6:20	22.2	5.2
19.4	Chapin Rd	Hudson	6:35	23	5.6
17.9	Rte 85 Dam	Hudson	6:45	24	7.7
14.2	Gleasondale Dam	Stow	6:55	24.1	6.5
11.4	Boon Rd	Stow	7:05	25	5.8
9.2	White Pond	Stow	7:20	24.5	5.7
8.6	Rte 62/117 Dam	Maynard	7:40	25	4.7
6.3	Powdermill Dam	Acton	7:55	25	6.5
6.3	4 ft depth		7:55	24.5	6.1
6.3	8 ft depth		7:55	24	3.1
6.1	Powdermill Dam (below)	Acton	8:05	24.5	5.8
3.1	Rte 62	Acton	8:15	24.5	6.6
3.0	Warners Pond Outlet	Concord	8:30	24.5	6.4
0.0	Assabet Mouth	Concord	8:50	24	5.4

Figure 2-1 Map of the Assabet River (MADEQE, 1988)

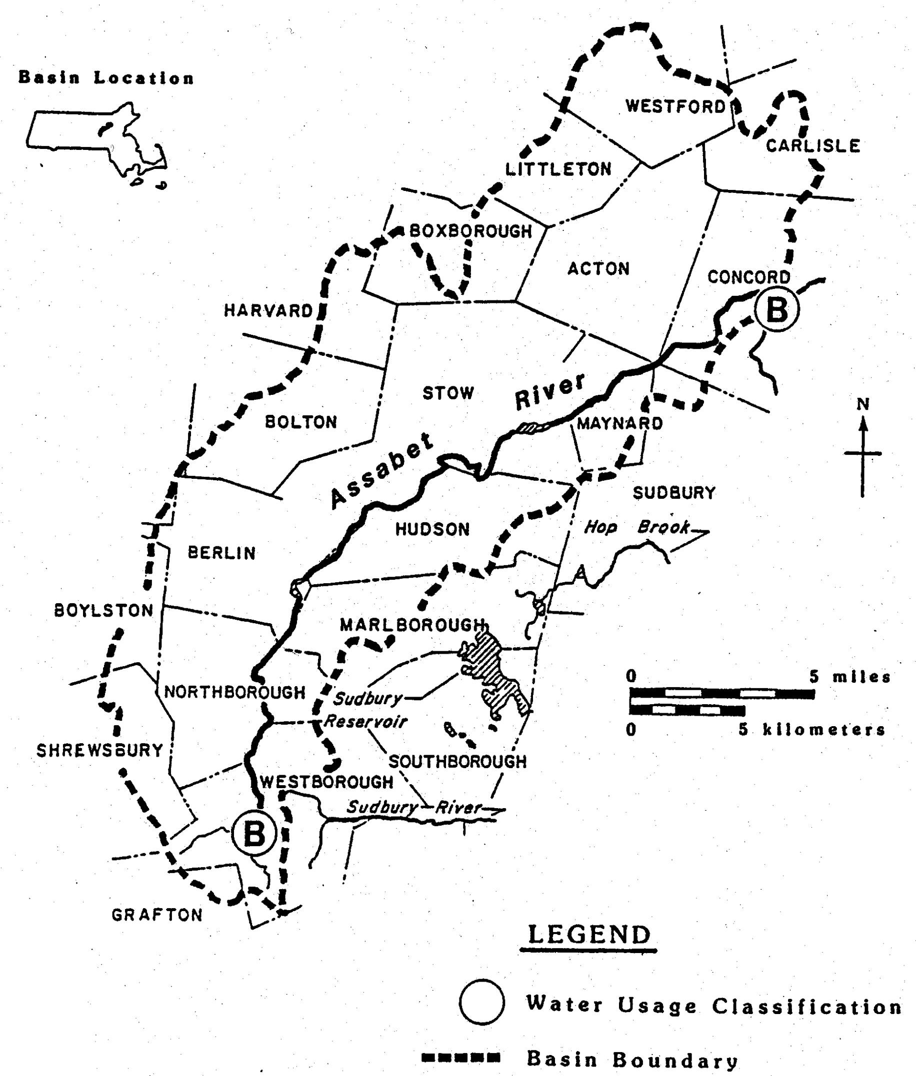


Figure 2-2 Schematic Physical Representation of the Assabet River, Rivermile vs. Elevation with Impoundments and Major Point Source Discharges Identified

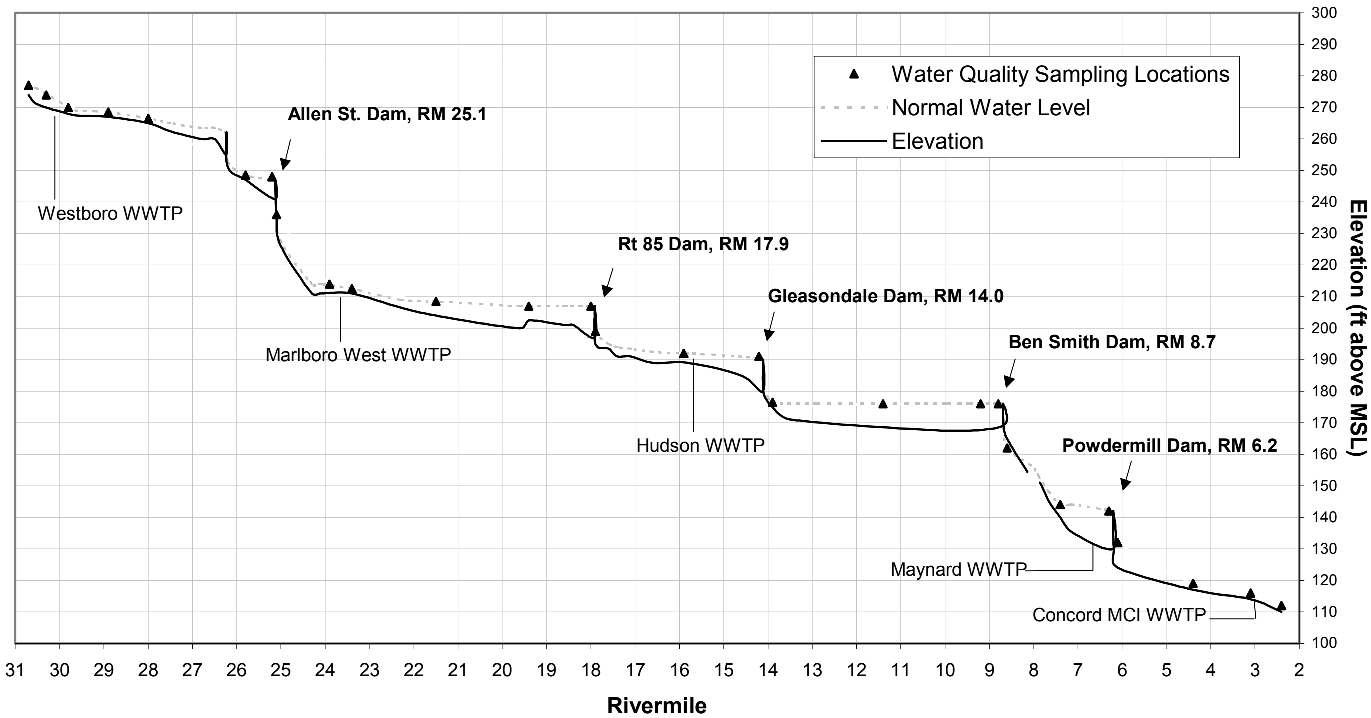


Figure 2-3 Average Monthly Streamflow in the Assabet River as Measured at the USGS Maynard Gauge (RM 7.7). Period of Record 1941-1997.

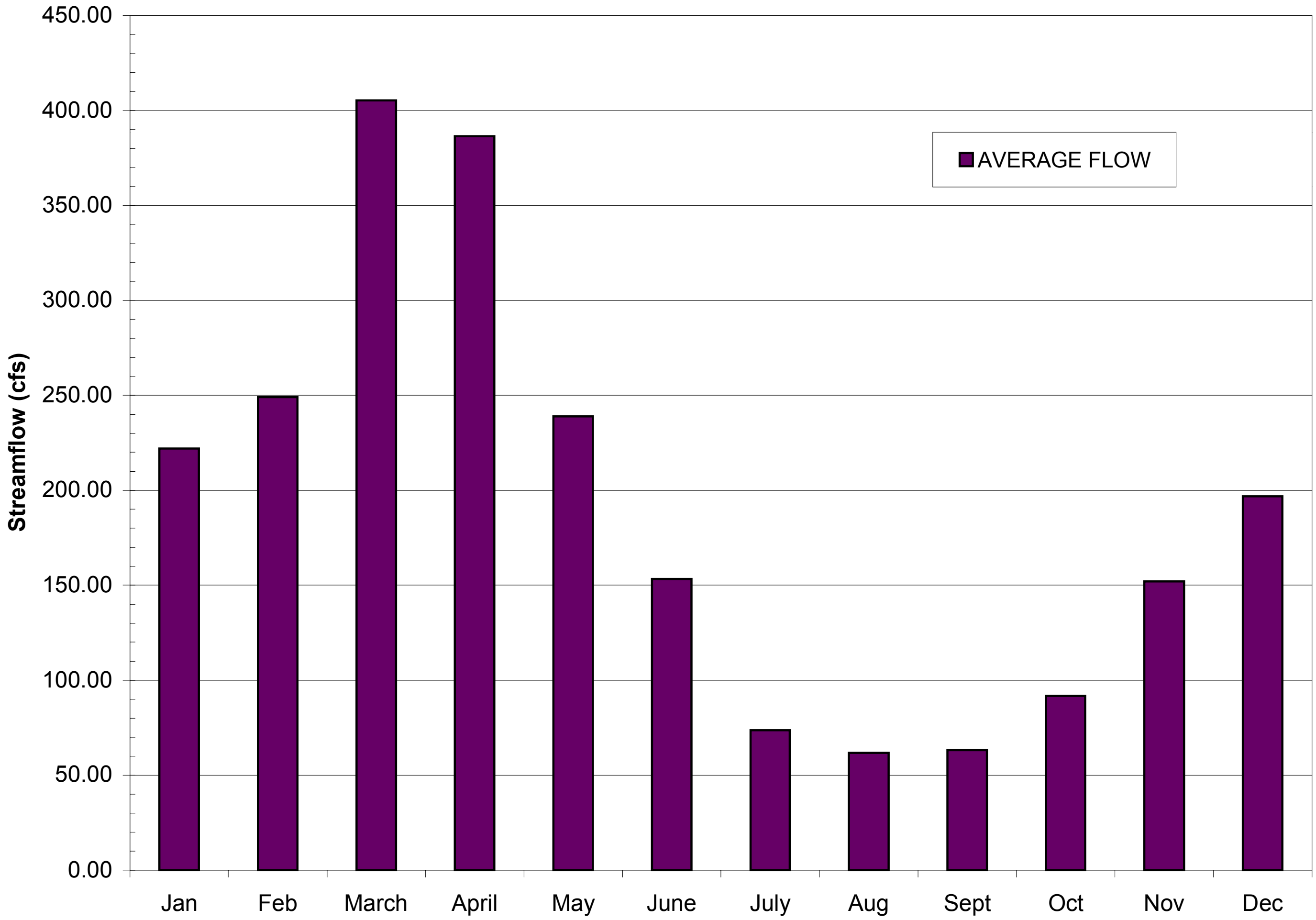


Figure 2-4 Rough Estimate of Streamflow vs. Rivermile Relationships for the Assabet River

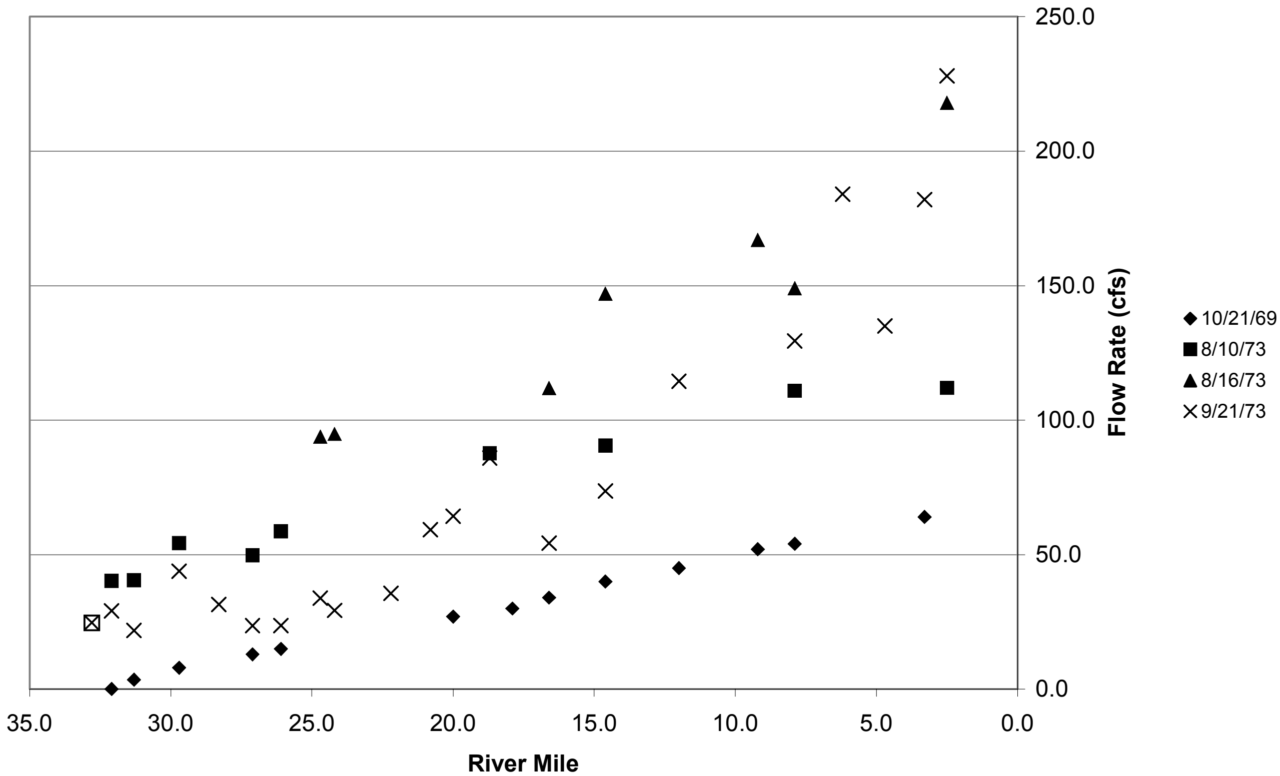


Figure 2-5 Map of the Assabet River with Locations of Sampling Locations of Previous Surveys (MADEQE, 1988)

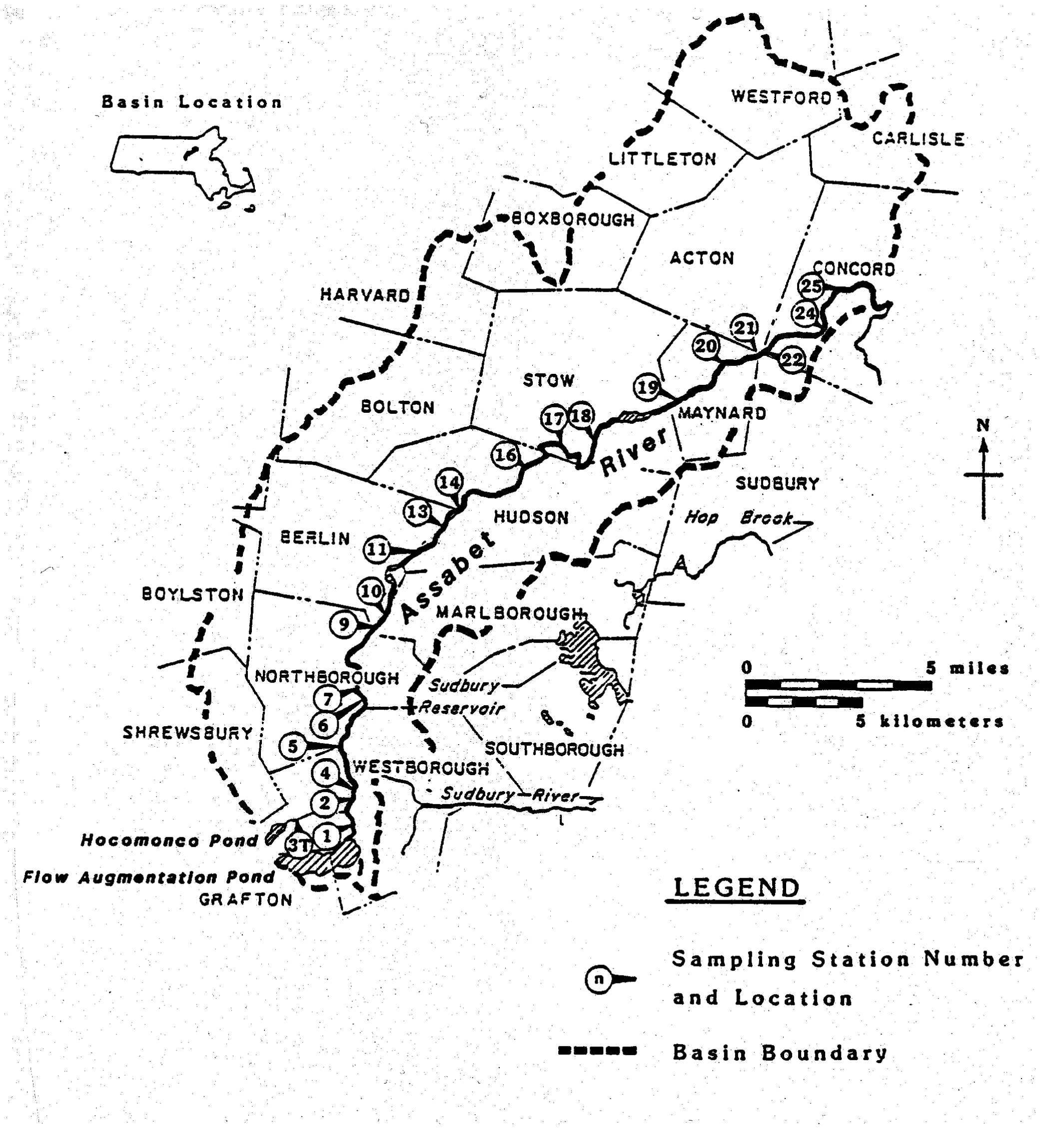
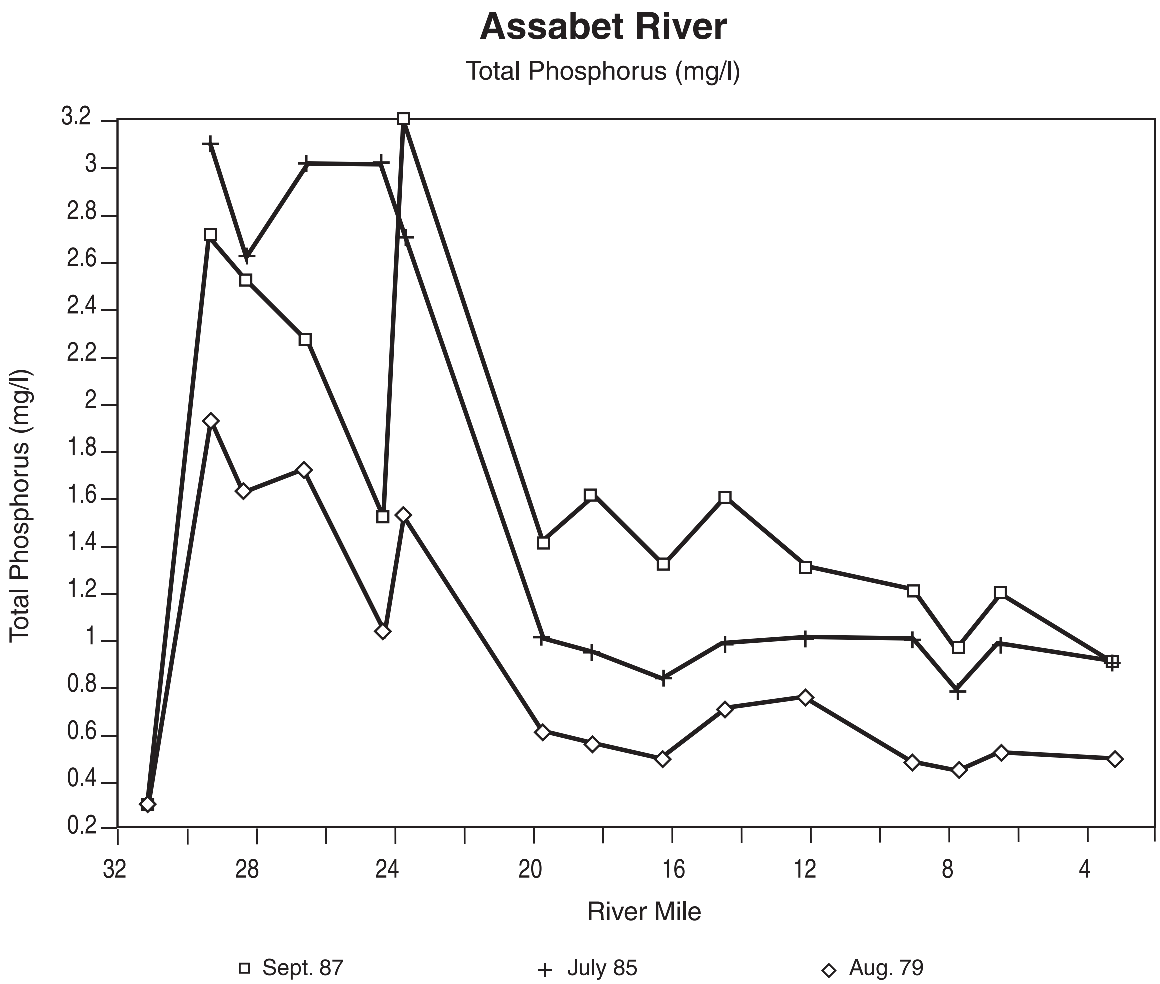


Figure 2-6 Total Phosphorus Concentration Measurements Collected During Three Previous Surveys vs. River Mile (MADEQE, 1988)



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